A GUIDE TO Amateur Radio

THIS IS AMATEUR RADIO
GETTING STARTED
COMMUNICATION RECEIVERS
AMATEUR TRANSMITTERS
THE LICENCE EXAMINATIONS
OPERATING A STATION

PRICE FIVE SHILLINGS

A guide to . . .

AMATEUR RADIO

TWELFTH EDITION

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Foreword

A GUIDE TO AMATEUR RADIO is intended to assist the newcomer to learn more about the hobby, and to help him or her to obtain a transmitting licence. The *Guide* also contains information on modern amateur receivers and transmitters, and other technical information and operating data of interest to all radio amateurs and short-wave (high-frequency) listeners.

This revised twelfth edition takes into account the important changes introduced in recent years in the UK amateur regulations. These now make it possible to obtain a form of Amateur (Sound) licence without passing a Morse Test and make it easier for amateurs to operate stations abroad.

There continue to be significant changes in the equipment used in fixed, mobile and portable amateur stations—in particular the far greater use of single sideband techniques and semiconductor devices. New guidance on these developments and several new constructional projects—including an economical transistorized h.f. receiver, a transistorized converter and a transistorized crystal calibrator—have been added.

Amateurs have continued to demonstrate their ability to keep in the forefront of radio communications—even to the extent of active participation in communications satellites experiments.

Amateur Radio is a unique hobby. It offers to the newcomer an exciting and fascinating combination of a scientific hobby, a competitive sport, and an entry into a world-wide fellowship which knows no boundaries of race, class or creed. It has its own customs and traditions, its own international language, and above all its inimitable "Ham Spirit."

The future progress of Amateur Radio lies in the hands of those who shortly will be sending their first CQ calls and experiencing the thrill of hearing their brand-new call-signs repeated back to them from afar. Will you be one of that number?

J.P.H.

ACKNOWLEDGEMENTS

The Publishers record their thanks to the General Post Office for permission to reproduce information from the pamphlet "How to Become a Radio Amateur" and Standard Telephones and Cables Ltd for the cover photograph.

Contents

CHAPTER ONE

This is Amateur Radio

The cover photograph shows G3NWF with his transistor transmitter. Transistors are providing experimentally minded amateurs with many new opportunities for useful work.

IF you tune carefully around certain spots on the dial of a short-wave receiver you will hear people talking about radio, exchanging interesting information, carrying out experiments . . . and obviously enjoying it all. These are the "amateurs" with private radio transmitters in their homes, in their cars or operated out-of-doors.

The World at Your Finger-tips

Often, especially around 20 metres, you will find that some of these stations are a long way off—much farther away than the stations on the medium and long waves or v.h.f./f.m. bands. You may hear these amateur stations from all over the world—in the tropics, or right across the United States, or in the Far North of Canada, or deep in the South American forests.

When you learn to recognise the radio call-signs and operating codes, it becomes possible to identify the whereabouts of the stations and to pick out the distant or unusual ones. But by then you will be on the brink of an exciting adventure—a scientific hobby that will keep you interested and keen for years to come—a hobby that is now old in years but is always offering scope for new ideas and experiments.

Amateurs "discovered" the Short Waves

Amateur Radio — and the Radio Society of Great Britain (R.S.G.B.) which exists to serve it—began before there were any short wave bands on radio receivers—indeed before there was any radio as we now know it. But there were many young people who were interested in "wireless telegraphy" and began to experiment with all sorts of simple apparatus. These amateurs, or "hams" as they are often called, later discovered that messages could be sent all over the world on low power, by using the "short-waves" which professional engineers had said were useless.

Amateurs Today

Today, although many official stations use the short-waves, certain wavelengths are set aside by almost every country in the world for amateurs, so that they may continue their useful work. In the United Kingdom alone there are more than 12,000 people who hold a special licence from the Postmaster-General to operate an amateur transmitting station. There are even a number of enthusiasts who possess amateur stations fully equipped for transmitting their own television pictures. Throughout the world, there are more than 350,000 licensed radio amateurs. Apart from these, there are also many thousands of young people who, though not yet operating their own transmitters, share in the excitement and interest of Amateur Radio by listening to and building short-wave receivers, so gaining the knowledge and skill needed to obtain a licence.

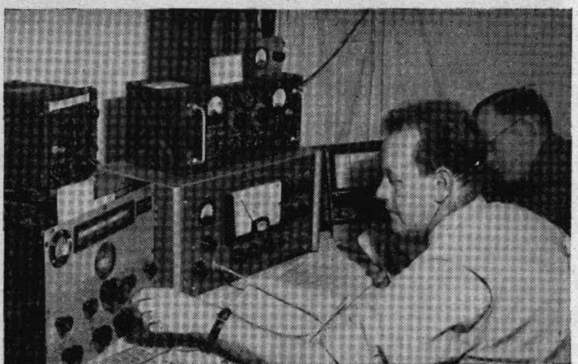
Expeditions, Emergencies and Space

Many well-known expeditions have used Amateur Radio stations to help keep them in touch with the world. For instance, the famous Kon-Tiki raft was regularly in contact with American and European amateur stations while it drifted across the Pacific Ocean.

Then again, amateurs have frequently provided emergency communication services in towns stricken by natural disasters, and have aided in the rescue of survivors from crashed aircraft and ships in distress. In the two world wars their operating and technical knowledge was widely drawn upon by the Services.

In recent years, in order to provide an efficient emergency service, the Radio Amateur Emergency Network has been formed by the RSGB and operates in conjunction with the British Red Cross Society, the St. John Ambulance Brigade and the Police forces.

G3MMK and G3IGW operate a local Amateur Radio Society Exhibition Station.



Amateurs have even designed, built and used their own communications satellites which have been put into orbit for them by the American services. These Oscar satellites, basically similar to Telstar and Early Bird have enabled amateurs to effect long-distance communication on the very high frequency bands. Amateurs have also been making contacts by "bouncing" signals off of meteor trails and the moon.

What exactly is Amateur Radio?

Amateur Radio must surely be the only hobby ever to have been defined by an international treaty drawn up by 90 nations. This was at the International Telecommunication Convention held in Atlantic City, New Jersey, U.S.A., during 1947, when Amateur Radio was defined as "A service of self training, intercommunication and technical investigations carried on by duly authorised persons interested in radio technique solely with a personal aim and without pecuniary interest."

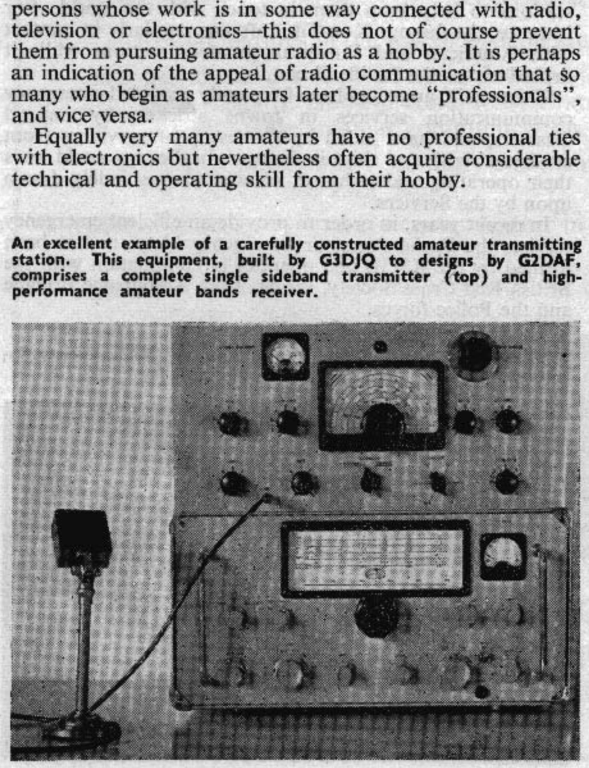
Most amateurs, however, would probably define their hobby more simply as "the practice of two-way, short-wave radiocommunication not as a business or means of profit but as a spare time hobby pursued for the pleasure to be derived from an interest in radio technique, construction and operation and for the ensuing friendships with like-minded individuals throughout the world."

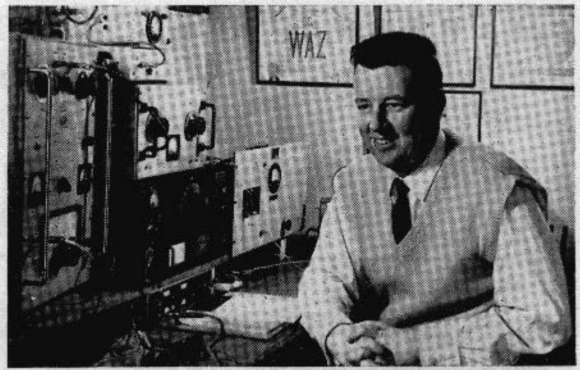
It should be noted that the term "amateur" is, strictly speaking, applied only to persons who hold official licences to operate transmitting stations, though there are of course many thousands of individuals who follow the hobby purely as listeners: such persons are known as "SWLs" (short-wave listeners) or—if members of the Radio Society of Great Britain—as "BRS" (British Receiving Stations) or ORS (Overseas Receiving Stations).

Something approaching one-half of all amateurs are in fact persons whose work is in some way connected with radio, television or electronics—this does not of course prevent them from pursuing amateur radio as a hobby. It is perhaps an indication of the appeal of radio communication that so many who begin as amateurs later become "professionals", and vice versa.

Equally very many amateurs have no professional ties with electronics but nevertheless often acquire considerable technical and operating skill from their hobby.

An excellent example of a carefully constructed amateur transmitting station. This equipment, built by G3DJQ to designs by G2DAF, comprises a complete single sideband transmitter (top) and high-performance amateur bands receiver.





Like the equipment at many amateur stations, that at G3LPS is partly home-built and partly factory-made.

How could I become a radio amateur?

To operate an Amateur Radio station in the United Kingdom it is necessary to obtain a licence from the Postmaster-General. Applicants must be over 14 years of age, furnish proof of British nationality, and pass a technical examination. To obtain the usual form of licence (Amateur (Sound) Licence A, see below) it is also necessary to pass a Morse code test. No Morse test is required for the Amateur (Sound) Licence B and the Amateur (Television) Licence. The various examinations are described in detail in Chapter 5.

Exactly what types of amateur licences are issued in the UK and elsewhere?

In the UK four different licences are issued: (1) Amateur (Sound) Licence A which covers operation on speech, Morse and radio teleprinter (RTTY) in all the appropriate amateur bands as listed in Chapter 5; (2) Amateur (Sound) Licence B which is for telephony (speech) operation only on amateur frequencies *above* 427 Mc/s; (3) Amateur (Television) Licence covering television operation above 427 Mc/s; and (4) Amateur (Sound Mobile) Licences available only to holders of Sound A or B licences and with the B licence-holders again restricted to frequencies above 427 Mc/s. There is of course nothing to prevent the same person from holding a Sound, a Sound Mobile and a Television licence. There are also the special Sound and Sound Mobile C licences issued to foreign amateurs in the UK; and the special Amateur (Maritime) licences permitting amateur operation on the 7, 14, 21, 28, 144 Mc/s and 21 Gc/s bands on board British ships.

Other countries have different forms of licences, and with different technical and Morse requirements, although in most countries these do not differ greatly from those of the UK. Some countries, including the USA, also issue special "Novice" licences which provide certain facilities after passing only a very simple Morse test. There is also, in some countries (but not the UK), a radio service known as "Citizen's Band" (CB) covering certain limited types of two-way radio communication, mostly on about 27 Mc/s. This cannot be regarded as "amateur radio"—although much of the information in this booklet will be found useful to CB operators.

Are the examinations difficult to pass?

Not really—provided that you are genuinely interested. Of course, they require a certain amount of preparation and willingness to learn; but with care, and regular spare-time practice and training, there is no reason why anyone should not feel confident of obtaining a licence. Many do so within twelve months of starting from scratch. Some amateurs obtained their licences when they were 14–16 years of age; others have not become interested until late in life—and have found the hobby an excellent means of enlivening their retirement.

Is it necessary to go to classes to prepare for the examinations?

No, though the evening courses provided by a number of local education authorities and by radio clubs form an excellent preparation for those who have little technical background. There are also a number of Correspondence Courses. But many amateurs are entirely self-taught, particularly on the technical side. It is certainly more difficult to teach oneself the Morse code—though many have done so—and assistance either from a licensed amateur, an ex-commercial or a Service operator is most helpful. Then again, two would-be amateurs often learn together. For those without such aids, Morse code disc records and tapes are available, and the Radio Society of Great Britain regularly publishes a list of amateur stations who send special slow Morse practice transmissions.

How much does an amateur transmitting licence cost?

The annual licence fee is £2 each for the Sound A, Sound B and the Television licence (a holder of a Sound A licence would not of course hold a Sound B licence and vice versa). The additional mobile licence fee is £1.

The normal licences permit operation from a fixed address ("main address"), or from any temporary or alternative location.

The transmitting licences do not entitle the holders to watch television programmes or to listen to radio broadcasting.

A charge of 30/- is made for the City and Guilds technical examination and 10/- for the Post Office Morse test.

What information can be gathered from an amateur call-sign?

The call-signs are allocated by the licence issuing authority which in the UK is the Post Office. Every call-sign includes at the beginning an *international prefix* of the country concerned. For example a station in England will start with G, in Scotland GM, in France F, etc. (a detailed list is given on page 80).

In some countries (but not in the UK) the call-sign also includes a "district" identification showing the particular region of the country in which the station is located.

In countries such as the UK where most call-signs are issued in alphabetical order it is often possible to gain a rough idea of when the licence was issued (see accompanying table for some selected dates).

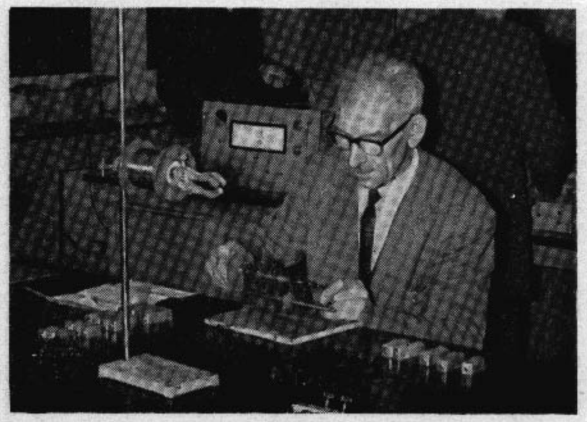
When the station is operated away from its usual location, or for certain other reasons, a *suffix* is added at the end (see table). Sometimes when an amateur is operating in a country or district other than his usual one the suffix takes the form of a country or regional identification. For example the call-sign WB2AAA/VE2 would denote that a station normally in New York or New Jersey is actually operating in the Province of Quebec, Canada. An exception is a foreign amateur operating in the UK who uses his special G5 three-letter called followed by his full home call sign: e.g. GC5AZZ/K6ZZZ would indicate a Californian amateur operating in the Channel Isles.

BRITISH AMATEUR CALL-SIGNS

Prefix	*Country*	*Prefix*	*Country*
G	England	GI	Northern Ireland
GC	Channel Isles	GM	Scotland
GD	Isle of Man	GW	Wales
GB	Exhibition and Special stations		

G2 two letters	1920-39	
G3 two letters	1937-38	
G4 two letters	1938-39	
G5 two letters	1921-39	
G6 two letters	1921-39	
G8 two letters	1936-37	
G2 three letters	pre-1939 "artificial aerial" licences with G prefix from 1946 onwards	
G3 three letters	1946 onwards	
G3A - -	1946	Year sequence began
G3D - -	1947	
G3G - -	1950	
G3J - -	1952	
G3M - -	1957	
G3P - -	1961	
G3T - -	1964	
G3V - -	1966	
G8 three letters	1964 onwards (Sound Licence B)	
G6 three letters/T	1964 onwards (Amateur Television Licence)	
G5 three letters/ home call sign	1966 onwards (Sound Licence C issued to foreign amateurs for use in the UK)	
Suffix /A	alternative address	
Suffix /M	mobile	
Suffix /P	portable	
Suffix /T	amateur television	

Construction and operation of amateur gear appeals to all age groups.



Frontiers are no barriers for Amateur Radio. This is Russian UA3FE/0 operating from Siberia. The Russian society is a member-society of the International Amateur Radio Union.

How much does an amateur station cost?

A small but complete and reasonably efficient amateur station—transmitter and receiver—can be built for about £25, or even less if you already have some radio components available. On the other hand, a wealthy amateur may spend say, £500 or more on elaborate equipment. In practice, most amateurs begin in a very modest way and add to their equipment as they go along. Fortunately, results depend as much upon the skill and knowledge of the operator as upon the possession of a well-filled wallet.

Are most amateur stations purchased as commercially-manufactured units or are they home constructed?

To answer this question accurately, it is necessary to consider an amateur station as two separate units: the transmitter (and auxiliary apparatus such as the frequency meter); and the receiver.

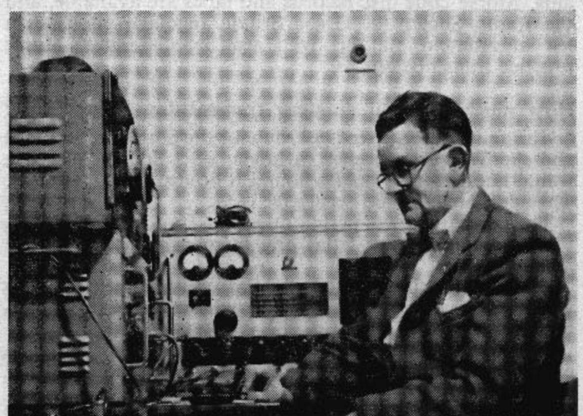
The majority of transmitters are home-built, whereas commercially-built and ex-Services communications receivers, on the other hand, now outweigh in numbers the home-built models—though for the amateur who is really keen on constructional work and who has sufficient time available, there are few more satisfying experiences than that of achieving good results on gear that he has designed and built himself.

Headquarters station of the Baden Powell House Scout Amateur Radio Society. The Chief Scout with some group members.

For those who wish to construct their own equipment to designs evolved and tested by others, there are a number of kits available for a wide range of amateur equipment. All components parts and detailed constructional information are normally supplied with such kits.

Does an amateur station take up a lot of room?

Photographs of amateur stations may give a misleading impression because they usually show a room crammed full of apparatus. An operating room—or "shack" as it is universally called—is fine for those who have the space to spare, but there are plenty of amateurs who are confined to a small hut in the garden or an unused attic. Others again find it possible to fit all their equipment into a cupboard, a desk or a bureau so that it is acceptable in the average living room.



Many physically-handicapped persons find Amateur Radio a truly absorbing hobby. This is a well-known sightless amateur, Leslie Knight (G5LK), seen here operating his station at Mitcham, Surrey.

Nowadays extremely compact transceivers (a transmitter and a receiver combined in a single compact unit, usually with a separate unit for the power supplies) are being used increasingly. A complete station can thus be very easily placed on a desk or table, or alternatively mounted in a car.

What can amateurs talk about—and what topics must they avoid?

The United Kingdom licence regulations state that messages must be "about matters of a personal nature in which the Licensee, or the person with whom he is in communication, has been directly concerned" and do not allow the use of the station for "business, advertisement, or propaganda purposes or for the sending of news or messages of or on behalf of, or for the benefit or information of, any social, political, religious or commercial organisation, or anyone other than the Licensee or the person with whom he is in communication."

In practice, this leaves plenty of scope for the amateur to exchange opinions on technical matters, talk about his equipment and compare notes on its performance with his opposite number. It leaves him full liberty to endeavour to get in touch with other amateurs all over the world and obtain reports on the strength and quality of his transmissions.

Similarly he may, if he so wishes, exchange information on what he has been doing recently—technically or personally—make arrangements to meet his friends, or even, should he so desire, just "ragchew" on almost any subject that may be of mutual interest to the two persons concerned.

Are most of the messages exchanged by speech or by Morse code?

Roughly, half and half. The majority of long-established stations are equipped to use both systems. Morse requires less complex equipment particularly for long-distance communication. On Morse, also, it is easier to communicate with foreign amateurs who speak no English, by using the operating codes described later. Nowadays, the British amateur may use either Morse or telephony operation from the moment he obtains his licence. Some amateurs use speech almost exclusively—though this seems a pity since Morse can be extremely useful and effective, particularly once speed has been increased by practical operation. For some forms of communication—such as amateur moonbounce—Morse is almost essential.

There are also an increasing number of amateur stations using radio teleprinter (RTTY) systems in which the messages are typed out on the keyboard of a teleprinter (much in the same way as for a typewriter) and automatically printed out on a second teleprinter at the reception point.

Are amateur stations confined to certain fixed frequencies (wavelengths)?

By international agreement, the Amateur Service—like every other radio service—is allotted certain fixed bands of frequencies, and amateurs may not operate outside the limits of these bands. The amateur, however, may at any time choose which band he wishes to use, and is permitted (subject to certain voluntary band-planning schemes) to select his own frequency and to change it whenever he so desires. This is an important point on some of the more crowded bands since it allows an amateur to search for and then use a clear frequency (or "channel") and, should heavy interference be experienced later, to move immediately to another position in the band. It also enables what is known as "single-channel operation" (with both stations on approximately the same frequency) to be used.

Many amateurs have always enjoyed experimenting with advanced communications techniques and present activities include space satellites and bouncing signals off the moon and meteors. Here is a Swiss amateur, HB9RF, with his 432 Mc/s parabolic dish aerial. It was an American amateur who built the world's first steerable radio telescope in the 1930s—forerunner of Jodrell Bank and all the other huge radio telescopes (several of which have been used in experiments with amateurs). Some of the leading figures in the field of radio astronomy—including Sir Martin Ryle (G3CY)—hold, or have held, amateur licences.

Home construction is again flourishing. Here is a group of Chester enthusiasts with some of the equipment they have built themselves including a high-performance communications receiver.

What is the maximum range of an amateur transmitter?

There is no simple answer to this question. On some bands, in good radio conditions, the only limit is the size of the globe. Many quite low-powered stations are in regular contact with stations all over the world. Several British amateurs have been in contact with more than 300 different countries! But, on other frequencies, distance can still be of great consequence: an amateur who contacts a North American station on "Top Band" (1.8 Mc/s) has accomplished a more difficult task than, say, in working an Australian on "Twenty" (14 Mc/s), whilst on ultra-high frequencies he may feel equally pleased if he is able to make contact with a station only a few miles away. Each band has its own limitations and special problems, and thus the amateur has always some new field to conquer.

Do amateur stations use transistors or valves?

Either or both. In recent years the introduction of transistors and semiconductors has opened up entirely new fields for the development of equipment. So far, this has had most influence upon mobile and portable gear since the cost of high-power transmitting transistors has remained higher than their valve equivalents—though more and more amateurs are finding that the building, for instance, of fully transistorised Top Band transmitters and receivers offers much scope—and this is spreading gradually throughout all new equipment. All-transistor transmitters and transceivers with powers up to about 10 or 15 watts are being increasingly used for mobile, portable and fixed-station operation.

Why are there some amateur transmissions which appear to be speech but which are completely unintelligible on a normal broadcast receiver?

These are almost certainly amateurs transmitting with single sideband (s.s.b.) which has been found to offer many advantages, and takes up only half the frequency space required for the more common amplitude modulated (a.m.) transmissions.

In order to receive s.s.b. signals it is necessary to generate a local carrier signal within the receiver in much the same way as for the correct reception of Morse signals. Receivers intended for s.s.b. and Morse include a beat frequency oscillator (b.f.o.) allowing such signals to be rendered intelligible.

Today an appreciable proportion of amateur telephony is by single sideband and this seems likely to increase still further in the future.

Would you recommend a newcomer to forget all about Morse and try for a Sound B (above 427 Mc/s) telephony licence?

The B licences offer a most useful facility for those who are concerned primarily with developing the technical side of u.h.f. and microwave equipment, and who are not unduly interested in world-wide or casual amateur contacts. But even on u.h.f. there are many applications—such as moon-bounce, meteor-scatter, etc.—where Morse is invaluable. Our advice would therefore be always to work towards the full A licence—but this can be backed up with the confident knowledge that if Morse has to be put off for any reason, it will still be possible, once the technical examination has been passed, to obtain a B licence with its specialised but very interesting possibilities. Quite long distances are now regularly covered on u.h.f. and compact transistorized equipment provides great scope for experimental work. For information on the type of equipment for u.h.f. and microwaves reference should be made to the *RSGB Amateur Radio Handbook*.

Can an amateur operate in another country?

In an increasing number of cases, amateurs can obtain special permits or temporary licences without taking any further examinations to allow them to operate in another country, for instance while on holiday.

Is it possible to transmit over long distances from a car or from compact transistorised portable equipment?

Most of the mobile transmissions from cars are on frequencies more suitable for making contacts over relatively modest distances of a few miles. But by operating on the long-distance bands during good conditions it is quite possible to work across the oceans during a car journey, though the aerials which can be mounted on a car are of course seldom as efficient as those which can be set up at a fixed location. Since aerials are usually much more important than power, very good results can often be achieved by small portable stations operating from good sites.

Operating a home-constructed mobile station from an Austin 1100—G2CLN/M at the wheel.

Many branches of the Services encourage Amateur Radio. This is the headquarters station of the Royal Signals Amateur Radio Society at Catterick, Yorkshire with G3RFI operating.

What are the QSL cards often mentioned by amateurs?

These are usually individually designed printed postcards which can be completed to provide details of a contact made by radio. These cards are often exchanged—usually via the various QSL Bureaux—so that operators can have a permanent record of particular contacts, for interest or so that they may apply for achievement certificates. By sending QSL cards in bulk via the RSGB QSL Bureaux—one of the most comprehensive services of its type in the world—the cost is very much less than sending cards direct to the amateurs concerned. Some typical QSL cards can be seen on the cover photograph.

Are newcomers to Amateur Radio welcome?

Yes, most certainly. Although some of the amateur bands become very crowded at popular operating times, such as weekends, there is still room for those who are willing to take care that their transmissions do not occupy more ether-space than is technically necessary. Amateurs realise that their hobby can flourish only by the continual recruitment of newcomers, and are always willing to extend the "helping hand" of advice and practical assistance to all who show a genuine interest in radio communication.

What is the first step that a newcomer should take?

Fortunately this is an easy question to answer. For more than 50 years the Radio Society of Great Britain (founded in 1913 as the London Wireless Club) has been recognised, officially, as representing the radio amateur not only in this country, but—as a Member-Society of the International Amateur Radio Union—throughout the world. By joining the Radio Society of Great Britain, the newcomer will have the experience, guidance and backing of 13,500 other members to help him or her before and after obtaining an Amateur Radio licence.

CHAPTER TWO

Getting Started

THERE is no better way of starting Amateur Radio than to spend some time with a shortwave receiver, listening to the transmissions on the amateur bands. For this purpose even a simple and relatively inefficient receiver will suffice to begin with; though as your interest is aroused and skill acquired you will soon want to listen to the weaker and more distant stations. Then a good receiver and an efficient aerial will be in demand.

Right from the start your listening should not be entirely haphazard but should, to some extent, be planned to help you to understand more about the peculiar and remarkable characteristics of shortwave reception. Such knowledge will be a tremendous help later on when you begin to operate an amateur transmitting station. In this country we are all used to, and take for granted, the ever-changing weather conditions—but it will probably come as a surprise to many to find that there is just as much variation in the radio conditions on the short waves. Some days you will hear a particular amateur band full of long-distance stations at good strength—the next day the same band may be devoid of all but local signals. The range of a band may suddenly lengthen or fade out altogether as night falls. At first there may seem to be little rhyme or reason about it all, and it may seem as though forecasting radio conditions must all be just a matter of luck. But, if you keep careful records, you will soon notice that, just as there are daily and seasonal variations in weather, so equally are there regular recurrences of likely radio conditions—although in this case there is one even longer cycle that plays an important part; this is the fairly regular increase and decrease of sunspot activity—a normal cycle of maximum activity through minimum to a second maximum taking approximately 11 years.

So if the first requirement of the newcomer to Amateur Radio is a receiver and an aerial, the second is a well-kept log book of stations heard and notes on

This entirely home constructed station comprises (left to right) a grid dip oscillator, transmitter, amateur bands receiver, wavemeter, microphone and Morse key.

their strength. You can never keep in your head the thousands of call-signs, the times when you receive stations in the various parts of the world and their relative strengths from day to day. It will also be good practice for later on, as an accurately kept log book is required by the G.P.O. for all amateur transmitting stations. A typical extract from a receiving log is given and indicates the type of information worth recording. You can either rule up an exercise book, or buy a radio log already ruled.

As your knowledge of the various bands increases you will find definite patterns emerging, along the following lines, which will give some indication of the type of stations you can normally expect to hear on each amateur band in the United Kingdom.

Station Log: B.R.S. 33,001

Date	Time (G.M.T.)	Band (Mc/s)	Station Heard	Calling	Mode of Emission	Signals			Notes	QSL	
						R	S	T		Sent	R'cd
25.3.19[illegible]	1915	21	EL1S	CQ	A1	5	7-3	9	Robertsfield, Liberia, Signals fading out	✓	
	1918	21	W5WW	UB5KCE	A1	5	8	9	Bill / Texas, using 800 watts with 4 el beam		
	1930	21	KC4AF	W7WZW	A3	5	6	-	Expedition to Navassa Is. W4KVX operating	✓	
	1945	14	VS6DX	CN8CR	A3	4	4	-	R.A.F Station, Hong Kong, Vee beam.		
	1950	7	UA3KBA	OH6NZ	A1	5	6	9	Moscow, Operator Valentin, 100 watts		
	2010	3·5	CT1ID	CQ	A3	3	7	-	Lisbon, Local interference		
	2020	3·5	G4ZZ	CQ	A3a	5	8	-	Testing new s.s.b rig		

Fig. 1. An extract from an amateur receiving log. For transmitting, the following extra details would be required: (1) A column to show time of ending each contact; (2) a set of three columns to record the incoming RST report received on your own signals.

1.8 Mc/s (160 metres): This band is shared by amateurs with coastal shipping and coast stations as well as other commercial stations. You can hear mainly semi-local (up to about 50–75 miles) telephony and c.w. (Morse) amateur stations during daylight, with the range lengthening at night to cover the British Isles and occasional Continental stations. In the winter some long-distance stations, including American, can be heard in the early

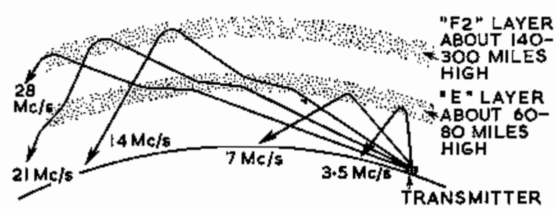


Fig. 2. Typical paths of amateur signals during daylight. The 14, 21, and 28 Mc/s signals may make further "hops" and, under good conditions, may travel thousands of miles. Direct "ground" signals from the transmitter will grow very weak within a few miles, and from there onwards up to the point where the signals bounce back from the ionised layers there exists a "skip zone" where only very weak signals are likely to be heard.

hours. This band is not so susceptible to radio disturbances as some others but the atmospheric noise increases considerably during summer months when amateur activity is mainly during the week-ends or late evenings or by mobile stations operating from cars.

3.5 Mc/s (80 metres): This band is also shared with commercial stations. Many British and Western European telephony and c.w. stations can usually be heard, particularly after nightfall. The occasional long-distance (DX) station can be heard at night and early morning, particularly in the winter.

7 Mc/s (40 metres): This band varies markedly at various periods of the 11-year sunspot cycle. Towards the peaks (1947, 1958, etc.) British stations can be heard at very good strength during most of the day, giving way to Continental signals towards dusk. With less sunspots British stations tend to be heard less frequently and most of the signals will be from the Continent, although many long-distance stations will come through in the evening and early mornings. The main drawback to this band are the many very powerful broadcasting stations which transmit throughout it.

14 Mc/s (20 metres): Of all the amateur bands, this one is the most consistently suitable for long distance transmissions. There will be few days when at least some DX signals cannot be heard on both telephony and c.w. In addition many European stations can be heard at very good strength during daylight. In sunspot minimum years, the band tends to fade out completely a few hours after darkness; in other years it may stay open all round the clock except in mid-winter when it usually closes late at night. Dawn and dusk are the traditional times for hearing the best DX (over 5000 miles).

21 Mc/s (15 metres): This is an extremely good daylight DX band except during sunspot minimum years when activity drops sharply. It tends to be best in the Spring and late Autumn when in the afternoons and evenings the band will be full of loud American signals, with fairly consistent signals from Oceania arriving in the mornings. Signals tend to fade out a few hours after darkness falls. The band is subject to severe disturbances and conditions therefore vary considerably from day to day. It is often open over North/South paths (e.g. UK to South Africa or South America) when closed for East/West paths.

28 Mc/s (10 metres): This is rather like 21 Mc/s. In sunspot maximum years it may be very good indeed with loud signals even from low power DX stations; in the sunspot minimum periods few signals may be heard for days on end. Even in the sunspot maximum years results tend to fall off in the summer months; after darkness the band usually fades right out. More consistent over North/South than East/West paths.

70 and 144 Mc/s (4 and 2 metres). These are very high frequency bands in which signals are not reflected from the ionosphere in the same way as on the lower frequency bands. Local and semi-local signals up to about 100 miles can be heard consistently and stations from several hundreds of miles away—including European—can be received when conditions are good.

427 Mc/s (70 cm): An ultra high frequency band which attracts the experimentally minded and those interested in Amateur Television. It requires specialised equipment and techniques but rewards its devotees with much fascinating work. Most contacts are between local stations, but distances of many hundreds of miles have been covered.

Above 427 Mc/s: These bands are for the technical expert; but for those who can build suitable equipment they offer limitless opportunity for original experimental work.

Sunspot maxima occurred around 1947 and 1958 and we are now building up towards another one which should reach a peak about 1969—thus extremely good radio conditions for the 21 and 28 Mc/s bands (and long night-time openings on 14 Mc/s) can be expected from roughly 1967 to 1970, though occasionally broken up by sudden ionospheric disturbances.

Listener Reports

The diligent listener will soon begin to wonder if reports on the transmissions which he (or she) hears would be of assistance to the amateurs concerned. Then also he will probably feel that it would be interesting to receive confirmation—in the form of QSL cards—of having heard certain stations; by obtaining such verifications he will be able to qualify for the special awards offered by the R.S.G.B. to listeners. These include the BCRRA (British Commonwealth Radio Reception Award)

Layout of a typical short wave listeners QSL card.

BRS 33001

28 LITTLE RUSSELL STREET, LONDON, ENGLAND

To Radio .... your .... Mc/s ssb/am/cw
signals received here at .... GMT on .... 196...
You were calling/working .... and you were RST ....
QRM .... QRN .... Conditions ....
Other countries audible at time were ....
Receiver .... Aerial ....
Remarks ....
....
I hope this report is useful. Do you need further reports?
Please QSL direct or via R.S.G.B. 73, Philip Hamm

requiring cards from 50 call areas in the British Commonwealth, and the "DX Listeners' Century Award", for those who submit proof of the reception of stations located in at least 100 different countries. "Four Metres and Down" listener awards have been introduced to mark outstanding reception achievements on 70, 144 and 420 Mc/s.

The newcomer, however, should always use his discretion when sending reports of reception, or he will find the percentage of answers rather low. Some years ago, owing to many listeners with little basic knowledge of Amateur Radio sending reports of no real interest, the practice fell into some disfavour with amateurs, and the very real value of detailed or rare reports was sometimes forgotten. Since then most listeners have shown a greater awareness of the amateur's requirements but even today stations using high power telephony on 14, 21 and 28 Mc/s, particularly those located in countries where there is little amateur activity, receive many listener reports every month from regions with which they are in regular two-way communication. Sooner or later such stations usually give up any attempt to answer all such reports. On the other hand, a newly licensed amateur or one who seldom works over long distances may be really pleased to know how far his signals are reaching or to have detailed observations covering a period of time. Even amateurs who have been operating for many years have been known to prize highly, for example, a listener report from Australia on a 7 Mc/s transmitter used for local working.

BRITISH ISLES TWO METRE BAND PLAN

Zone	Mc/s	Area
1	144.0 –144.1	**Nationwide allocation for c.w. (Morse) operation only.**
2	144.1 –144.25	**Cornwall, Devon, Somerset, Berkshire, Dorset, Hampshire, Wiltshire, Channel Isles.**
3	144.25–144.5	**Brecknockshire, Cardiganshire, Carmarthenshire, Glamorgan, Gloucestershire, Herefordshire, Monmouthshire, Pembrokeshire, Radnorshire, Worcestershire.**
4	144.5 –144.7	**Kent, Surrey and Sussex.**
5	144.7 –145.1	**Bedfordshire, Buckinghamshire, Essex, Hertfordshire, London, Middlesex.**
6	145.1 –145.3	**Cambridgeshire, Huntingdonshire, Leicestershire, Norfolk, Northamptonshire, Oxfordshire, Rutland, Suffolk, Warwickshire.**
7	145.3 –145.5	**Anglesey, Caernarvonshire, Cheshire, Denbighshire, Flintshire, Merionethshire, Montgomeryshire, Shropshire, Staffordshire.**
8	145.5 –145.8	**Derbyshire, Lancashire, Lincolnshire, Nottinghamshire, Yorkshire.**
9	145.8 –146	**All Scotland, Northern Ireland, Isle of Man, Cumberland, Co. Durham, Northumberland, Westmorland.**
—	145.41	**Nationwide allocation as spot frequency for single-sideband (s.s.b.) operation (s.s.b. can also be used in appropriate zonal frequency bands for 144.1–146 Mc/s).**

With the object of providing a rough guide to whether or not a reception report is likely to be considered of real interest, the following list of recommendations has been drawn up, though of course there is no need to stick too closely to the suggestions if you have reason to believe that a detailed report may be useful or if you really need a QSL card from the country concerned.

1.8 Mc/s: Stations heard during daylight more than 150 miles distant, or more than 500 miles away during the night.

3.5 and 7 Mc/s: Stations outside Europe not observed to be in regular communication with the British Isles.

14 Mc/s: Newly licensed or low power stations more than 4000 miles distant not observed to be in regular communication with Europe.

21 and 28 Mc/s: Overseas stations not regularly in contact with Europe, particularly when heard at unusual times of the day or night or during seasons when their region is usually inaudible.

70 and 144 Mc/s: Any station newly active on the band and more than about 50 miles away. Reports on such signals are usually most welcome.

Above 427 Mc/s: Any stations heard.

In general, reports covering a period are of greater value than those giving a single instance of reception, and a careful comparison with other signals heard from the same region are usually of interest to the amateur.

Listen particularly for the weaker stations who often call CQ without getting replies—they will be glad to learn their signals were reaching you and the chance of their sending QSL cards will be good.

Information supplied should always include:

Date; time (in 24 hour G.M.T. system); frequency; signal strength in RST code (see page 78); fading, atmospherics and quality of modulation; comparison of signals with other stations audible at the time; details of receiver and aerial; any special remarks.

If you wish to receive cards direct from the amateur it will usually be necessary to enclose reply postage in the form of International or Commonwealth Reply Coupons which are available at all main post offices. However if you are in no particular hurry it is possible, when you are a member of the R.S.G.B., to send and receive cards for certain countries through the Society's QSL Bureau, and this will reduce considerably the cost. The addresses of British amateur stations can be obtained from the R.S.G.B. Amateur Radio Call Book.

The really keen listener will find addresses of amateurs throughout the world in the *Radio Amateur Call Book Magazine* (issued in two parts, one of which covers the United States only). It is available in the U.K. from the Short Wave Magazine Ltd., 55 Victoria Street, London, S.W.1.

PREPARING FOR TRANSMISSION

After a spell of regular listening, the itch to be able to transmit back to the stations heard soon becomes irresistible, and the attention of the newcomer turns to the problems of obtaining a licence. If he has not already done so to help his listening, he begins to study the elements of receiving and transmitting theory and to learn Morse so as to be able to pass the G.P.O. test. At the same time he will continue to keep in touch with current amateur activities by means of his receiver and, if possible, by joining a local group or club, which may have special classes for those studying for the examinations.

It is quite likely that by the time the newcomer begins to think about transmitting equipment, certain preferences and interests will already have become apparent. There are some amateurs who find time to have a crack at almost every type of amateur activity: local as well as long distance contacts; several types of telephony transmission and c.w. (Morse); constructional work and the detailed study of propagation; DX as well as v.h.f. work; mobile and fixed station operation; contests and club networks. But for the average amateur there is just not time—at least in any given period—to indulge in all the many facets of Amateur Radio, and he will tend to specialise in those aspects which appeal to him most. These particular interests will determine the type of equipment which he will build and operate.

However it is as well when planning your station to provide for a later shift of interest and to make your equipment as flexible as possible. The information which follows discusses the design of equipment for the bands from 1.8 Mc/s to 30 Mc/s as separate transmitters using slightly different techniques are normally used for v.h.f. and u.h.f. work

Amateur Transmitters

On 1.8, 3.5 and 7 Mc/s many contacts can be achieved with fairly low power; on 1.8 Mc/s all British amateurs are limited to a maximum power input of 10 watts. (Note.—The input power of a transmitter is found by multiplying the direct current flowing in the anode circuit of the output stage

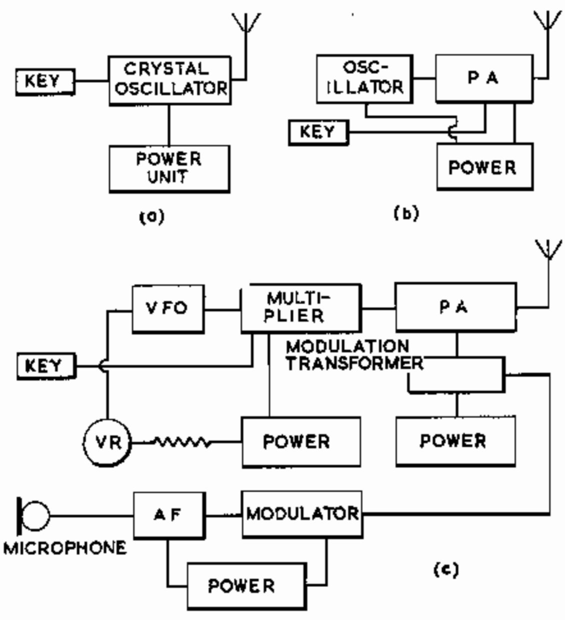


Fig. 3. Block outlines of simple transmitters. (a) The simplest telegraphy transmitter is a single valve oscillator. This is seldom suitable for more than 15-20 watts input and will have low efficiency (b) A simple two-stage transmitter usually provides a much cleaner and more potent signal; the input power will be governed by the type of valve used as power amplifier and the voltage and current available from the power supply unit. (c) The incorporation of a multiplier stage makes it easier to operate on a number of different amateur bands while the audio-frequency amplifier and modulator stages permits the use of telephony as well as telegraphy.

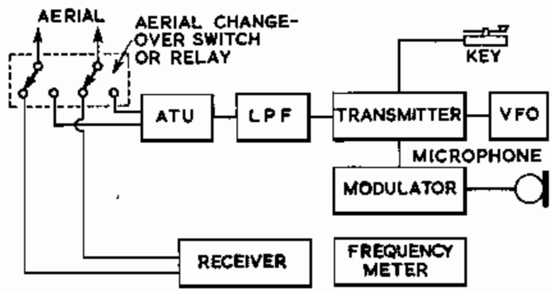


Fig. 4. The basic units of a typical amateur station. V.F.O. is a variable frequency oscillator to allow the frequency of the transmitter to be changed easily within the amateur band. L.P.F. is a low pass filter which permits power from the transmitter to reach the aerial but reduces greatly any harmonic output. A.T.U. is an aerial tuning unit to match the transmitter output impedance with that of the aerial or aerial feeders.

by the voltage applied, e.g. 30 mA at 300 volts = 30/1000 × 300 = 9 watts). It is therefore convenient to have a transmitter which can be run at 10 watts on 1.8 Mc/s and about 25–40 watts c.w. on 3.5 Mc/s (and possibly 7 Mc/s) and up to about 25 watts amplitude modulated telephony. If this transmitter can be kept entirely separate from the main high frequency transmitter then it will always be available when working on the main rig. A typical transmitter of this type would comprise an oscillator stage (crystal controlled or variable frequency) driving a power amplifier stage, which could conveniently use an 807 or similar type of transmitting or television line output valve. All the other valves in the equipment could be receiving types such as the 6V6 or 6AQ5, a pair of which would form a good high level speech modulator. A main h.t. supply of 350–500 volts would be sufficient. The construction of such a transmitter is an ideal method of learning, before tackling a more complicated type.

The main transmitter will usually be designed to work on all bands from 3.5 to 28 Mc/s (though some amateurs prefer to restrict it to the higher frequency bands from 14 Mc/s upwards), preferably with band-changing controlled solely by switches. As the design of a band-switched transmitter is more complicated than changing frequency by means of plug-in coils, it may prove quite practicable at first, to use a transmitter of the latter type, particularly if it is intended to confine your activities mainly to one or two favourite bands. It is really only for contest operation that the band-switched transmitter is essential.

The transmitter should be capable of being tuned to any frequency within the required bands (or to a selection of crystal-controlled frequencies) and operate with at least 25 watts input on all bands; 50 or 75 watts is preferable for the more crowded bands such as 14 Mc/s. It should be designed with an eye to modification later to run at the full 150 watts input. The power amplifier valve could be an 807 or 6146, or two such valves connected in parallel or push-pull, or the recent TT21 tetrode valve, or even an 813 for high power. There may be one other transmitting type valve used as a driver if a high power output valve is used, and two power tetrodes in a high power modulator, otherwise all valves—with the exception of the h.t. rectifiers—can be normal receiving types.

The tendency in transmitters today is to pack the entire equipment into one "table-top" cabinet: this will include the variable frequency oscillator; the frequency multiplying stages; the power amplifier; the modulator and speech amplifier; and the necessary power supplies. This arrangement produces a very neat and convenient package and simplifies the screening of the transmitter, but the design and construction is by no means simple, and subsequent modification may be difficult. For the newcomer there is something to be said for building the transmitter as a number of distinct units; (1) a variable frequency oscillator with its associated isolating stage(s), providing about 0.5–1 watt of radio frequency output on say 3.5 Mc/s; (2) an "exciter" multiplier/amplifier which delivers about 2–5 watts on any of the required bands; (3) a power amplifier (if this is to be less than 75 watts it may be conveniently be combined with the exciter unit) which develops the r.f. power fed to the aerial; (4) a speech amplifier and modulator; (5) a main h.t. supply of say 750 volts at up to 200 mA; (6) a lower h.t. supply of say 350 volts at about 120 mA and including any bias voltages which may be required; (7) a low-pass filter to reduce the radiation on television frequencies; and (8) an aerial tuning unit for matching the transmitter to the aerial. Any of these units may then be modified or adapted to meet changing requirements without the need to rebuild completely the entire station. The design of transmitter units will be discussed in greater detail in Chapter 4.

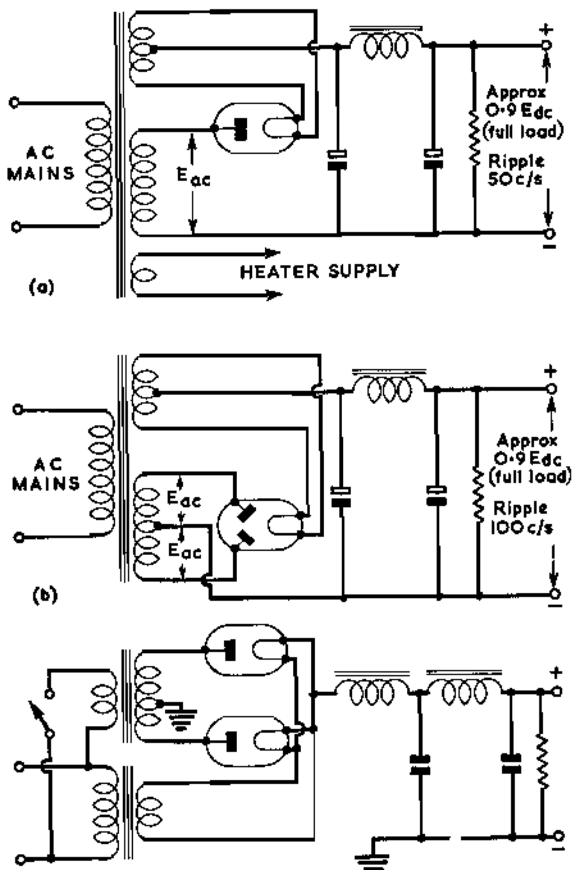


Fig. 5. Basic h.t. power supply circuits. (a) Half-wave rectifier followed by a condenser input filter. (b) Bi-phase (full-wave) rectifier also with a condenser input filter. Off load the d.c. voltage rises to about 1.4 x Eac. (c) For voltages above 1000 volts, it is usually necessary to use two separate valves and a separate heater transformer. This circuit shows a high-voltage full-wave power supply with a choke input filter.

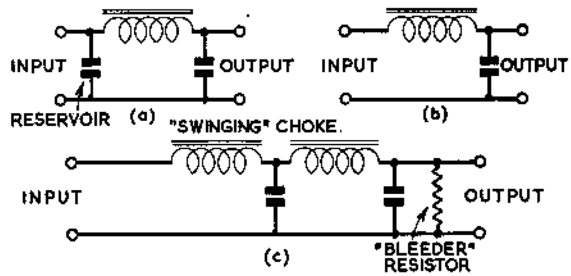


Fig. 6. Basic ripple filters to reduce the "hum" content of power supplies. (a) A conventional condenser-input filter provides effective smoothing but has poor voltage regulating qualities when used with varying loads. It also imposes a considerable strain on the rectifier valve. (b) A simple choke-input filter. This provides less smoothing but gives better voltage regulation and imposes less strain on the valve. (c) A double section filter combines the advantages of both choke- and condenser-input filters, and is commonly used in power supplies for modulators. In all these circuits, condensers should be at least 4 μF and generously rated—particularly the reservoir condenser in a condenser-input filter.

During recent years, there has been a marked trend towards the miniaturization of amateur equipment. Some years ago a 150 watt transmitter was often built in a 6 ft. rack with the exciter, power amplifier, modulator and power supplies all in different units, and often with the variable frequency oscillator in a separate small cabinet on the operating desk. This gradually gave way to the table-top design in which only a single moderate-sized cabinet was used to house the entire transmitter.

More recently still the trend has started towards transceivers in which both the transmitter and receiver are built in a single compact unit, often with some stages used during both transmission and reception. While most of these have been s.s.b. units as described later, a number of amplitude modulated v.h.f. transceivers have also appeared.

One of the main units, both from the viewpoint of cost and also its importance in determining the remainder of the design, is the main h.t. power supply. For medium power, 500 volts, at about 150 mA, may be ample for both power amplifier and the exciter; and this can be obtained from a conventional type full-wave rectifier circuit followed by a simple ripple filter, see Fig. 5(b). For higher powers there will be need for a husky supply at either 750, 1000 or even 1500 volts and rated at from 100 to 300 mA. Power units of this voltage call for careful choice of components with ample tolerances, care in construction and in operation. The failure of a second-grade or over-run smoothing condenser)can easily lead to the loss of high-voltage rectifiers and an expensive transformer, and with such lethal voltages involved *full safety precautions are essential.*

A point not always appreciated by newcomers to power supply construction is that the peak voltages present may be considerably above the transformer ratings. For example, with a 500-0-500 volt transformer and conventional full wave rectification feeding a c.w. transmitter, the voltages when the supply is fully loaded by the transmitter will be of the order of 500 volts, but when the load is removed, as will usually be the case whenever the Morse key is not depressed, the d.c. voltages will rise to about 1.4 x 500 = 700 volts. All condensers and components in such a unit would have to be capable of withstanding this higher voltage; in practice it would be better to add an extra safety margin to take care of voltage surges and to fit condensers rated at a minimum of 1000 volts. It is the peaks, surges and the combination of radio-frequency with d.c. voltages that cause flash-overs and break-downs. Closer regulation of voltage can be obtained by using a choke-input smoothing filter: see Fig. 6.

In recent years there has been a growing tendency to use silicon semiconductor power rectifiers in the place of valve or metal (selenium) rectifiers. Silicon junction diodes are extremely efficient rectifying devices having a low forward resistance and high reverse resistance, and maintain these characteristics much better than selenium rectifiers. They can be made almost as compact as small resistors and can similarly be supported in the wiring. Since they require no heater supplies, they are particularly useful for various bridge and voltage-doubling circuits which with valves would need several well-insulated heater supplies.

Silicon diodes are thus almost an ideal form of rectifier and can give excellent service over many years when correctly used; on the other hand they can easily be ruined—often causing further damage to mains transformers and other components—unless certain precautions are taken in the design of the power units. This is because silicon diodes are capable of withstanding only their rated peak inverse voltage (p.i.v.) and their rated forward current and these ratings

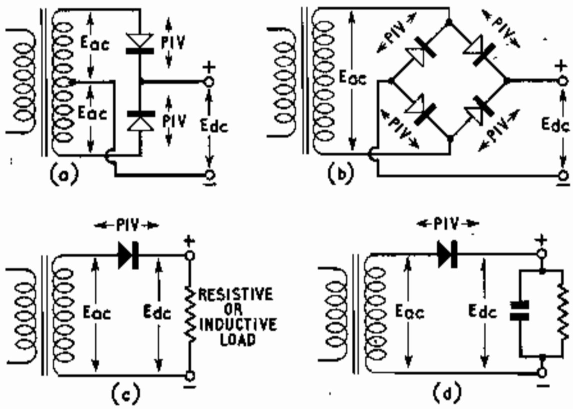


Fig. 7. Fundamental power supply relationships. (a) Full-wave rectifier. P.I.V. about 2.8 times Eac or 3.14 times E_{dc}. E_{dc} is about 0.9 times E_{ac}. With a capacitive load the actual value of d.c. output voltage will be affected by the value of the reservoir capacitor in relation to the d.c. load. (b) Full-wave bridge rectifier. P.I.V. (each diode section) about 1.4 times E_{ac} or 1.57 times E_{dc}. E_{dc} is about 0.9 times E_{ac} but note in (a) also applies. (c) Half-wave rectifier with inductive or resistive load P.I.V. about 1.4 times E_{ac}. E_{dc} is 0.45 times E_{ac}. (d) Half-wave rectifier with capacitor load. P.I.V. about 2.8 times E_{ac}. E_{dc} is 0.9 times E_{ac} and note in (a) applies.

must not be exceeded, even momentarily, whereas other rectifiers are usually much more tolerant in this respect.

When building power supplies making use of silicon diodes it is essential to ensure that no excessively high voltage or current surges, even of extremely short duration, can occur. Such surges or transients are normally found in power supplies for various reasons. There are, for instance, many short duration "overvoltages" on normal domestic mains supplies. Transients can also be caused by the inductive surges that build up when an inductive winding, such as a mains transformer or smoothing choke, is switched into or out of circuit. Strong current surges occur when a supply is switched on due to the rapid charging up of the high value reservoir capacitor.

It is thus absolutely essential to ensure that not only is the rated p.i.v. of the silicon diodes well above that required in the normal functioning of the circuit but also, equally important, that there will be no excessively high voltage or current transient surges.

Fig. 7 shows the normal peak inverse voltage conditions found in a number of typical rectifier circuits. This indicates that for the popular full wave circuit the p.i.v. across each leg of the rectifiers is just over 2.8 times the a.c. voltage across each half of the transformer secondary windings. Thus with a 350-0-350 volt transformer, the minimum p.i.v. to each rectifier chain must be at least 980 volts. To provide a good margin of safety a p.i.v. rating of around 1200 volts would be desirable in such circumstances. Diodes with a

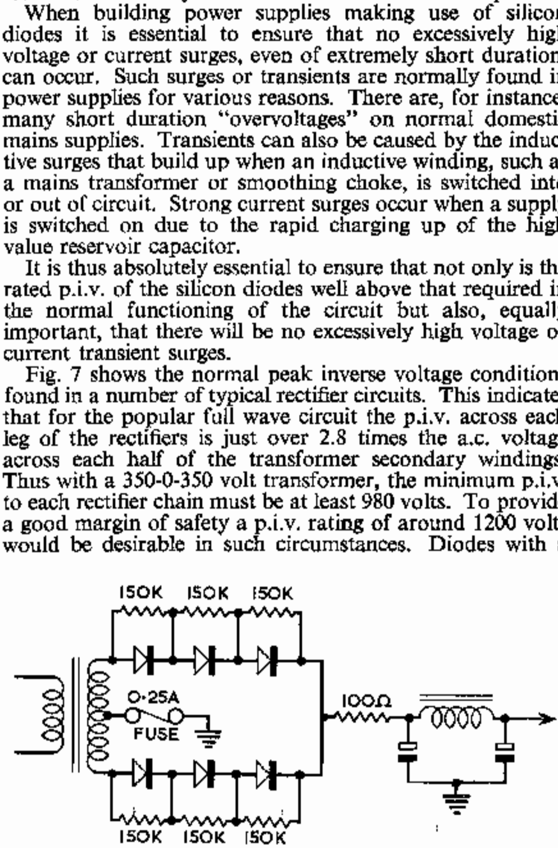


Fig. 8. Typical 350-volt power supply using series connected 400-volt p.i.v. silicon diodes.

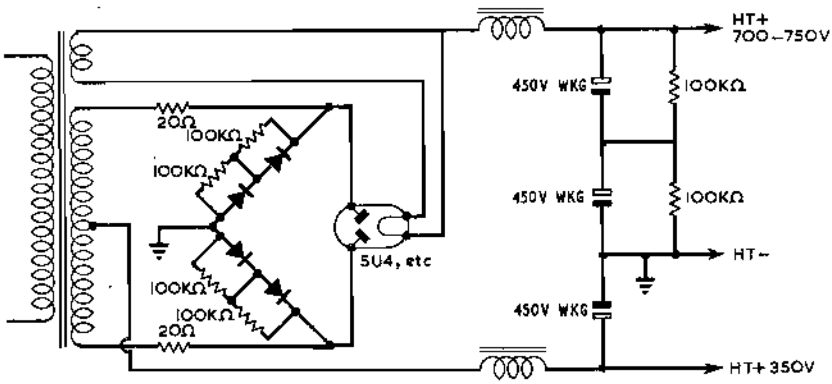


Fig. 9. Power supply providing 700-volt and 350-volt outputs from a 350-0-350-volt transformer. The silicon diodes are BY100 or similar types (800 p.i.v. rating).

p.i.v. rating as high as this are rather expensive, and in practice one might replace each of the two diodes by three series-connected diodes each with a p.i.v. of 400 volts (or two of 600 or 800 volts) *provided that* steps are taken to equalize the inverse voltages across each diode. This can be done quite simply by connecting 100,000 or 150,000 ohm resistors as shown in Fig. 8, or alternatively by using equalizing capacitors.

In Fig. 8 the use of the 100-ohm resistor should also be noted. This is to limit the initial flow of current into the reservoir smoothing capacitor, and the value can safely be based on a figure of about 5 to 30 ohms per diode in each leg. Thus in this particular design each rectifying leg has three diodes (six diodes altogether) so that 100 ohms is more than adequate.

A combination of valve and silicon rectifiers in a bridge rectifying circuit can provide a most useful and economical power supply for a medium power transmitter from only a single 375-0-375 or 350-0-350 volt transformer with a current rating of about 150–200 mA, such as those commonly used in the larger domestic audio amplifiers (see Fig. 9). This will provide a 700 to 750 volt main h.t. supply and also a lower voltage "rail" of about 350 volts or so. The total current which can be drawn remains that of the transformer rating—despite the high voltage. Thus with a transformer rated at 200 mA, one could draw say 700 volts at 150 mA for power amplifier anode supply to give a transmitter input of 105 watts plus say 50 mA at 350 volts for screen grid and exciter supplies.

In this type of supply there would be nothing to prevent the use of silicon diodes only, but the "hybrid" combination shown is often a more economical arrangement if one already has an existing 350 or 375 volt power supply and wishes to convert it for transmitter applications, at a cost little more than that of the silicon diodes.

Single Sideband Equipment

So far in this chapter, the type of telephony (speech) transmitters that have been considered are for amplitude modulation (a.m.). In this mode of transmission the radiated power is contained in a steady carrier (representing the basic unmodulated output of the power amplifier) plus, whenever there is speech, in two sets of sidebands equally placed on either side of the carrier (see Fig. 10(c)). For a long time it has been appreciated that all the power represented by the steady carrier is wasted, in the sense that it conveys none of the actual speech information which is what we want to transmit. The sole use of the carrier is its value in making it easy for the receiver to recover the original speech information from the incoming signals. Yet during typical a.m. telephony, some 80 per cent of the power is in the carrier.

By eliminating the basic carrier from the transmission (and replacing it locally in the receiver), all the transmitted power can be used to convey the actual speech information. We can do this by using what is termed a *balanced modulator*; such a stage, when fed with an r.f. carrier and an a.f. signal, produces as output the amplified sidebands of a normal modulator but balances out or suppresses the carrier. Such an output signal, if radiated, is known as a double sideband suppressed-carrier transmission, or more simply as d.s.b. (although this abbreviation is used by some professional radio engineers to describe an ordinary double sideband a.m. signal with carrier). This type of transmission is used by a number of amateurs, and has the advantage that a

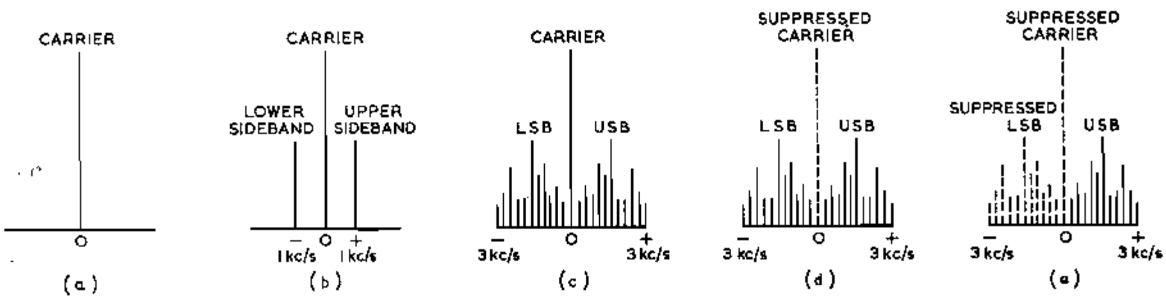


Fig. 10. R.F. spectrum diagrams of various forms of transmission. (a) Basic unmodulated carrier, occupying only bandwidth of carrier; (b) same carrier fully modulated with a 1000 c/s audio sine wave, note that two exactly similar sideband signals are generated 1000 c/s from carrier frequency; (c) A.M. speech transmissions contain many audio frequencies simultaneously, up to about 3000 c/s for communications, and corresponding sidebands appear on either side of the carrier frequency, each set of upper and lower sidebands forming a mirror image of the other. The total r.f. bandwidth is thus at least 6 kc/s; (d) D.S.B. speech transmission is similar to a.m. except that the carrier is suppressed (unless received as "s.s.b." by filtering in the receiver a synchronous demodulator must be used); (e) an s.s.b. speech transmission with the carrier and the lower sideband-suppressed. Note that the total bandwidth occupied is now less than half that for (c) or (d).

conventional a.m. transmitter can often be altered very easily to provide d.s.b.—but for various reasons is much less popular than *single sideband* (s.s.b.) transmission.

In s.s.b. we go one stage further than in d.s.b. and eliminate not only the carrier but also one or other of the two similar sets of sidebands which result from a balanced modulator. Since each set of sidebands is merely a mirror image of the other, clearly any information contained in them both is available from only one. Thus for s.s.b. we concentrate the entire output power of the transmitter into one set of sidebands, covering a bandwidth equal to the audio bandwidth which we are transmitting, preferably for speech about 200 to 3500 c/s. The s.s.b. signal thus has the same benefit over a.m. of d.s.b. in that all power is put into useful information, but has the advantage that this full power gain can be utilized at the receiver without the special frequencies, the amateur can build his own sideband filter, usually around 450 kc/s, inexpensively and without undue difficulty, provided that a certain amount of test equipment is available.

The initial carrier (that is r.f. drive) fed to the balanced modulator is crystal controlled. Once the d.s.b. output from the balanced modulator has been converted to s.s.b. by passing it through the filter, it can be amplified and heterodyned (in one or more steps) to the required transmitter output frequency by mixing it with appropriate signals. The h.f. heterodyne oscillator providing one of these signals can be made variably tuned; the transmitter output can then be tuned to the required position in the band by adjusting the v.f.o.; any variable oscillator must be of very high stability.

At the receiver, a steady carrier is needed to assist in the recovery in the detector or demodulator of the original audio

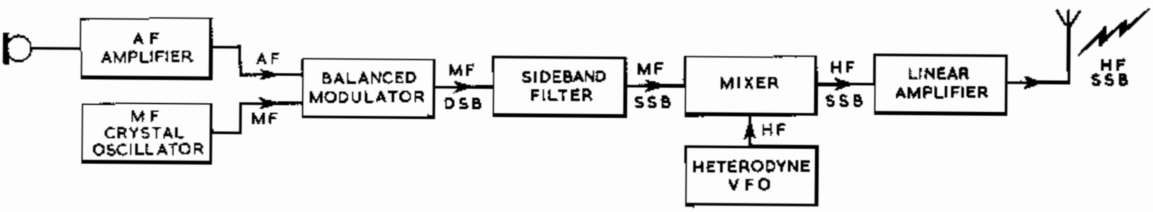


Fig. 11. Basic arrangement of filter type single sideband transmitter. To facilitate band switching more than one frequency conversion stage would usually be incorporated.

synchronous demodulation techniques which would be required for optimum d.s.b. reception. And also—most important—s.s.b. reduces the total bandwidth of the radiated signal, when correctly adjusted, to rather less than half that required for either a.m. or d.s.b. With so many amateurs packed into relatively narrow amateur bands this is indeed a most valuable feature of s.s.b. Furthermore there are no carriers to produce the unpleasant heterodyne interference that occurs with closely spaced a.m. signals.

But how can we eliminate the unwanted sideband from the output of a balanced modulator? In practice the balanced modulator works at low power and the unwanted sidebands are then *filtered* or *phased* out. Although two different phasing methods have been fairly widely used by amateurs on the grounds of their economy and their ability to generate an s.s.b signal directly at a high frequency, the tendency in recent years has been much more towards systems using *sideband filters*. Such filters must have rigorous selectivity characteristics to allow them to pass the wanted sidebands while eliminating the unwanted ones, which will be spaced only some 200–2000 c/s away. This calls for a very good filter with a pass bandwidth of roughly 2600 c/s and a high degree of rejection of signals outside these limits. At one time it was only possible to design filters meeting these requirements with a very low passband centre frequency of say around 100 kc/s, using high-quality inductors and capacitors. Nowadays however suitable filters can be achieved with *half-lattice crystal filters* using some four or more crystals with carefully staggered resonant frequencies, or alternatively with *mechanical filters*. Most of the mechanical filters have a resonant frequency (passband centre frequency) of about 455 kc/s and are available at a cost in the region of £10 or so; many crystal filters are also designed for use at about this frequency, but more recently crystal filters up to 5 or 9 Mc/s have become available with the necessary selectivity characteristics, though at some cost. The higher the frequency at which the initial s.s.b. signal can be generated the less complex will be the later frequency conversion arrangements, but on the other hand the more difficult it is to achieve high selectivity in the sideband filter.

At present, by using "surplus" crystals and either by carefully selecting them, or by "etching" them to the desired signals. This is generated in a low power oscillator in the receiver itself, usually at the intermediate frequency, and re-inserted alongside the incoming signals in the correct relationship. Often the same oscillator is used as b.f.o. for c.w. reception. This re-insertion process has to be done accurately, for unless the local signal is within about 25 c/s of the original (suppressed) carrier frequency, there will be distortion. If the frequencies differ by appreciably more than this figure or if no locally generated carrier is available, the s.s.b. transmissions remain completely unintelligible.

This indicates clearly that one of the most important requirements for both transmitters and receivers for s.s.b. working is a very high order indeed of frequency stability. Since even a drift of 25 or 50 c/s will cause distortion we must try to ensure that the equipment stays well within such a tolerance over quite long periods. A tolerance of 25 c/s is very little when we are thinking in terms of transmitting frequencies of say 21,200,000 c/s.

Apart from the actual generation of the s.s.b. signal, an s.s.b. transmitter differs in several respects from those designed solely for a.m. Normally in amateur a.m. practice, only the final power amplifier stage is modulated whereas, as we have shown, in s.s.b. this is always done at a very early stage. This has the big advantage of eliminating completely the need for high power audio amplifiers for use as a modulator, but it does mean that all subsequent frequency conversion and amplifying stages must be *linear*. The power amplifier for an s.s.b. transmitter is thus often called a *linear amplifier*, or simply a *linear*.

Once any amplitude modulated form of signal (a.m. or s.s.b.) has been generated it is important that its waveform should not be distorted by any non-linear amplification. This makes it impossible to use what are termed class C frequency multipliers or power amplifiers (as described in Chapter 4). Although from the viewpoint of simplicity and power efficiency this is a disadvantage, nevertheless the power gain which results from not having to waste energy in transmitting the steady carrier more than compensates for this. The main practical differences between a linear and a class C power amplifier, apart from the changed biasing conditions, are in the more stringent requirements for well regulated power supplies and drives to all valve electrodes. While for frequency conversion we have to use heterodyne systems (as in superhet receivers) instead of frequency doublers (see Chapter 4).

When some amateurs first began using the rather different circuits and techniques involved in s.s.b., many others believed that these were too complex, or too expensive, or too difficult to adjust correctly, for widespread adoption. At first s.s.b. thus appealed only to those with considerable experience. However over the years it has proved possible to simplify the circuits, to reduce the cost of sideband filters, and to generate the low power s.s.b. signals at much higher frequencies than in the early days. Receivers have also tended to become more stable, lessening the need to retune frequently. Because of the elimination of the high power modulator, s.s.b. equipment above a certain power tends to be cheaper than the equivalent a.m. rig, although at lower powers the a.m. rig is still usually cheaper.

The result of all these improvements is that today many newcomers go straight to s.s.b. without a long apprenticeship on a.m. or c.w. This has been much encouraged by the appearance on the market of many factory-built s.s.b. units and kits for home-construction, and particularly s.s.b. transceivers. These are combined transmitter-receiver units capable of providing extremely compact stations.

It was soon appreciated that many of the more expensive parts of an s.s.b. transmitter, such as the sideband filter, were equally valuable for high performance receivers, in this case as an i.f. selectivity filter. The same high-stability oscillators and other stages can be used. Today there are many compact s.s.b./c.w. multi-band transceivers (often with some facilities also for a.m. transmission) which are often cheaper to build or buy than would be separate units of comparable performance. Frequently, these equipments are built for use with alternative power supply units; one for normal home operation from domestic a.c. mains supplies; the other for 12 volt d.c. supplies (using transistor *inverters* for converting the d.c. to a.c.) to allow mobile operation. Even where separate receivers and transmitters are used it is becoming common for a single v.f.o. to be used to tune both together.

There is much to be said in favour of this rapid progression towards more widespread s.s.b. operation, provided that the newcomer takes care to ensure that he really understands the techniques involved and the correct adjustment of his equipment before using it on the air, just as he or she always needed to do for a.m.; but with the added awareness that a fault in the adjustment of an s.s.b. rig may pass unnoticed by any unwary or unskilled operator. Some amateurs still consider that a good oscilloscope is needed for s.s.b. adjustments. Even if the rig is purchased ready built, there is no reason why any amateur should be content to be just a "plug-in appliance operator," as it has been termed.

In an introductory booklet it is impossible to deal adequately with all the circuits and adjustments of s.s.b. transmitters and transceivers. The interested reader is referred to the many excellent sources of information on s.s.b. for amateurs now readily available, including the *RSGB Amateur Radio Handbook*. Even if it is the intention to operate exclusively on s.s.b., the reader will find that the information given in Chapter 4 on a.m. and c.w. transmitters will form a useful basis on which to build further knowledge.

Obviously, quite early on in station planning a decision has to be made on whether to concentrate on a.m. or s.s.b. for telephony operation; many amateurs now use both. If the main interest is in long-distance telephony transmission on the h.f. band, there is little doubt that s.s.b. will be adopted eventually, even if a.m. is used at first. On the other hand, the bulk of v.h.f., semi-local h.f. telephony and low power Top Band (1.8 Mc/s) working still remains on a.m. But few forward-looking newcomers can now afford to ignore s.s.b.; every opportunity should be taken to study this subject, even if at first it all seems a little complicated.

Because there is no steady carrier output (so that the output of an s.s.b. transmitter drops almost to zero in the intervals between speech), s.s.b. transmitters are rated in terms of *peak envelope power* (p.e.p.). Peak envelope power is defined as the power (r.m.s.) developed at the crest of the modulation envelope.

It is worth pointing out that a 150 watt a.m. transmitter (the maximum power of the British licence) and developing say 100 watts output has (when fully modulated) a p.e.p. input of 600 watts and hence a p.e.p. output of about 400 watts. But of the 400 watts 200 are wasted in producing the carrier, so that a 200 watt p.e.p. output s.s.b. transmitter can produce a similar signal-to-noise ratio at the receiver. British amateurs are permitted to operate s.s.b. transmitters with up to 400 watts p.e.p. output, equivalent to the output of a 150 watt a.m. transmitter but with twice the useful power in half the frequency space. It should be noted that a method of determining the power of an s.s.b. transmitter, based on measuring the *output* in terms of p.e.p. while using a two-tone test signal, has been approved by the Post Office.

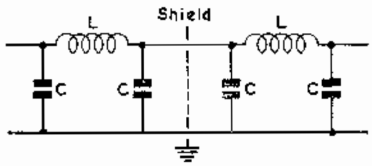
This is some indication of the advantage of s.s.b., although it must be pointed out that there are various speech processing techniques (such as speech clipping) which can be applied more easily on a.m. signals than with s.s.b. so that the practical advantage may not always be that suggested by theory. Perhaps the single greatest benefit of s.s.b from an amateur viewpoint is the reduction of the frequency space occupied by these signals, followed by such points as reduction of distortion during certain types of fading, ease of working duplex or break-in, and the absence of heterodyne whistles.

Television Interference

The most difficult single problem arising in modern transmitters is to avoid causing interference to near-by television receivers. Unless interference can be avoided, operation has to be restricted to those hours when the television stations are not on the air. No amateur would pretend that this is a simple problem or that there is any one all-embracing remedy. However, experience has shown that in most areas it is possible to avoid interference by effective screening and filtering of the exciter and power amplifier, and of all leads before they emerge from the metal screening cabinets. The techniques for reducing harmonic radiation, the most common cause of television interference, are discussed in Chapter 4. There are today many amateurs who have to all intents and purposes completely solved their interference problems and can operate their stations at all times even with television receivers running in the same room—though the occasional unexpected complaint may still turn up from time to time to test their ingenuity in devising further means of protection.

Provided that the transmitter is itself effectively screened and filtered so that no harmonics can leak out through the cabinet or along the power supply or auxiliary leads, then any harmonics generated by the transmitter can only be radiated if they reach the aerial system. One of the most successful methods of preventing such harmonic radiation thus consists of placing a harmonic filter in the low-impedance co-ax transmission line used to feed the transmitter power to the aerial system. For an h.f. transmitter this is often a *low pass filter* (l.p.f.) designed to reduce (attenuate) to a high degree all output from the transmitter above say 30 Mc/s while having little effect upon signals below this frequency. The construction and alignment of such filters are described in the standard amateur handbooks. A filter of this type can simply be left in position on all bands below 30 Mc/s.

An alternative arrangement which does not have this advantage, but which is somewhat simpler to build and adjust—and is quite suitable where most activity is on only a few bands—consists of a series of separate *band-pass filters*,



3·5 Mc/s	C, 800 pF L, 2·3 mH	(11½ turns, 1 in. long, 1 in. inside diameter)
7 Mc/s	C, 500 pF L, 1·0 mH	(10½ turns, ¾ in. inside diameter)
14 Mc/s	C, 220 pF L, 0·55 mH	(6½ turns, ¾ in. inside diameter)
21 Mc/s	C, 150 pF L, 0·37 mH	(7½ turns, ½ in. inside diameter)
28 Mc/s	C, 110 pF L, 0·28 mH	(6 turns, ½ in. inside diameter)

Fig. 12. "Harmoniker" band-pass filters are rather easier to build and adjust than low-pass filters but require a separate filter for each amateur band on which the station is used.

each designed to pass signals on only one amateur band and to attenuate all other frequencies. The appropriate filter for the band in use is plugged into the aerial feeder. Harmonic suppression may not be as good with this type of unit as with a correctly adjusted low pass filter, but impedance matching problems are less likely to arise. Fig. 12 shows the circuit of a band-pass filter, together with basic constructional details for the main amateur bands. Like all TVI filters they should be built in totally enclosed metal boxes with effective screening between the input and output sections, and with co-ax plugs and sockets for connection into circuit without destroying the effectiveness of the screening. These filters have been designed for use with standard value disc ceramic capacitors, although some adjustment of the coils may be needed to resonate them correctly.

The simplest form of band-pass filter takes the form of a good *aerial tuning unit* (a.t.u.) whose main purpose is often to match the low-impedance co-ax output from the transmitter into the aerial system. A good a.t.u. combined with a pi-network (see Chapter 4) in the power amplifier tank circuit (or preferably the slightly more effective "pi-L" network) may well provide all that is required to eliminate TVI in areas where there are strong television signals. An a.t.u. may, of course, be used in combination with a low pass or band-pass filter since the attenuation of a series of filters will normally add together, each reducing any harmonic content still further.

TVI problems most often arise with television stations operating in Band I (British TV channels 1–5) particularly where the television signals are very weak. Interference to television stations using Bands III or Bands IV/V is usually much less serious and easier to overcome.

The Aerial(s)

More than any other section of an amateur station, the aerial governs the final results. At long distance the difference between the signals from a good and a poor aerial of similar design may easily amount to the equivalent of some 100 or so times the power. However this does not mean that DX stations cannot be worked with simple or easily erected aerials—a simple wire aerial at no more than 30 ft. above ground may easily out-perform an elaborate beam aerial that has not been properly adjusted or is wrongly matched to the transmitter. Until a sound understanding of the mysteries of aerial and feeder impedances has been achieved—and this will come best from a combination of practical experiment with a study of the theory—the newcomer will be well advised to concentrate on the simpler aerials, rather than immediately buying or erecting a more elaborate aerial the finer details of which are not fully understood.

Generally the aerial should be erected as high as possible and well clear of all structures; this is of course the counsel of perfection, so do not despair if in your location there is room for only a short sloping span well below the building line or in an attic. Very often an apparently poorly sited aerial will give good results in a limited number of directions (often at variance with theoretical radiation patterns). A good tip in such circumstances is to have two or more aerials with provision for switching the transmitter and receiver to any one of them.

However well the receiver may appear to function with only a short piece of wire slung up indoors, it is important to remember the results will always be improved by using the best possible receiving aerial. Owing to the directional effects of even simple aerials it is very much better to use the same aerial for transmission and reception.

Because of the vital importance to the amateur of a really effective aerial, and also because of the severe physical limitations existing at many of the locations where an amateur station is to be installed, much attention has been paid in recent years to improving the performance of aerials of restricted size, and also in making them suitable for use on several different bands (*multi-band aerials*).

By confining the major portion of the transmitted power into a particular direction (*beam aerial*) it is possible to

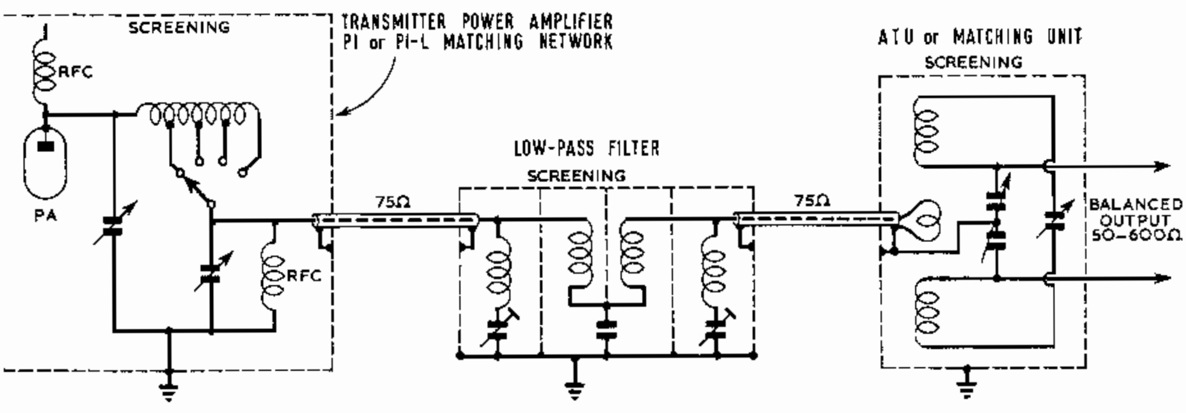


Fig. 13. Typical anti-TVI precautions to prevent the radiation of transmitter harmonics. The harmonic signals are reduced first by the pi-network output circuit, then by the low-pass filter, and finally by the aerial tuning unit.

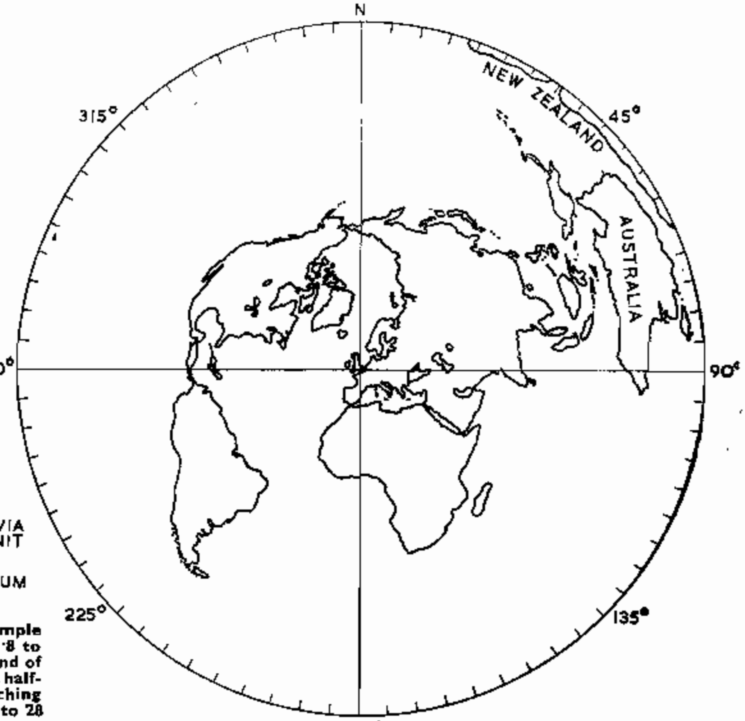


Fig. 14A. A great circle map, based on the United Kingdom. This is how the world appears to an amateur transmitter. Radio signals travel along great circle routes (which are the shortest routes on the globe) and which on the above map would be represented by straight lines radiating outwards from the centre. Such a map is essential when planning an aerial installation as it shows the directions along which signals will travel to particular countries. However, it should be noted that, in the mornings, signals to and from Australia, New Zealand and the Far East often travel the "long way round" across South America. These directions will be exactly 180 degrees more than those indicated on the above map. A special Admiralty Great Circle Map centred on London is available from the RSGB.

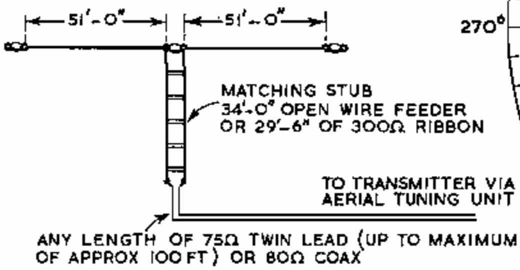


Fig. 14B. The popular G5RV "multi-band dipole" is a simple aerial which can be used effectively on all bands from 1·8 to 28 Mc/s. If space is insufficient the final 10 ft. at each end of the "top" can be dropped downwards. Alternatively, a half-size version, with dimensions of the "top" and "matching stub" each scaled down to one-half, can be used on 7 to 28 Mc/s bands.

obtain an increase in signal strength in the chosen direction equivalent to raising the power of the transmitter by many times. The same aerial when used for reception not only increases similarly the apparent strength of the incoming signals but discriminates against interfering signals coming in from other directions.

The power gain of aerials is usually quoted in terms of *decibels* (db) *gain* referred to a simple dipole aerial. The decibel is a logarithmic expression used for comparing power (and sometimes voltage) ratios. A power gain of 3 db is equivalent to doubling the transmitter power; a 6 db gain is almost four times the power; a 9 db gain almost eight times the power; and a 10 db gain represents a ten-fold increase of the power. Since each 3 db gain doubles the power, a 13 db gain would be 20 times the power and 16 db 40 times the power and so on.

A typical h.f. beam for 14 Mc/s or above may well have a gain of say 6–10 db. So this is equivalent to increasing the power of the transmitter by between 4–10 times. With the British maximum power of 150 watts, it is thus possible to have an *effective radiated power* (e.r.p.) of over 1 kW along the line of the beam.

Furthermore for long distance transmission the vertical angle at which the bulk of the radiated power leaves the station (*vertical radiation pattern*) is of great importance. Low angle radiation is reflected over greater distances by the ionosphere, and will be more readily reflected than transmissions at high angles. This is a factor of particular importance as a given *path* between transmitter and receiver begins to fade out. With beam aerials it is usually possible to achieve appreciably more low-angle radiation than with dipole aerials, unless these are mounted vertically.

Beam aerials may be *fixed beams*, that is permanently erected to direct signals in one or more favoured directions. Alternatively, some means of mechanically (or electronically) rotating the beam direction may be used so that the beam can be swung in any desired direction. Arrangements for such *rotary beams*, often including an indicator system in the amateur shack to show the direction in which the aerial is pointing, can be quite complex and expensive to erect. But some amateurs with a flair for mechanical construction are able to design, build and erect such beams for a remarkable small sum. On the v.h.f. bands where the physical size of the aerials is so much smaller, beam aerials are used by most operators.

Two popular forms of directional aerials are the *Yagi*, as widely used for television reception, and the *Cubical Quad* which has several advantages including a somewhat smaller turning radius, allowing it to be erected in quite small gardens. Some very ingenious designs, permitting Yagi and cubical quad aerials to be used effectively on several different bands have been developed, and new arrangements appear quite frequently in the amateur publications.

But although beams undoubtedly provide a great advantage for DX working it should not be supposed that long-distances cannot be covered without them. Particularly on c.w. it is entirely possible to contact stations throughout the world using modest dipole-type aerials or the increasingly popular simple vertical aerials with which low angle radiation can be achieved.

A very practical arrangement for erection on the roofs of urban houses or bungalows, or wherever there is little space available, is the *ground plane*, consisting basically of a quarter-wavelength vertical rod (usually of aluminium-alloy) with four "radials" sloping downwards and forming an artificial ground or earth plane. The rod can often be mounted quite high up on a chimney stack with the wire radials conforming approximately to the roof slope. Fig. 15 shows details of this simple yet often very effective DX aerial.

Although there are now a very large number of different aerials in use by amateurs, these are mostly variants of a few fundamental types; the information given in Chapter 4

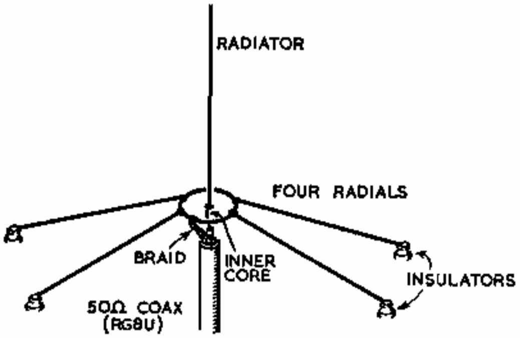


Fig. 15. The ground plane aerial is one of the simplest yet most effective DX aerials for installation in restricted spaces. For operation on 14 Mc/s the rod is 16 ft. 11 in. long and the radials can be made from hard drawn copper wire each 17 ft. 2½ in. long. The radiator is insulated from the fixing mount with the inner core of the 50-ohm co-ax soldered or bolted to the end. The radials are soldered to a copper ring together with the braid of the co-ax and kept well apart from the vertical rod and the inner core of the co-ax. For good match to the 50-ohm feeder, the radials should slope downwards at roughly 120° to the radiator. Dimensions can be scaled up or down for other bands.

should be assimilated before attempting to understand the operation of more complicated types.

No matter how good the aerial and transmitter may be effective transmission will depend upon the transfer of the power from the transmitter to the aerial, usually along the *transmission line* which often consists of low-impedance coaxial line or 300-ohm ribbon-type twin line feeder. For optimum transfer of power the feeder must be reasonably accurately matched in impedance at both the transmitter and aerial element ends, as discussed in Chapter 4. Where optimum conditions are not achieved, standing waves will exist upon the feeder and can be detected by a suitable *s.w.r. indicator*. Some very simple instruments for this purpose have been developed and are described in the handbooks. While an s.w.r. indicator is a very useful device to have available, it is perhaps worth mentioning that quite considerable standing waves can often be tolerated on untuned transmission lines without seriously reducing radiation.

Semiconductors

Another factor which nowadays must be taken into account by newcomers planning future equipment is the gradual trend towards transistors and other semiconductor or solid-state devices, including for example the silicon power diodes already mentioned.

Completely solid-state stations, except for fairly low power portable or mobile operation, are still quite rare, although now technically feasible for fixed station operation at medium powers. The main problem is that h.f. power transistors still tend to be considerably more expensive and provide lower gains than valves of equivalent power rating. Recent years have seen a steady reduction in the prices of these special semiconductors. Again, most high power transistors call for power supplies of 28-40 volts at fairly heavy currents, so that there is only limited operational and size advantage in solid-state transmitters, the major bulk represented by power supplies being little affected. It is also easy to damage or destroy the expensive h.f. transistors unless care is taken—normally, for example, such transistors should never be operated without a correctly matched load unless adequate protection circuits have been incorporated.

On the other hand for audio work and for receivers and low power stages in exciters, the compact size, simple circuitry and low price at which many "surplus" transistors are now available all make these attractive for current designs. We can therefore expect to see many more "hybrid" equipments—that is units employing a combination of valves and transistors—with valves being retained mainly for r.f. power amplification, in the next few years, even though these are at present still rare.

Then again, there are some applications in which semiconductors offer new facilities and so are already attracting considerable attention. One example is the use of semiconductor diode switches to overcome the problems which have always attended the use of mechanical switches for switching low power radio frequency circuits. Semiconductor diodes also possess the important characteristic that their capacitance can be changed by altering the reverse voltage applied across them, providing us with a form of variable capacitor which can be "tuned" by altering a d.c. voltage—particularly useful for some forms of bandspread tuning or for remote operation of a variable frequency oscillator, etc. Semiconductors are also, of course, extremely useful for compact test instruments needed in amateur stations including grid dip oscillators, field strength meters and monitors.

Although at present many amateur stations use few semiconductors for normal fixed station operation, this is sure to change gradually with increasing use of semiconductors during the next few years. Already some of the compact transceivers are using transistors in many stages.

One of the first fields in which they have made real impact is for v.h.f. converters providing reception of v.h.f. bands on normal h.f. communications receivers. There are also many advanced techniques including parametric amplifiers, parametric frequency multiplication (varactors), etc., already attracting the interest of keen experimenters.

A transmitting application for which transistors have proved their worth is for stable variable frequency oscillators. Since very little heat is generated in a low power transistor, a transistor v.f.o., if mounted well away from other sources of heat, will show very little frequency drift. The circuit shown in Fig. 16, originally designed by W3JHR, has proved particularly effective, and uses mainly ex-ARC5 (Command series) components for the tuned circuit (L1, C1, C2) in this particular case to provide an output tunable

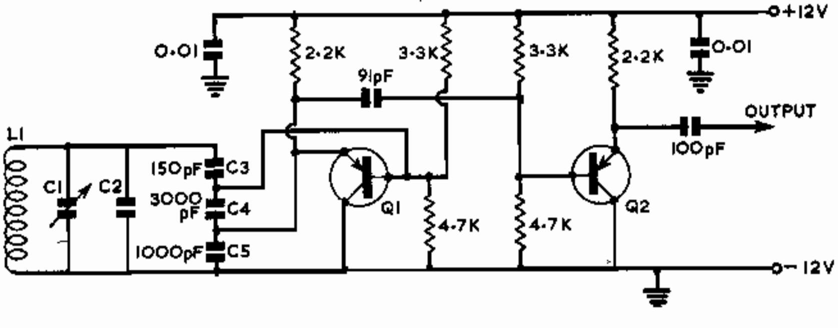


Fig. 16. Many amateurs are finding that transistor variable frequency oscillators, if kept well away from sources of heat, can provide a higher degree of stability than can be achieved easily with valve oscillators with their greater internal generation of heat. This particular circuit has proved very popular using OC171, 2N384 or similar h.f transistors. Many other circuits incorporating semiconductor devices are given in the RSGB publication *Technical Topics for the Radio Amateur*.

between 4.9 and 6.1 Mc/s. The transistors can be types OC171, 2N384, etc. The v.f.o. provides only a small output for subsequent amplification by a high-gain valve stage using a 6AH6, etc., or by further transistor stages.

Certain precautions must always be taken in any equipment using semiconductors: transistors can be damaged or destroyed by applying supply voltages the wrong way round, by excessive transient voltages, or by subjecting the junctions to excessive heat or mechanical shocks. The internal resistances of transistors are low, and even quite low voltages applied across the wrong electrodes can cause excessive currents which can burn out or damage the junction. The larger power transistors are among the most susceptible to this hazard because of their very low internal resistances. Some of the ways in which these conditions can accidentally occur include: (i) leakage voltages to earth from the bit of an electric soldering iron (the answer is to earth the casing of the iron) or from the output leads of mains operated test gear such as signal generators (always include isolating capacitors in the leads between such test gear and the transistor equipment); (ii) voltages from internal batteries in low-resistance continuity testers or low-resistance ohmmeters (internal resistance of instruments should exceed 10,000 ohms or an external resistor of this value should be connected in series), or from the sudden discharge of a large-value electrolytic capacitor; (iii) excessive currents arising from too great an input from a signal generator or nearby transmitter.

There is also some hazard arising from a sudden disturbance in operating conditions: do not disconnect a transistor until all potentials have been removed; do not run a transistor with its collector circuit open; do not short-circuit base to collector while a transistor is operating. With power transistors, both a.f. and r.f. types, it is important not to operate them without a properly matched load, since otherwise excessive high voltages may appear on the collector. Power transmitters normally have to be mounted in "heat sinks"; these are pieces of metal which help to dissipate internal heat to the surrounding air.

The Station Layout

From the beginning it should be appreciated that an amateur station is more than just a number of separate items of equipment—receiver, transmitter, frequency meter and the like—gathered together haphazardly in the same room. There should always be forethought and planning, bearing in mind the ultimate *operation* of the equipment as a single unit. An efficient transmitter is useless without good receiver performance; a stable variable frequency oscillator unit is wasted unless the output frequency can be readily adjusted to any required channel from the operating position; slowness in changing from transmission to reception and vice versa can spoil endless contacts.

A station should be planned not only to keep abreast of technical developments, but also with the objectives of comfort, rapid change-over, and general ease of operation. Many hours will be spent searching for and copying weak signals; yet, too often, the newcomer gives little thought to his own comfort. For example, receiver tuning controls may be so placed as to require the operator to keep his arms outstretched without support from the operating table which may, in turn, be pressing relentlessly into the pit of the stomach owing to the receiver being too far back. Or the change-over from transmission to reception may require a sudden flurry of effort and concentration.

The following are some of the factors which govern the "operability" of an amateur station:

The operating table should be as large as space permits, and never allowed to become cluttered up with stray pieces of equipment or spare parts. There should be plenty of room for the log and scribbling pads directly in front of the operator.

The receiver should be placed comfortably back on the lefthand side of the operating table so that the forearm may be rested while tuning. The height of the most frequently used controls is important and can often be adjusted advantageously by mounting the receiver on rubber blocks, which also reduce the effects of vibration. Four to six inches is normally a good height for the main tuning and gain controls.

Where variable frequency control is employed, the oscillator unit should be within easy reach of the operator, preferably in the back right-hand corner of the table. Switching arrangements should permit the operation of the oscillator unit by itself (i.e. with the exciter and amplifier stages inoperative) in order to provide a weak signal on the receiver to allow adjustment to any desired frequency.

Change-over from transmission to reception should be by means of not more than one switch: for telegraphy it will be better still if this is accomplished solely by the action of the Morse key; for telephony the ideal is a voice operated change-over device (VOX) or a single push-to-talk switch on the microphone. Where, as is usually the case, it is desired to switch a number of separate circuits, this should be done by means of a multi-contact relay operated by a single change-over switch.

Where the main transmitter is not constantly under view from the operating position, it is advisable to provide some indication on the operating table to show whether the transmitter is functioning correctly. This can be either a Morse or telephony monitor, providing a low-level indication of the transmitted signals in the operator's headphones, or alternatively a meter or bulb indicating the current being delivered to the aerial feeder.

Finally, look round for the most comfortable cushioned chair (preferably one with arms), provide yourself with a handy bookshelf and space for pencils, reference lists, a good atlas—and do not forget to leave plenty of room for your legs and feet!

Test and Auxiliary Equipment

Little can be done in radio construction and operation without some items of test equipment, although fortunately an amazing amount can be achieved with very little. A test meter for measuring d.c. voltages and currents in various ranges up to about 1000 volts and currents up to about 200 mA (a.c. ranges though useful

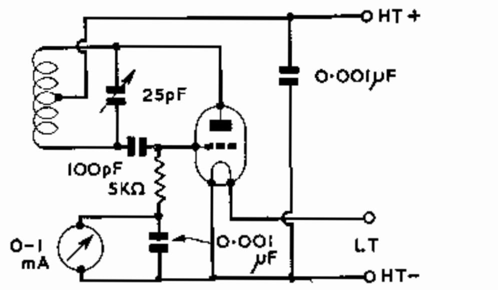


Fig. 17. One of the most useful pieces of test gear is a grid-dip oscillator. In this circuit, almost any small triode or pentode connected as a triode may be used. Approximate coil dimensions: 3.5 Mc/s 60 turns 28 s.w.g.; 7 Mc/s 34 turns 24 s.w.g.; 14 Mc/s 14 turns 24 s.w.g.; 21 Mc/s 10 turns 24 s.w.g. All coils are centre-tapped and closewound on 1½in. diameter formers.

are not essential and great sensitivity or accuracy is seldom required for routine testing); a single d.c. milliammeter of say 1 mA full scale deflection used with series and shunt resistors will prove adequate for most purposes. One or more milliammeters should be permanently connected in the transmitter for tuning up and checking.

Some means of providing check points for frequency calibration purposes are essential, preferably based on a crystal controlled oscillator (see Chapter 4). A simple absorption-type wavemeter is of tremendous assistance and can usually be made easily from junk box components.

A simple monitor—for example a crystal diode or Westector rectifier receiver—is most useful for checking the quality of outgoing telephony signals. On c.w. many operators like to listen to their own Morse and this calls for either a heterodyne monitor or neon oscillator.

A grid dip oscillator is extremely useful for receiver, transmitter and aerial construction and adjustment; this is also a simple instrument to build as it consists of a single stage valve oscillator which indicates when the oscillator circuit is in resonance with any external circuit to which it is coupled by a dip in grid current.

Almost any type of neon bulb will prove invaluable for checking radio frequency voltages in transmitters and aerials, and is also handy for detecting points at "live" mains voltages.

Mobile Operation

Over 2100 British amateurs—approaching 20 per cent of the total—have taken out additional mobile licences which permit them to operate compact amateur stations in their cars. In the UK the greater part of this mobile operation takes place on the 1·8 Mc/s band ("Top Band"), but considerable use is also made of the v.h.f. bands (70 Mc/s, and particularly 144 Mc/s). The h.f. bands are used by relatively few British mobile operators although some of these bands, especially 28 Mc/s, are popular for this application overseas. Greater use of 28 Mc/s has been urged in the UK, since this band can provide consistent local results, plus long ranges during band openings even with simple whip aerials.

Transmitter power on 1·8 Mc/s is limited by the UK licence to 10 watts, and a similar order of power is commonly used on v.h.f. Operation is almost always on phone, and ranges of 10–20 miles are usual; much longer distances can be achieved on h.f. bands, or in favourable circumstances.

Equipment for mobile operation conforms in many ways to low-power fixed station practice; though a mobile station is often designed for use on a single band, and the receiver may consist simply of a converter in conjunction with a standard car radio receiver. The limited space in small family cars calls for considerable ingenuity if the best use is to be made of what is available. But the paramount consideration should always be that of safety: if the station is to be operated by the driver, the layout and controls must not in any way distract his attention from his prime task of driving the car.

The power source for low power operation is almost invariably the normal car battery, often providing a nominal 12 volts (usually in practice about 13·5 volts). While this voltage is sufficient to operate fully transistorized equipment directly, many mobile operators still use valves for power amplification in their transmitters, and this means that a transistorized d.c.–d.c. inverter will often be used (occasionally older forms, including vibrators or rotary converters, may still be found). The transistorized d.c.–d.c. inverter consists basically of a power oscillator with two or more power transistors oscillating rapidly between their "on" (low resistance) and "off" (high resistance) states, and so converting the d.c. supply into a form of a.c. at roughly 200–1000 c/s so that it can be stepped up by transformer action, and then rectified and smoothed. Such units can operate at very high efficiencies, and provide sufficient h.t. for a small valve transmitter; the same technique may be used with valve modulators, but increasingly all audio amplification is by means of transistors. The future trend is likely to be towards full use of transistors in the transmitter also, and this will usually eliminate the need for an inverter (although some r.f. power transistors operate more efficiently with 28 or 36 volt supplies, and this would require an inverter).

A major problem with all mobile installations is that of suppressing to a high degree all the electrical interference which stems from the ignition system and other car electrics. Full guidance for interference suppression techniques will be found in the *RSGB Amateur Radio Handbook* and other publications.

Another problem, particularly for 1·8 Mc/s operation, is that of achieving maximum radiation from a short whip aerial, which can seldom exceed 7 or 8 ft. in length; usual practice is to inductively load the aerial with a weather-proof coil inserted either in the centre or at the base of the whip. On v.h.f. rather more efficient aerials can be realized: one popular type is the omni-directional "halo" which consists essentially of a half-wave dipole bent round in the form of an open circle about 1 ft. in diameter, and mounted some 2 ft. above the car roof.

Commercially-built amateur mobile equipment—including all-transistor stations—suitable for British cars is available, although some amateurs find the construction of mobile equipment, with its challenge of compact size, an interesting test of their own ingenuity.

RSGB

MOBILE SAFETY RECOMMENDATIONS

1. All equipment should be so constructed and installed that in the event of accident or sudden braking it cannot injure the occupants of the car.
2. Mobile aerials should be soundly constructed, taking into account flexing at speed and possible danger to other vehicles or pedestrians. The maximum height must not exceed 14 ft. above ground.
3. Wiring should not constitute a hazard, either electrical or mechanical, to driver or passengers.
4. All equipment should be adequately fused and a battery isolation switch is desirable.
5. The transmit/receive switch should be within easy access of the operator and one changeover switch should perform all functions.
6. The microphone should be attached to the vehicle so that it does not impair the vision or movement of the driver.
7. A driver/operator should not use a hand microphone or double headphone.
8. All major adjustments, e.g. band change by a driver/operator, should be carried out whilst the vehicle is stationary.
9. Essential equipment controls should be adequately illuminated during the hours of darkness.
10. Logging must not be attempted by the driver whilst the vehicle is in motion.
11. All equipment must be switched off when (i) fuelling, (ii) in close proximity to petrol tanks and (iii) near quarries where charges are detonated electrically.
12. A suitable fire extinguisher should be carried and be readily accessible.

CHAPTER THREE

Communications Receivers

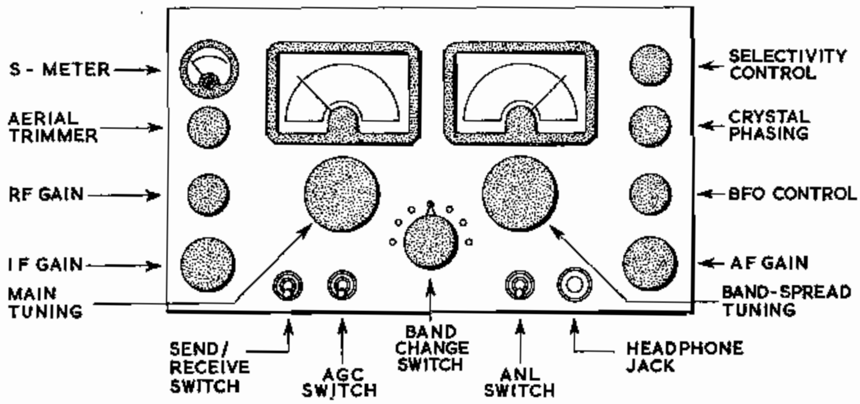


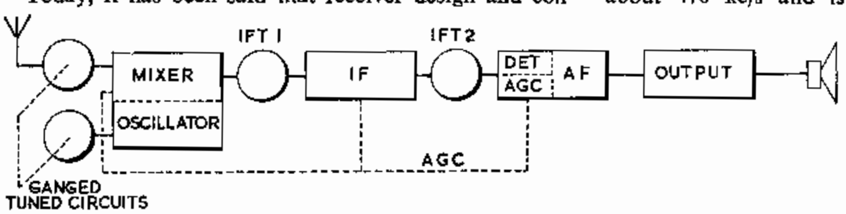
Fig. 1. Panel layout of a typical amateur communications receiver, showing the most useful controls.

THE first requirement of every newcomer to Amateur Radio is a good receiver covering the amateur bands—and the skill to make the best use of it. Almost any "all-wave" broadcast receiver or simple one- or two-valve "straight" receiver will bring in amateur signals on some bands, but will usually prove unsatisfactory for serious listening in one or more respects. The crowded amateur bands, the relatively narrow spaces they occupy in the full short wave spectrum, the extremely wide variation between strong and weak signals (which may easily differ in voltage by 10,000 times and can occasionally be of the order of 500,000 times), all impose very stringent demands upon the receiver. Over the years high performance receivers which are not unduly expensive and which have become known as "communications receivers" have been evolved to meet these special needs. Although there are now many users of such sets other than amateurs—including the Services and commercial organizations—it is to the credit of the radio amateurs that this type of receiver was originally produced in large numbers.

Today, it has been said that receiver design and construction by the amateurs themselves is a lost art; and it is true that only a small minority use receivers entirely constructed at home. But whether you build or buy your receiver, it is certain that you will not obtain the best results unless you have a sound understanding of the main features of a communications receiver, how it differs from a standard broadcast set, and the purpose of the various refinements and controls.

"All-wave" Superheterodyne Receivers

For broadcast entertainment usually only a few stations of relatively high signal strength are wanted and the user is satisfied if he can obtain these few stations at a steady level of volume, with good quality reproduction, as free as possible from electrical interference or interference from other stations. The majority of domestic receivers use an almost standard four-valve or six-transistor circuit which will meet these demands reasonably well: see Fig. 2. The first valve is a combined mixer and local oscillator which changes the incoming signals to the intermediate frequency of about 470 kc/s and is coupled to the next valve by



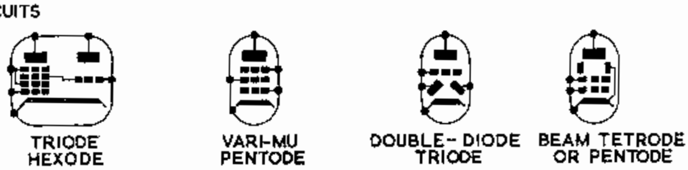


Fig. 2. Representative design of a conventional broadcast-type superhet receiver.

means of the first intermediate transformer containing two inductively coupled resonant circuits. This second valve, invariably a pentode, amplifies the i.f. signals and passes them on, through a second i.f. transformer, to a diode detector which is usually enclosed in the same valve envelope as a triode or pentode section used to amplify the voltage of the audio frequency output from the detector. Either the same diode or a second diode is used to provide a d.c. voltage which varies with the strength of the signal and this voltage is used to control automatically the gain of the first two valves so as to keep the output from the receiver fairly constant despite any fluctuations in the strength of the incoming signals. The final valve (ignoring any valves which may be used to rectify the a.c. mains) is a tetrode or pentode amplifier providing sufficient power to operate a loudspeaker.

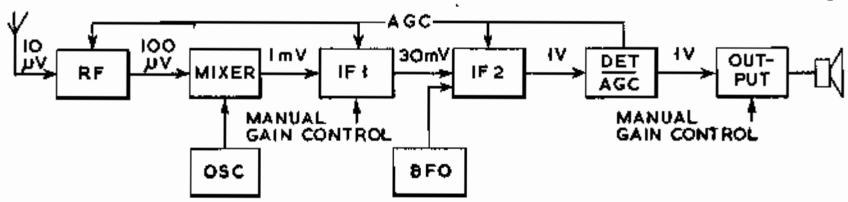


Fig. 3. Block diagram of a basic superhet receiver suitable for general purpose short wave reception and amateur communication.

Four-valve broadcast receivers of the type outlined above frequently incorporate a short wave band or bands and many newcomers to Amateur Radio receive their first amateur transmissions on such receivers; indeed many local and long-distance stations can often be received successfully. It will soon be found however that many transmissions are spoilt by other stations on adjacent frequencies or lost altogether in attempts to tune them in more accurately or because the receiver drifts in frequency between transmissions. When the stations are weak and the volume is turned up there is either insufficient amplification available or valve noise drowns the stations. It will also soon be noticed that most receivers will tune to the louder commercial and broadcast stations at more than one point on the dial, and this will make the bands sound even more crowded with stations than they really are, particularly on the higher frequency bands. Amateur telegraphy stations can usually be heard only as a series of "thumps" which are extremely difficult to copy even if you can read Morse. There will also be some signals which will be completely unintelligible; these emanate from stations using suppressed carrier systems. Thus if we were to attempt to use a receiver of this category for serious amateur operating we should be able to hear and work only the louder stations and would miss altogether many of the weaker long distance signals. It would be rather like entering for a T.T. race on a motor scooter. These objections apply also to entertainment-type transistor receivers.

It will not be long before we begin to sum up the needs of a receiver for communications purposes. Our list will be more or less as follows: (1) very good *selectivity* to separate the stations; (2) a high degree of *sensitivity* to permit reception of weak stations; (3) *ease of tuning* with the ability to return quickly to a given frequency; (4) *stability*, so that the set does not drift off a station or lose it suddenly due to shock or vibration; (5) absence of *spurious* signals, so that even the loudest stations are heard at only one point on the dial and with no tunable whistles generated within the receiver; (6) there must be an internal oscillator (called a *beat frequency oscillator*) for listening to Morse signals and suppressed carrier telephony stations.

Selectivity

The ability to separate stations on closely adjacent frequencies is governed by the selectivity of a receiver. Our elementary radio textbooks tell us that a high degree of selectivity is extremely difficult to achieve in straight receivers and that in the superheterodyne receiver this characteristic will be determined very largely in the intermediate frequency section. It has been stated earlier that the standard broadcast set usually has one intermediate frequency amplifying stage with an i.f. transformer, comprising two tuned circuits, in both the input and output circuits of the stage. This provides altogether four resonant circuits peaked to accept signals at a given frequency, usually between 455 and 470 kc/s (about 640 metres). Now four circuits at this frequency *can* provide a fair degree of selectivity even in crowded amateur bands, although the most powerful stations will usually tend to spread out over a fair number of kilocycles. But the type of i.f. transformers fitted in broadcast receivers are not generally the most efficient for communication purposes. For good quality broadcast reception we need to receive without undue loss frequencies up to about 9000 c/s (9 kc/s) on each side of the nominal station frequency; for amateur telephony this figure could be reduced by about three times, to some 3000 c/s either side, and for telegraphy we need a bandpass of only 100–200 c/s. Broadcast i.f. transformers are often deliberately "over-coupled" or peaked to different frequencies in order to produce a broader response and are not of high-Q construction (Q is a term denoting the "goodness" of a coil and it is this which determines the selectivity of a given tuned circuit).

Thus as we tune our broadcast receiver across a powerful signal, we shall hear the station without distortion over a fairly narrow band and then for some kilocycles on either side we shall continue to hear the transmission with increasing sideband distortion until the set is between say 15 and 25 kc/s away from the carrier frequency. Thus a really powerful signal may block out weak stations over a channel up to 50 kc/s wide. There is also the possibility that a very loud signal may affect the receiver over an even wider band, due to a form of interference called cross-modulation.

There are a number of ways in which the selectivity can be improved.

(1) The coupling in the i.f. transformers can be decreased by placing the windings farther apart.

(2) The i.f. transformer windings can be of higher Q or some other form of tuned circuit can be used having a much higher Q (in practice this may be either a quartz crystal, a mechanical filter, or a device known as a Q-multiplier which depends on the fact that a circuit near oscillation has a very high Q).

(3) The total number of tuned circuits can be increased; this is most easily done by adding i.f. valves, with additional i.f. transformers to provide the coupling between each valve.

(4) The intermediate frequency can be lowered; this will increase selectivity because the response of a tuned

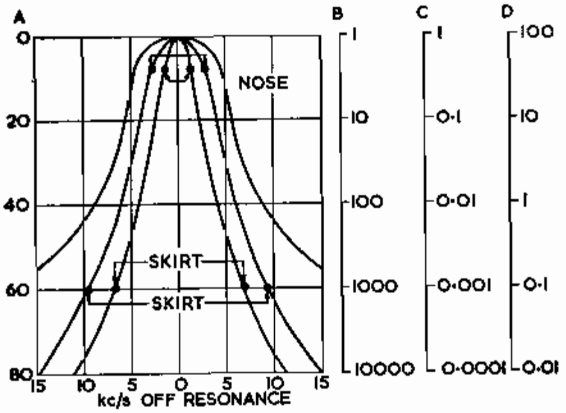


Fig. 4. One of the most important characteristics of a good communications receiver is adequate selectivity. This graph shows three different selectivity curves varying from the "just adequate" to the type of results obtainable in a good modern receiver. A, B, C and D indicate four different scales in which such curves are often given: A is a scale based on the attenuation in decibels from maximum response; B is relative inputs for a constant output; C is output voltage compared with that at maximum response; D is the response expressed as a percentage.

circuit to a signal off resonance depends upon the percentage difference between these two frequencies. For example a signal at 490 kc/s fed to a 470 kc/s i.f. amplifier represents a percentage difference of 20/470 x 100, approximately 4 per cent. If we lower the i.f. to 50 kc/s and feed into the amplifier a signal the same number of kilocycles off tune (i.e. 20 kc/s), the percentage difference is 40 per cent, and the rejection will be correspondingly greater. We shall see later, however, that merely lowering the i.f. brings in other problems that off-sets this advantage.

In practice a modern communication receiver will often use a combination of all these four methods of achieving high selectivity: it will use specially designed under-coupled i.f. transformers of high *Q* construction, with a very high *Q* crystal filter or *Q*-multiplier for optional use; it will have two or even three valves as i.f. amplifiers and may have as many as twelve circuits resonant at the i.f.; and it may achieve its main selectivity at a very low intermediate frequency (40–100 kc/s). Several different degrees of selectivity can usually be selected by a switch.

To compare the selectivity of different receivers, or receivers having more than one position of selectivity, we can use selectivity curves such as those shown in Fig. 4. There are two ways in which we must consider these curves: the first is the "nose" figure which represents the bandwidth in kilocycles over which a signal will be heard with relatively little loss of strength; the other figure—and many amateurs will consider this the more important—is the bandwidth over which a really powerful signal is still audible (often taken as a reduction of 1,000 times (60 db) on the peak strength) and this is often termed the "skirt" performance. These two sets of figures are related by what is known as the "shape factor" of the receiver. Since, even with a very good receiver, the "skirt" bandwidth will tend to be from 2.5 to 5.5 times as great as the "nose" bandwidth, it is most important always to distinguish between these two sets of figures. In practice, any receiver which has a "skirt" bandwidth of less than about 10–15 kc/s can be considered a very good one, though the "nose" figures for even medium grade receivers will look much more impressive!

Sensitivity

Weak signals clearly need to be amplified very much more than strong ones in order to make them easily readable. Now it is quite easy to amplify any signal by means of a valve or transistor, so at first glance it might seem that all we need to do in order to receive weaker and weaker signals would be to add more and more stages of amplification. Unfortunately it is not so simple as this—as we can quickly observe if we turn up all the gain (i.e. amplification) on any receiver having more than about four valves. What happens is that the "noise" from the set rises and masks any very weak signals that may be present. No matter how much further we increase the gain we shall simply hear more and more noise and the signal itself will remain inaudible. How weak a signal can be heard on a receiver then is not governed by how much the set will amplify but by how small a signal can be heard above the general noise level. This characteristic of a receiver is described by stating the minimum signal voltage required to produce a given output for a certain ratio of signal above the noise level at a specified selectivity, and is known as the *signal-to-noise ratio* (or more strictly as the "signal-plus-noise to noise ratio.").

To see how the signal-to-noise ratio, or in other words the sensitivity, of a receiver can be improved it is necessary to discover where this background noise comes from, since if this can be reduced then clearly weaker

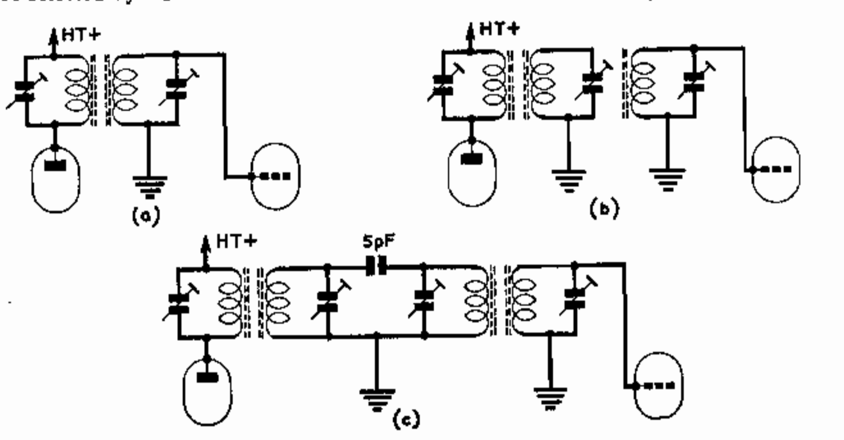


Fig. 5. Inter-valve couplings for increasing i.f. selectivity. (a) The conventional double-circuit i.f. transformer. (b) The triple tuned i.f. transformer will provide a useful improvement in skirt selectivity. (c) If a triple tuned i.f. transformer is not available, two conventional i.f. transformers can be used to provide four tuned circuits per stage.

signals will be heard. Without going too deeply into the subject, it is possible to distinguish between a number of different sources of noise.

(1) There will be some noise from atmospherics, radiation from space and other natural phenomena. There is not much that any of us can do about this type of noise, which would in fact limit the usable sensitivity of an ideal noise-free receiver.

(2) There will be local or "site" noise caused mainly by the local operation of electrical appliances. This noise will vary widely in different localities. While in extreme cases it may be possible to have specific sources of interference suppressed, very few amateurs are blessed with anything like ideal noiseless sites. Automatic noise limiting devices (a.n.l.) fitted in a receiver can remove some of the more objectionable "peaks" of interference, but it must be accepted that in many locations and on some at least of the bands this man-made interference will limit the usable sensitivity.

(3) A certain amount of noise will be generated within the valves due to the so-called "shot" effect and in multigrid valves by "partition" noise. The noise produced in the early stages of a receiver will be amplified by all succeeding valves and so will be more important. In order to compare different valves it is usual to consider this noise in terms of an imaginary resistance in series with the grid of the valve. The equivalent value of this resistance varies widely according to the design of the valve and how it is being used. It is important to note that a valve used as a frequency changer is much noisier than when employed as a straight amplifier. A good modern r.f. pentode valve may have an equivalent noise resistance as low as 1,000 ohms whereas for frequency changers it is not unusual for the equivalent resistance to be higher than 200,000 ohms. This gives us a clue as to one of the most important features of a really sensitive communications receiver; it must have one or more carefully chosen valves operating as tuned radio frequency stages to amplify the very weak signals *before* they pass through the frequency changing stage. If this is done, the signals will then be strong enough to over-ride the unavoidably large amount of noise contributed by the frequency changer. This explains why our broadcast receivers, few of which today include an r.f. amplifier, are not suited to deal with very weak signals, and also explains why "straight" t.r.f. receivers, which do not have a frequency changer, can be made very sensitive, though unfortunately they cannot be made selective enough to cope with modern conditions. Some low-noise mixers—including triodes and special beam-deflection valves and field effect transistors—allow sensitive superhets without r.f. amplifiers, though an r.f. amplifier may have other uses.

(4) Even if we were to achieve the impossible and to eliminate all valve noise and then were to remove the aerial to prevent any signals from reaching the receiver, there would still be some background noise left. This would be due to what is called the "thermal agitation" voltages which are always present across any impedance. In a receiver the most important source of this noise will be the first tuned circuit impedance, and a very good test for a receiver is to ascertain whether, with a resistor equal to the input impedance connected across the aerial terminals, this noise peaks up as the circuit is adjusted for resonance. The ultimate effect of this noise will depend upon the total pass band of the receiver which means that a receiver which has variable selectivity will tend to have a better signal-to-noise ratio when adjusted to its most selective position (it is for this reason that the sensitivity of a receiver is often described in terms of its *noise factor* which does not depend upon its bandwidth).

(5) Finally there may be some noise contributed by mains hum due to insufficient smoothing in the mains power supply or poor insulation of the valve heaters. This form of noise is seldom a limiting factor on a good communications receiver and when encountered can be cured by more efficient smoothing or valve replacement.

Before leaving the subject of sensitivity, the importance must be stressed of always presenting to the input terminals of the receiver the best possible signal provided that this does not cause overloading of any stage. This may seem self-evident but it is not always appreciated that any "gain" that can be achieved at this end of the receiver—either by improving the aerial or its coupling (i.e. matching) to the first tuned circuit will be noiseless gain, an ideal form of amplification that can never be repeated elsewhere in the receiver.

To give an idea of practical performance, any receiver with a 10 db signal-to-noise ratio with an input of 1 to 3 microvolts is in the high quality class, while if you can obtain this figure for a 5μV signal you will not miss many signals.

Ease of Tuning

For many applications, the ability to tune a station in easily and accurately, to tune away, and then to be able quickly to re-set the receiver back to the original station is an even more desirable characteristic than extreme sensitivity. For illustration, we need only to think once again of our imaginary all-wave broadcast receiver; on most sets of this type the entire 20 metre (14 Mc/s) amateur band, although 350 kc/s wide, will

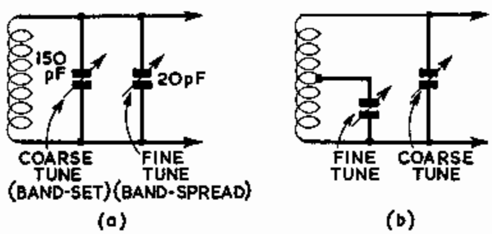


Fig. 6. Alternative methods of providing electrical bandspread tuning. (a) Small condenser connected in parallel across the main tuning condenser. (b) Tapped coil, this system can be made to provide different degrees of bandspreading to suit individual amateur bands.

occupy under a quarter-inch of a dial which has to cover all frequencies between 6 Mc/s (50 metres) and 18 Mc/s (16 metres). It is usually almost impossible to re-set such a dial to a particular amateur station unless it has some outstanding characteristic. What is needed is to spread out the amateur band so that it occupies much more space on the dial, and this process is called band-spreading. For instance if we could arrange to eliminate all the unwanted portions of the short wave band and leave just the 20 metre amateur band occupying almost the entire dial then it would be very much easier to tune or re-tune to a given station, more especially if the dial was accurately calibrated. In practice bandspreading can be achieved by placing across the main tuning condensers (which may vary in capacity anything between 150 and 500 pF), much smaller tuning condensers having a variation of about 20 pF (Fig. 6). Alternatively, instead of electrical bandspread—as the method just described is termed—much the same final result can be achieved by increasing the gear ratio in the slow-motion tuning mechanism and coupling this with some device to lengthen the dial itself. However if this method is adopted great care will be needed in the design and construction of the gearing to avoid "play" or "backlash" which would prevent accurate setting.

Most good communications receivers use a combination of electrical and mechanical bandspread so that a complete rotation of the tuning knob will cause the frequency to be changed by only a few kilocycles and this permits accurate re-setting to any given frequency. Some extremely ingenious mechanisms have been developed both commercially and by amateur constructors to provide an effective scale length of the dial running to many feet.

Stability

It is little use having an accurate dial and a high degree of selectivity unless the receiver is stable. There are several forms of instability all of which tend to become worse as the frequency increases. First there is the steady drifting of the frequency of the local oscillator so that any given station appears to be gradually changing frequency; the set thus requires periodic retuning or else the station may be lost altogether. This drifting is caused mainly by the effect of heat on the oscillator components and can be minimised by careful layout of the receiver, by adequate ventilation and by the inclusion of compensating components chosen to balance out the changes in inductance and capacity. However even with the most careful design there will usually be some drift during the first 10–15 minutes after switching on a cold receiver; but in a good design the set should then settle down and no further significant change in frequency should occur.

It should be noted that after undergoing a number of heat cycles (that is to say warming up and then cooling down again) some components do not return precisely to their original values. This is one of the reasons why it is difficult to maintain accurate calibration of a bandspread dial over a long period. Some receivers include a crystal controlled oscillator of high stability providing marker signals with which the calibration can be regularly checked and adjusted. A calibration marker

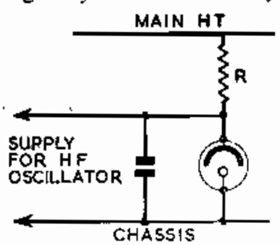


Fig. 7. The use of a neon voltage regulator tube to stabilise the h.t. voltage to the h.f. oscillator stage. R must be calculated to provide a standing current of about 5 mA through the regulator tube, taking into account the current drawn by the oscillator valve.

of this type is also extremely useful where the set has both a coarse main (bandset) tuning knob and a fine (bandspread) tuning knob as it enables the main dial to be re-set accurately.

Another form of instability which cannot be ignored is mainly mechanical in origin. Even if you have not already done so, you are sure to come across a receiver which suddenly shifts slightly in frequency when subject to any form of mechanical shock, or even a sudden burst of electrical interference. It is difficult to eliminate completely the effects of vibration on a tuned circuit but good construction with a heavy chassis and suitable mountings will reduce this to insignificant proportions; tuning circuits must be wired solidly with no long leads left to vibrate.

A third type of instability is that of inter-acting controls. This usually takes the form of a gradual change in frequency when a gain control is varied, and is almost always due to insufficient regulation of the h.t. applied to the oscillator. Fortunately this effect can be largely overcome by fitting a neon voltage regulator to stabilise the oscillator h.t. (Fig. 7).

Spurious Signals

One of the major defects of a simple superheterodyne receiver is that the same signal can often be heard on at least two settings of the dial; one considerably stronger than the other. As the frequency increases, the relative strengths of these two signals becomes more nearly equal. In effect this means that loud commercial and broadcasting stations can often be heard within the amateur bands and greatly reduces the chances of hearing a weak amateur station free of interference. There are a number of causes of these spurious signals, as they are called, and these are described in detail in most standard text books. Here, however, we must confine ourselves to the most common cause; the reception of a station operating on what is called the "image" frequency.

The elementary principle of the superheterodyne receiver is that when two signals of different frequency are mixed together they combine to produce a signal on a frequency equal to the difference in frequency of the two signals. One of the original signals will be that of the required station, the other will be that produced in the local oscillator in the receiver which will be tuned to track a fixed number of kilocycles (equal to the intermediate frequency of the receiver), away from the signal frequency. The oscillator is usually (but not always) on the high frequency side of the signal frequency. Supposing our local oscillator is tuned to $F1$ kc/s and the set has an intermediate frequency of $F2$ kc/s, then the frequency to which the receiver will be tuned is equal to $F1 - F2$ kc/s, and this is the frequency to which the circuits in the mixer and any r.f. amplifier stages will be trimmed. But unfortunately there is another frequency on which a signal would beat with our local oscillator to produce a signal on $F2$ kc/s: this is $F1 + F2$ kc/s (since $(F1 + F2) - F1 = F2$) and a little calculation will show that this second frequency differs from that to which our receiver is tuned by $(F1 + F2) - (F1 - F2) = F1 + F2 - F1 + F2 = 2 \times F2$ **kc/s.** In other words if the two signals differ by twice the intermediate frequency of the receiver, they may both be heard. Now this means that if signals on either of these two frequencies reach the grid of the frequency changer valve, they will be converted to the intermediate frequency of the set, and will be amplified in the i.f. stages without there being any way in which we can distinguish between them. It is thus vitally important to prevent the signals on $F1 + F2$ kc/s (the "image" frequency) from appearing at the grid of the mixer stage, and the only way in which we can do this is by means of tuned circuits which will accept the signals on our wanted frequency of $F1 - F2$ kc/s whilst rejecting signals on our image frequency of $F1 + F2$ kc/s. Now in the earlier discussion on selectivity it was shown that, as frequencies increase, a fixed difference becomes relatively less important. For example, supposing that our set has an i.f. of 450 kc/s, and that when tuned to 4,000 kc/s the oscillator is on 4,450 kc/s, then the "image" frequency will be 4,900 kc/s. Our pre-frequency changer tuned circuits have to discriminate between signals on 4,000 and 4,900 kc/s, a percentage difference of about 22.5 per cent. Should we now tune the same receiver to 28,000 kc/s, the image frequency will be 28,900 kc/s, a percentage difference of only just over 3 per cent, so that more tuned circuits would be needed to provide equal rejection of image interference. This explains why the protection against such interference becomes progressively less in any given receiver as the frequency is increased. It can be similarly shown that if we lower the intermediate frequency, so that the signal and image frequencies become closer together, the protection also becomes less.

Here then is the dilemma in which a set designer is placed when choosing the best intermediate frequency for a receiver. In the section on selectivity it was shown that the *lower* the i.f. the easier it is to obtain high *selectivity*; but now it can be seen the *higher* the i.f. the better will be protection against *image* signals. Before explaining one method of overcoming these opposing needs, practical results in general terms are as follows:

With no r.f. amplification there will generally be only one tuned circuit before the mixer grid, and even this may be heavily damped (i.e. made less sharp) by the effect of the aerial; with an i.f. of 470 kc/s such a receiver would almost certainly suffer badly from image interference above about 3.5 or 7 Mc/s. With one r.f. amplifier (two tuned circuits) there would be a great improvement, but image responses of powerful stations would almost certainly be strong enough to be a nuisance on 14 Mc/s and above; two r.f. stages (three tuned circuits) accurately adjusted, would give good protection even on 30 Mc/s. With an i.f. above say 1,600 kc/s, good image rejection can be obtained with two tuned circuits (i.e. one r.f. amplifier) while even one well designed circuit (no r.f. stage) would give reasonable protection on 14 Mc/s and below. In general terms, the "image" response of a given signal compared with the response on its proper frequency needs to be reduced by 30 db (32 times) on 30 Mc/s for the receiver to come into the high performance class.

Double Superheterodyne Receivers

The conflicting desire to have a low i.f. for selectivity and a high i.f. for good image protection has led to the present popularity of receivers having a double change of frequency. The incoming signals are first converted to a fairly high intermediate frequency, of the order of 1.6–2.5 Mc/s, providing a high order of image rejection with say one stage of r.f. amplification, and thus avoiding the high cost of many r.f. tuned circuits. Then in turn these signals are changed, with the aid of a fixed tuned local oscillator, to a much lower frequency, of the order of 50–100 kc/s (or occasionally to the standard i.f. range of 455–470 kc/s). It is at this second i.f. that the main amplification takes place and high selectivity can be achieved. Thus this double-conversion system (see Fig. 8) can offer both good image protection and high selectivity, but at the cost of added complexity in design and construction. Great care is necessary if spurious signals resulting from the harmonics of the several oscillators within the set are to be avoided completely; there is also some risk that the full benefits of the high selectivity may be lost owing to cross-modulation occurring due to overloading one of the earlier stages.

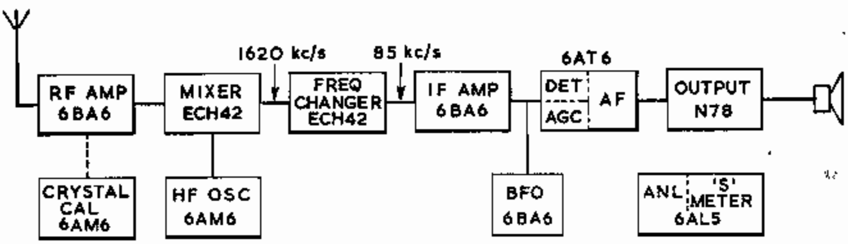


Fig. 8. Block outline of a modern double-conversion communications receiver designed for Amateur Radio use.

There is one interesting form of double superhet used in some of the more elaborate receivers such as the G2DAF receiver described in another RSGB booklet. In this system the frequency of the first local oscillator is fixed for each band, usually by a crystal, and the output from the first frequency changer thus varies as the band is tuned. The first i.f. section is made tunable over a definite band, e.g. 2 to 3 Mc/s and the calibration and spread for each band thus remains exactly 1 Mc/s wide, and direct calibration can be provided with a high degree of accuracy; a very wide band such as 28–30 Mc/s would be split into two bands each 1 Mc/s wide. This type of design has become much more popular since the spread of s.s.b. with its need for high stability. This principle is frequently used by amateurs when employing an h.f. or v.h.f. converter in front of a lower frequency communications receiver; the converter is fixed-tuned with the actual tuning being done on the main receiver: see Fig. 9.

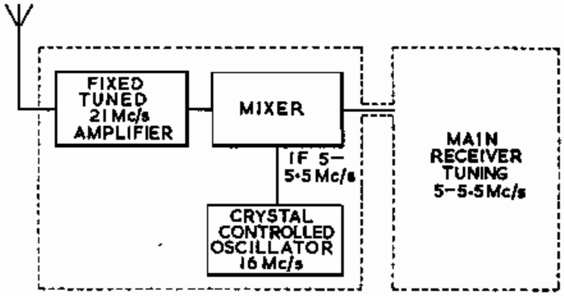


Fig. 9. Showing how a fixed tuned converter is used in conjunction with a communications receiver. All tuning is done on the main receiver. A similar system is frequently used to receive 144 Mc/s and other v.h.f. bands.

Alignment Errors

It will be readily appreciated that any receiver which has many tuned circuits in the form of i.f. transformers, and r.f. and oscillator tuning circuits can provide optimum performance only when all these circuits are accurately adjusted. The i.f. transformers must all be peaked to the same frequency, and if a crystal filter is fitted, the peak of the transformers *must* coincide with the crystal frequency. Only sturdy construction and the use of high grade components can bestow the ability to retain this accuracy of adjustment over long periods. For this reason regular re-alignment of a receiver will almost certainly prove beneficial.

In the front-end of a receiver, one of the main problems in superhet design is to obtain accurate tracking of the oscillator with the signal frequency circuits, so that these always differ by the constant figure of the intermediate frequency. In practice, perfect tracking cannot be achieved over a wide band which means that the signal frequency circuits will be slightly off tune. In most designs exact alignment is possible only at three evenly spaced points within each waveband and a certain amount of error has to be accepted over the remaining portions of the tuning range. These errors can be minimised by keeping the total frequency coverage of each waveband as narrow as possible; the situation will be improved if the amateur bands can be made to coincide with the accurately tuned portions. For this reason, despite the added complications in the coil assemblies, it is usually preferable that a general coverage receiver should have as many wavebands as possible, even if a good electrical or mechanical bandspreading system makes this unnecessary from the viewpoint of ease of tuning. Receivers which tune the amateur bands only can keep alignment errors to a very low figure.

It has already been stated that the first tuned circuit in a receiver is of especial importance in determining the final signal-to-noise ratio; however the alignment of this circuit presents particular problems owing to the effects produced when coupling different types of aerial to the receiver. If the aerials are reactive their connection will affect the alignment of the first tuned circuit. A satisfactory method of overcoming this difficulty is to fit a panel control aerial trimmer to allow this circuit to be brought into accurate alignment by the user whenever changing bands or aerials.

OPERATING THE RECEIVER

Part of the interest in operating a communications receiver lies in acquiring the skill to obtain the very best results of which it is capable. No two receiver designs are exactly the same, but there are a few simple hints which are worth learning.

If, as is desirable, your receiver has separate controls for a.f., i.f. and r.f. gain (often a single control is used for i.f. and r.f. gain), the relative settings of these controls will influence the apparent signal-to-noise ratio obtained with the weaker signals. Clearly if the r.f. gain control is near minimum setting while the other two are well advanced, most of the gain of the receiver will be after the frequency-changer stage and there will be nearly maximum amplification of the noise produced in this valve. On the other hand, if the r.f. gain is always kept full on the sensitivity of the set will be high but the stronger signals may overload one or more of the valves and this will cause "cross-modulation" and blocking. Generally therefore the a.f. gain control should be set at not more than half travel, the r.f. gain towards maximum and the level of signal or inter-station noise kept under constant control by means of the i.f. gain. In the neighbourhood of strong signals the r.f. gain should be reduced.

The aerial trimmer, if fitted, should always be set on each band to peak the noise and hence the sensitivity of the receiver.

On most models, the a.g.c. (a.v.c.) switch must be turned "off" for c.w. reception to prevent the sensitivity of the receiver from being reduced by the output of the b.f.o.

Reception of Suppressed-carrier Stations

Amateur telephony stations using either single- or double-sideband suppressed-carrier modulation systems are now often heard on almost all bands. These transmissions are completely unintelligible when received on a set operated as for normal telephony reception, producing a noise which has been likened to Donald Duck speaking on an extremely badly adjusted transmitter.

In order to render these signals intelligible it is necessary to re-insert the missing carrier. This can be done on any good communications receiver either by using the beat frequency oscillator or, preferably, by a separate "carrier insertion oscillator" which is usually crystal-controlled. The normal b.f.o. method is most likely to be used by the newcomer and can be quite successful provided that both the b.f.o. and the high frequency oscillator in the receiver have a high order of stability. If these oscillators are not sufficiently stable it will be found that the set has to be constantly adjusted to prevent the signals from becoming distorted. On some older receivers it may be found that either the tuning or the b.f.o. adjustments are too coarse to allow the signals to be correctly tuned.

Assuming that the receiver is stable and can be adjusted with sufficient accuracy, the procedure for tuning these signals is as follows:

(1) The receiver a.g.c. should be switched off.

(2) The receiver should be tuned until the unintelligible sideband modulation is heard at maximum strength.

(3) The a.f. gain should be tuned up to maximum and the r.f. gain turned down.

(4) The b.f.o. should then be switched on.

(5) Leaving the tuning unaltered, the b.f.o. control should be carefully rotated until the speech becomes clear.

During this time the i.f. and r.f. gain controls should be kept in check as overloading any stage will cause distortion.

It should be noted that until the final adjustment of the b.f.o. the signals will remain unintelligible and that when the adjustment is nearly but not quite correct the speech can be understood but will sound "bass" or "high-pitched".

Many operators now prefer to leave the b.f.o. set and to tune the signals by adjusting the tuning; this requires good bandspread as with the special type of double superhet described earlier.

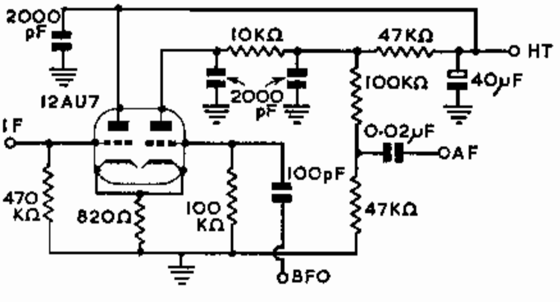


Fig. 10. The product detector has become popular for the reception of s.s.b. and c.w. signals. Suitable valves are the 6SN7, 12AU7 or ECC82.

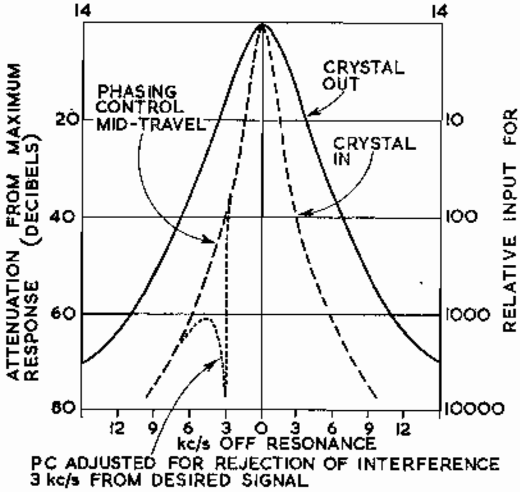


Fig. 11. A graph showing the improvement in selectivity obtained by the use of a crystal filter.

Reception of C.W. through a Crystal Filter

Certain piezo-quartz crystals possess the property of resonating at a frequency which depends upon their dimensions. By means of chemical etching and "grinding" it is possible to produce crystals tuned to almost any desired frequency. The crystal may be regarded as the equivalent of a series-tuned circuit of extremely high "goodness" or *Q*. When the frequency of a crystal is made to coincide with the intermediate frequency of a receiver it can form a very sharply tuned "acceptor" filter, with an adjacent parallel tuned rejector circuit formed by the capacity of the metal plates in which the crystal is held. The exact setting of the rejector frequency can be adjusted by including a variable condenser in the circuit, and this is known as a "phasing" control. The resulting i.f. response curve of a receiver with a crystal filter will be similar to that shown in Fig 11.

The degree of selectivity provided by a single crystal is often too sharp for distortionless telephony reception (this limitation can be overcome by using two crystals of slightly differing frequency to form a bandpass circuit or by tone correction) but is highly suitable for c.w. reception which requires a band-pass of only 100–200 c/s.

Now although amateurs played an important role in the development and application of crystal filters, their use is not always popular, especially among newcomers and also among some operators who have not grasped fully the technical principles involved. One often hears such remarks as "When heavy interference came on, I switched in the crystal filter but it reduced the strength of the signals so much that I lost the station". Now a correctly adjusted filter will seldom reduce the strength of a c.w. signal by any appreciable amount but instead should considerably enhance the signal-to-noise ratio. Why then do some users so often complain of serious loss of signal strength? Simply because the b.f.o. control has not been correctly set in advance; this has meant that the station could not be correctly tuned in with the crystal switched into circuit; the loss of strength in such circumstances is really an indication that the crystal is doing its intended job of narrowing the bandwidth.

It is essential with a crystal filter (Fig. 12) that the b.f.o. control should not be used—as it often is—as a form of tuning trimmer but should be set in advance to a frequency between 500 and 1000 c/s higher or lower than the crystal frequency. It should then be varied only when a change in the output note is required.

To set the b.f.o. control, the phasing control should be positioned at about mid-travel and, with the b.f.o. turned "off", a steady carrier carefully tuned in to give maximum S-meter reading (or maximum audible output if there is no meter). At this point the b.f.o. is turned "on" and adjusted to give the beat note — usually between about 500 and 1000 c/s—most acceptable to the operator. This setting of the b.f.o. should be carefully noted, and normally the control should not be touched again, all signals being carefully tuned on the normal tuning control for maximum output. An interfering heterodyne note can then be eliminated by adjusting the phasing control, the effect of which is to move slightly the very sharp rejection "notch" produced by the parallel resonance of the various capacitances across the crystal.

With a set in which the b.f.o. has been correctly adjusted, the switching in of the crystal should cause little drop in signal strength, though of course if the signal has not been exactly tuned in it may be necessary to adjust the tuning slightly to restore the strength of the signal.

A twin 'band-pass" crystal filter is better for speech reception than a filter using a single crystal which is liable to cause some a.f. distortion on account of its very narrow response. Nevertheless the conventional crystal filter is a very useful adjunct, particularly on account of its ability to reject heterodyne interference by means of the phasing control. It should be noted however that since the filter will attenuate the sidebands there will normally be a drop in audio output when the filter is switched into circuit—but the signal-to-noise ratio should improve.

Another device that has become popular is the *Q*-Multiplier which depends on the very high *Q* obtainable from a conventional tuned circuit when operated near to the point of oscillation. This type of filter provides variable selectivity and also an adjustable "notch" rejection characteristic. It may be built as an external unit for improving the selectivity of almost any receiver. In operation it is much the same as a crystal filter.

With all highly selective receivers, with or without a crystal filter, there should be a noticeable difference between the strength of the signal at the two tuning points one each side of the carrier frequency and equally spaced from it at which the same a.f. beat note is produced. If the selectivity is of a sufficiently high order, the strength of the signal at the second tuning point may be so reduced as to be practically inaudible except for the strongest signals. This condition is known as

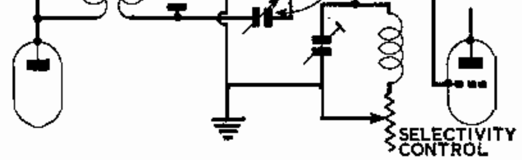


Fig. 12. Variable selectivity crystal filter. For optimum results there must be no stray coupling between the input and output circuits.

single-signal reception, and is a highly desirable characteristic for c.w. reception, since it reduces the likelihood of suffering interference by one half.

To receive speech through a selective single-crystal filter or Q-multiplier a treble-boosting network should be added in the audio section; this may consist of passing the a.f. signal through a 2 megohm resistor shunted by a 200 pF capacitor.

In recent years a new type of filter—the mechanical filter — has become available possessing certain advantages over the crystal filter; two of these filters can provide a very effective solution to the differing selectivity requirements for c.w. and telephony but are at present more costly than bandpass filters built with surplus crystals.

PRACTICAL DESIGNS

TYPICAL VALVES FOR H.F. RECEIVERS

The following list is based on the valves used in a selection of recent British and American receivers and forms a quick guide to suitable types (some of the American-type valves are not generally available in the United Kingdom). Older octal-types are now seldom used for current equipment.

R.F. Amplifiers: 6BA6 (EF93, W727); EF85; 6AK5 (EF95); 6SG7; 6BZ6; 6CB6; 6CW4; 6DC6; 6DS4; EF183; ECC84 (cascode).

Mixers: 6BE6 (EK90, X727); 6U8 (ECF82); ECH42; ECH81; 6BY6; 6SA7; 7360 (beam deflection tube).

H.F. Oscillators: 6C4 (EC90); 6AM6 (Z77, EF91); 6AH6; 12AT7.

I.F. Amplifiers: 6BA6 (EF93, W727); 6SG7; 6SK7; 6BJ6; 6CB6; EF183; EF85.

Detectors, etc.: 6AL5 (EB91; D77, 6D2); 6H6 (EB34, D63); 6T8 (EABC80, DH719, 6AK8); 6AT6 (EBC90, DH77); 6BJ7.

A.F. Amplifiers: 6AU6 (EF94); 6SG7; 6SC7.

Output: 6AQ5 (EL90, N727); 6K6, 6F6, 6V6, 6AM5, EL84.

Having read so far, the newcomer may be thinking: "Well, I can see that a good communications receiver is a fairly complex piece of equipment, but does this mean that there is no alternative to buying a ready made set, and forgetting about constructional work?" The answer is *no*. Emphatically there is no better way than constructing a receiver — even a comparatively simple one—for finding out infinitely more about receivers than you can ever learn purely from reading theory. Even a straight two or three valve receiver will teach you a good deal about the finer points to look for in tuning condensers, slow motion dials, careful adjustment of regeneration controls, and the like. The simplest of superhets will bring you straight up against the problems of oscillator tracking, i.f. alignment and the reduction of spurious images. And after you have gained some experience on these circuits, even the "full specification" communications receiver is by no means beyond the capabilities of an amateur having only a minimum of test equipment; this is especially true if the switched coil units are obtained as a complete assembly, or alternatively if plug-in coils are used. There are also complete kits available for building amateur-band communication receivers.

Simple superhet and even straight receivers can be quite effective, particularly for c.w. reception, and there is a considerable scope for modern designs, both for two-way working and for listening. Some suggestions for practical experiments are given in Fig. 13. If room is left on the chassis, it is always possible to add extra stages and refinements from time to time. By using valves containing more than one electrode assembly, a "single-valve" (two stage) straight receiver will bring in plenty of stations, while a "two-valve" superhet is a practical proposition.

Alternatively, you may buy a relatively cheap ex-government receiver such as the R1155, R107, CR100, BC348 or even one of the inexpensive "Command" series, and then set about improving its performance by adding such accessories as a crystal filter (if not already fitted), or an external r.f. pre-amplifier (Fig. 26). Or you may extend its tuning range and improve its performance on the higher frequencies by building an external converter unit for those bands which the original set does not cover or covers with poor sensitivity. Good converters are not difficult to build—they can be put together in an evening or two—and yet can show the constructor almost as much about the problems and principles of superhets as a complete receiver.

Again a set which is deficient in selectivity may be improved beyond recognition by adding an external second frequency changer coupled to the receiver i.f. strip and followed by a low i.f. amplifier (a device

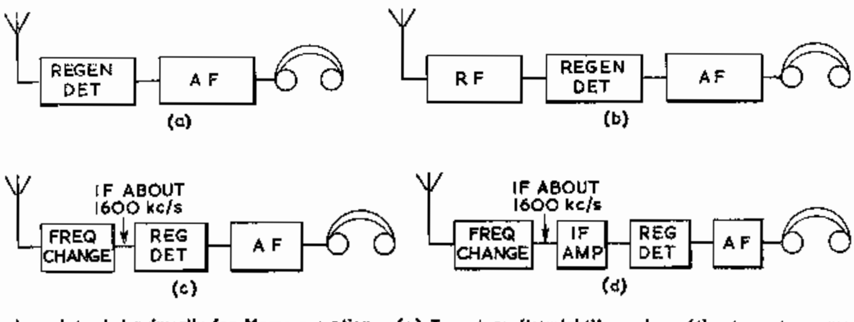


Fig. 13. Simple receivers intended primarily for Morse reception. (a) Two-stage "straight" receiver (the two stages may be combined in a single multiple valve, such as a double-triode). (b) The addition of a tuned r.f. stage will improve sensitivity and selectivity (an arrangement often known as a "t.r.f." receiver). (c) The simplest "superhet" circuit. By using modern triode-pentode valves such as the ECF82 or 6U8 all stages can be accommodated in a two valve receiver. (d) The addition of an i.f. stage will greatly increase the gain and make the receiver suitable for the reception of the stronger telephony stations.

usually known as a Q5-er), or alternatively by adding a Q-multiplier. Then again, for c.w. reception it may be possible to improve selectivity by altering the audio frequency response and fitting peaked audio filters.

The keen amateur never takes the design of even an expensive receiver too much for granted. All receivers turned out on an assembly line are essentially a matter of compromise; whereas amateurs tend to specialise in their interests. For example, the keen c.w. operator will have very different ideas from the telephony man on what constitutes an ideal receiver. The 1.8 and 3.5 Mc/s user will seldom worry as much about extreme sensitivity as the enthusiast working 21 and 28 Mc/s where the external noise level is much lower.

Then again the valves used in the r.f. amplifiers and frequency changer stages of many of the war-time receivers are now relatively out-dated and better sensitivity can often be obtained by redesigning these early stages. Even the thorough overhaul of an older type receiver—replacing "leaky" or inefficient condensers, checking that resistors have not changed value, and re-aligning—can be an interesting and instructive experience as well as a most rewarding operation from the viewpoint of improving the performance of a receiver.

This is not to suggest that the newcomer should rush into tampering haphazardly with, say, a Drake 2B, Eddystone 888, KW 77, AR88 or HRO but he should nevertheless always be ready to try a new gadget—and countless useful devices are described in the amateur journals—rather than be content to regard a receiver as a mysterious black box labelled "not to be opened."

Receivers for S.S.B.

The rapidly increasing use of the single sideband mode of transmission by amateurs—and the likelihood of a further expansion of this system has brought about considerable re-thinking of the problems of receiver design. Many popular receiver designs of earlier years while giving good results on normal A3 telephony transmissions are not so satisfactory for s.s.b., usually because of the difficulty of tuning with the necessary degree of accuracy or because of frequency drift. On the other hand a receiver which has been designed to provide good performance on s.s.b. will usually be equally good for c.w. and conventional telephony. It is therefore becoming important when planning or choosing an elaborate receiver to pay particular attention to its capabilities on s.s.b. signals.

The main requirements of a receiver for s.s.b. are:

(1) It must be capable of being tuned very accurately. In practice this requires a very low "tuning rate" which is to say that one complete revolution of the tuning knob should change the frequency by only a few kilocycles. (A small "handle" can be fitted to the tuning knob to reduce the time needed to tune from one end of a band to the other). Preferably the set should have the same tuning rate on all bands. A slow tuning rate enables s.s.b. transmissions to be accurately tuned in without the need to adjust the b.f.o. control (see page 29).

(2) It must possess the ability to stay accurately tuned to any particular frequency. In other words the drift, other than the almost inevitable "switching on" drift, must be reduced to a very low level and the receiver must not be affected by mechanical vibration, etc., otherwise s.s.b. signals even if correctly tuned to begin with will soon become distorted or unintelligible. To meet this requirement calls for all oscillators within the receiver to be highly stable. For instance to maintain a stability of 25 c/s at 28 Mc/s calls for much the same order of precision as to keep a watch accurate to within one second per week.

(3) Sufficient injection voltage must be available from the b.f.o. and it should be possible to change the frequency of the b.f.o. to permit rapid selection of the upper or lower sideband position (or alternatively some other means of doing this should be provided).

(4) To obtain optimum benefit from the reduced bandwidth of s.s.b. signals, the "nose" selectivity of the receiver should not be greater than about 2.5 kc/s, and preferably, as for any other type of reception, the "skirt" bandwidth should be as little greater than at the nose as it is possible to achieve.

(5) It should preferably incorporate an a.g.c. system which is not affected by the b.f.o. and which has a sufficiently long time constant to enable it to be used on s.s.b. and c.w. signals.

To provide a slow tuning rate and to obtain good h.f. oscillator stability, it is becoming increasingly popular to use crystal control of the first h.f. oscillator—a separate crystal being used for each band—and to tune the receiver by means of a variable first intermediate frequency (this is the system outlined on page 30). Where a conventional tunable h.f. oscillator is used, the second frequency changer oscillator is often crystal controlled, two crystals (one above the first i.f., the other below) being fitted to provide switched sideband selection: other methods of providing rapid sideband selection include: (1) crystal controlled b.f.o. with one crystal above and another below the final intermediate frequency; (2) making the oscillator of the second frequency changer or the b.f.o. readily tunable over about 5 kc/s.

While factory-built receivers for s.s.b. work must inevitably be relatively expensive, the keen and experienced constructor can obtain highly satisfactory results at much lower cost. The design, construction and alignment of such receivers, however, are likely to require several months of intensive effort.

After a number of years during which most amateurs have used factory-built and ex-Government receivers for the high frequency bands (often with home-built converters for 144 Mc/s and other v.h.f. bands), there is today a noticeable swing back towards home-built receivers using valves or transistors, or a combination of both.

Whether you use home-built or factory-built sets, it is worth repeating that a good understanding of the technical design of modern communications receivers will help you make the very best use of your station.

A Simple T.R.F. Receiver

The straight "1-v-1" (a traditional way of indicating a receiver having one stage of r.f. amplification, detector, and one stage of a.f. amplification) can still form an effective receiver for the listener and amateur provided that its fundamental limitations are recognised. These include an inherent lack of selectivity which becomes progressively worse with increasing frequency and the inability to resolve weak modulated signals. But, particularly on the lower frequency bands such as 1.8 and 3.5 Mc/s, it can compete with all but the best superhets in the realm of c.w. reception so long as extreme selectivity is not a first requirement.

This simple receiver built by G. D. Roe (G3NGS) takes advantage of modern miniature valves and components: it was originally constructed on the R.S.G.B. stand at a recent National Radio and Television Show.

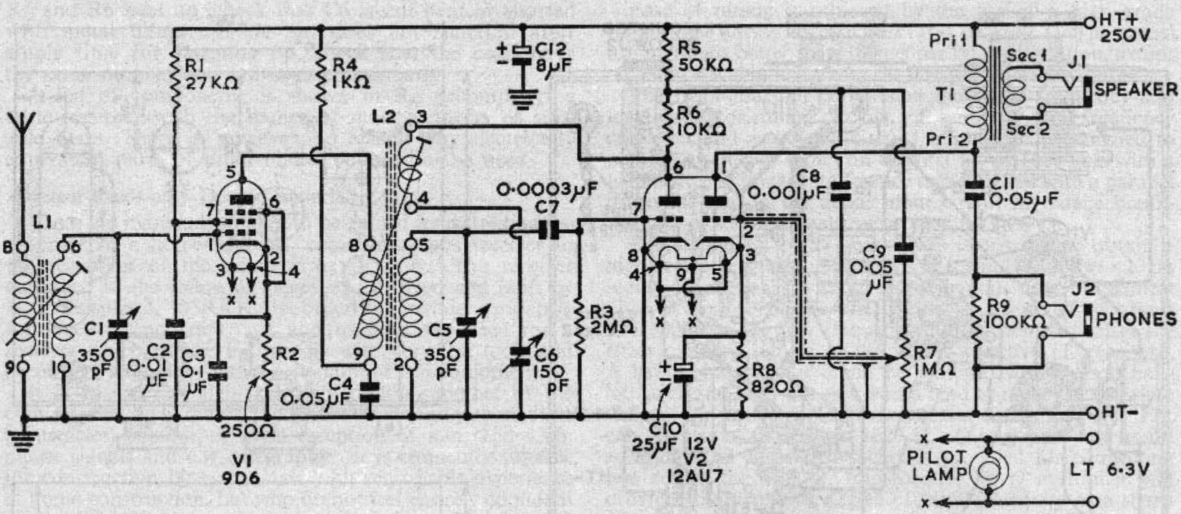


Fig. 15. Circuit diagram of the simple T.R.F. receiver using miniature valves.

The circuit has three stages: a variable-mu pentode as r.f. amplifier and two triodes, contained in the same valve envelope, as regenerative detector and a.f. amplifier.

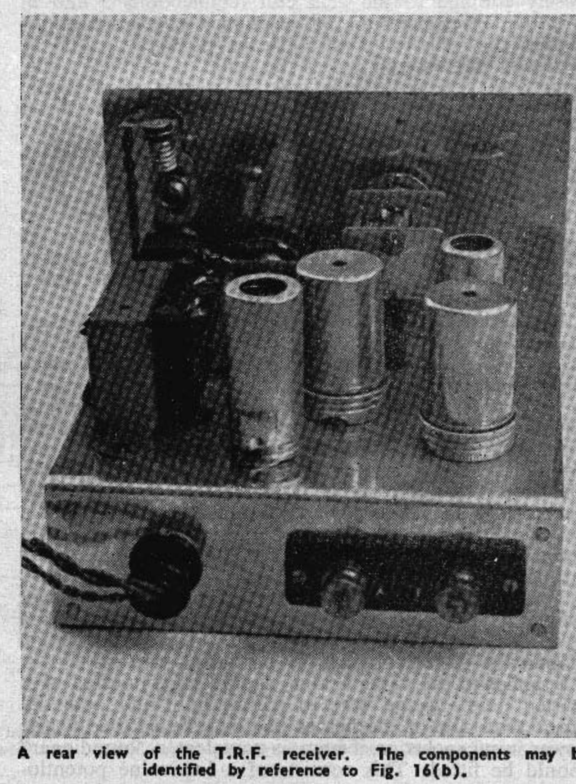
The signal picked up by the aerial is transformer-coupled to the first tuned circuit consisting of the secondary of L1 and the tuning capacitor (or condenser) C1 and applied to the control grid of V1, the r.f. amplifier valve. After amplification the signal is fed via the untuned primary of L2 and its associated tuned secondary to the coupling capacitor C7 and so to the grid of the detector V2a. It will be observed that a third winding (connections 3 and 4) is included in the L2 assembly and wired from the anode of V2a via the variable capacitor C6 to earth. This third winding is

LIST OF COMPONENTS

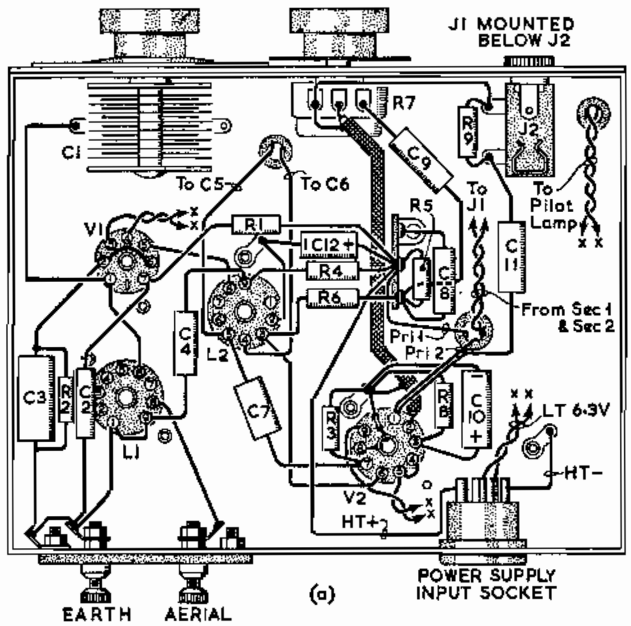
C1, 5 350 pF air-spaced variable capacitor (Jackson Bros. (London) Ltd., U-type miniature)
C2 0·01 μF 350 volt working capacitor (Dubilier)
C3 0·1 μF 200 volt working capacitor (Dubilier)
C4, 9, 11 0·05 μF 350 volt working capacitor (Dubilier)
C6 160 pF air-spaced variable capacitor (Jackson Bros. (London) Ltd.)
C7 0·0003 μF silver mica capacitor (Dubilier)
C8 0·001 μF 350 volt working capacitor (Dubilier)
C10 25 μF 12 volt electrolytic capacitor (Dubilier)
C12 8 μF 350 volt electrolytic capacitor (Dubilier)
L1 Maxi-Q miniature coil (blue) for range desired (Denco (Clacton) Ltd.) Screening can supplied with coils.
L2 Maxi-Q miniature coil (green) for range desired (Denco (Clacton) Ltd.) Screening can supplied with coils.
R1 27 K ohms ½ watt (Dubilier)
R2 250 ohms ½ watt (Dubilier)
R3 2 Megohms ½ watt (Dubilier)
R4 1 K ohm ½ watt (Dubilier)
R5 50 K ohms ½ watt (Dubilier)
R6 10 K ohms ½ watt (Dubilier)
R7 1 Megohm potentiometer with switch (Dubilier)
R8 820 ohms 1 watt (Dubilier)
R9 100 K ohms ½ watt (Dubilier)

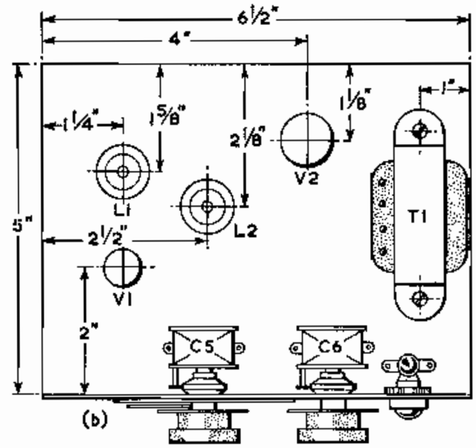
Miscellaneous

T1 output transformer for speaker
2 Noval valve bases for coils (McMurdo XM9/U)
1 dial lamp (Bulgin D 170 or similar)
2 phone jacks (Bulgin type J2)
1 9D6 valve (Brimar)
1 12AU7 valve (Brimar)
2 terminals (aerial and earth) (Bulgin)
2 knobs with skirts (Bulgin K401 and K405)
2 knobs (Bulgin K400 and K410)
1 six-way connector (Bulgin P149)
6 solder tags (Bulgin T17)
1 Noval valve base for V2 with screening can (McMurdo XM9/UC1)
1 B7G valve base for V1 with screening can (McMurdo XM7/UC1)
2 slow motion epicyclic 6 : 1 drives for C5 and C6 (Jackson Cat. No. 4511)



A rear view of the T.R.F. receiver. The components may be identified by reference to Fig. 16(b).





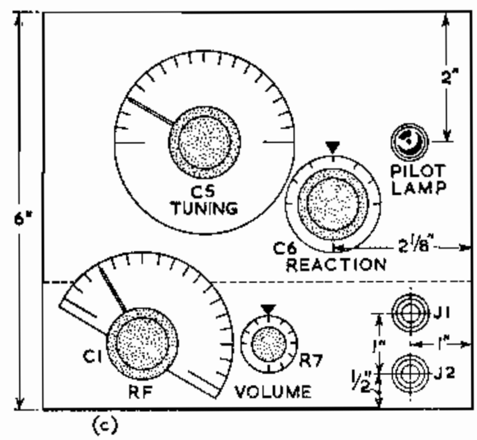


Fig. 16. Wiring and layout diagrams of the simple T.R.F. receiver. (a) Under-chassis layout of the components showing the point-to-point wiring. (b) Above-chassis layout of components. (c) Arrangement of the controls on the front panel.

closely coupled to the grid coil (connections 5 and 2) to provide regeneration or reaction. Regeneration increases the sensitivity of V2a as a detector and if increased far enough causes the valve to oscillate. The amount of regeneration or reaction is controlled by the variable capacitor C6. For phone work, it is best to set the control just below the point where oscillation begins but for the reception of c.w. (telegraphy) signals C6 should be advanced to the point where V2a just begins to oscillate. This point will be marked by a faint "rushing" sound in the headphones or loudspeaker. No advantage will be gained by increasing the amount of regeneration beyond this point. R6 prevents r.f. energy present at the anode of V2a feeding into the audio amplifier.

The audio signal from the detector is built up across the load resistor R5 and fed via C9 to the volume (or gain) control R7. The slider of this control (the centre terminal) is connected to the grid of V2b which functions as an audio amplifier to raise the level of the signal sufficiently to drive a small loudspeaker or headphones. Bias for this valve is developed by the flow of current through R8 in a similar manner to the bias for V1. The amplified audio signal is fed to the loudspeaker by transformer T1 which provides the necessary match for a low impedance (3 ohms) voice coil. The use of headphones is made possible by feeding the audio signal through C11 to the jack socket J2.

The complete receiver, with the exception of the power supply, can be built on an aluminium chassis measuring 6½ in. × 5 in. × 2 in. fitted with a front panel 6 in. high, though the dimensions are by no means critical.

Supplies to the valve heaters should be connected with twisted heavy gauge wire to reduce hum and potential drop. One side of the heater line may be earthed at the power input socket or, if hum is prevalent, a "humdinger" should be fitted. This consists of a low-value potentiometer (about 50 ohms) with the outer two contacts connected across the heater line and the centre contact (slider) earthed. The slider should be moved around the centre of its travel until a minimum of hum is found. The potentiometer should then be left at this setting.

Component layout is not critical so long as interstage wiring is short and direct. The radio frequency amplifier (V1 and its associated components) should be well screened from the following stages to lessen the chance of feedback. For the same reason C1 should be mounted sub-chassis and C5 above chassis level. The only other components above the chassis are the speaker transformer T1 and the reaction control C6. Miniature slow-motion drives should be fitted to C5 and C6 to ease the tuning in of weak signals.

Fig 16(a) shows the underchassis layout and provides a point-to-point wiring diagram. The placement of parts above chassis is shown in Fig. 16 (b) and the front panel layout in Fig. 16(c). The power requirements of the receiver are very small and a power pack giving 6 volts at 1 amp and 250 volts at 30 milliamps will be found to be quite adequate. The live side of the mains may be brought into the set via the six-pin plug, taken through the switch on the volume control (R7), and taken out again to the primary of the mains transformer.

Before switching on, it is a good practice to check for any short across the h.t. terminals as this can cause serious damage to the power pack. If, on switching on, R5 and R6 heat up, check that C6 is not bent or shorted with metal filings. If the set does not function after ample time for warming up, check that the coils have the same number and are inserted correctly.

A list of components is shown in the accompanying table together with the names of manufacturers of suitable items. There is, however, no reason why electrically equivalent parts of other makes should not be used.

Amateur-bands-only Double Superhet

There are many advantages to be gained by restricting the coverage of a home-built h.f. communications receiver to the reception of the amateur bands only. The receiver described in the following pages was evolved and built by A. J. Shepherd, G3RKK, in order to provide good performance at moderate cost and to meet the need for a receiver which can be built easily with very few tools and capable of alignment with a minimum of test equipment.

It is basically a high-sensitivity double-superhet of the conventional type (that is fixed first and second intermediate frequencies) capable of good reception of a.m. and s.s.b. phone signals and c.w. telegraphy. It is eminently suitable for construction by enthusiasts with reasonable experience of home-construction, but who do not feel entirely confident of tackling the more complex type of tunable first i.f. receivers such as that described by G2DAF in the RSGB publication *Communication Receivers*. The cost of this receiver will be in the region of £30, assuming that all components have to be purchased.

The key to the simplicity of the construction and alignment lies in the use of a commercial front-end supplied pre-aligned. A suitable unit is available from Electroniques (proprietors STC Ltd), Edinburgh Way, Harlow, Essex. This provides about 170° of bandspread coverage on six bands as follows: Band 1 (160 metres) 1·8–2 Mc/s; Band 2 (80 metres) 3·4–4 Mc/s; Band 3 (40 metres) 7–7·5 Mc/s; Band 4 (20 metres) 14–14·4 Mc/s; Band 5 (15 metres) 21–21·5 Mc/s; Band 6 (10 metres) 28–30 Mc/s.

It will be noted that the width of the 3.5 Mc/s band covers the full allocation available to American amateurs, of which only 3.5–3.8 Mc/s are available to European amateurs. The availability of a 2 Mc/s wide band (Band 6) means that the receiver can be used with a 144 Mc/s crystal-controlled converter to give full coverage of the 2m band.

Ease of tuning is achieved by the use of a high grade tuning dial having a reduction ratio of 110 : 1. The actual tuning rate is better than 10 kc/s per knob revolution, except on Band 6 where it is about 40 kc/s per knob revolution.

The front-end unit comprising the signal frequency and local oscillator tuning circuits, r.f. amplifier, first frequency converter and associated circuits is supplied pre-aligned to provide an output signal on the first i.f. of 1620 kc/s with a high degree of image interference rejection and with a parallel tuned i.f. trap in the aerial input circuit to reduce breakthrough of strong signals on or near the first i.f.

The second i.f. of 85 kc/s makes it possible to obtain a high degree of selectivity (about 3 kc/s bandwidth for −20 db reduction on peak) without using crystals or a mechanical filter. Response of the a.f. circuits is restricted to about 400–3000 c/s, the low frequency cutting helps to offset the effect on a.m. signals of the highly selective i.f. response. A better shape factor could be achieved with a good half-lattice crystal filter but this would tend to make the set more difficult for newcomers not having test equipment, etc. For c.w. reception, an external 1620 kc/s Q multiplier is a useful addition, and a suitable socket is provided for connecting one across the first i.f. transformer. A Q multiplier will provide a controllable degree of extra selectivity or a sharp rejection notch. The unit described later is suitable.

A product detector is fitted for use on c.w. and s.s.b., with a diode integrator envelope detector for use on a.m. signals. The receiver incorporates a peak noise limiter function on audio peaks, a fast and slow acting a.g.c. system, an S-meter and a built-in 100 kc/s crystal calibrator to provide calibration check points throughout the tuning range of the receiver.

The important characteristic of frequency stability depends to a considerable extent upon the mechanical construction. With rigid bracing and suitable ventilation, drift can be kept very low. Once the set has fully warmed up, frequency drift may be less than 500 c/s per hour, even on 30 Mc/s, and considerably less on the lower frequency bands. The use of silicon diode rectifiers with their low operating temperatures helps keep cabinet temperatures down. A voltage regulator tube provides a stabilized 150 volt line for supplying stages which could be affected by supply variations.

Bascially the receiver has an EF183 tuned r.f. amplifier stage and ECH81 first frequency converter in the factory-

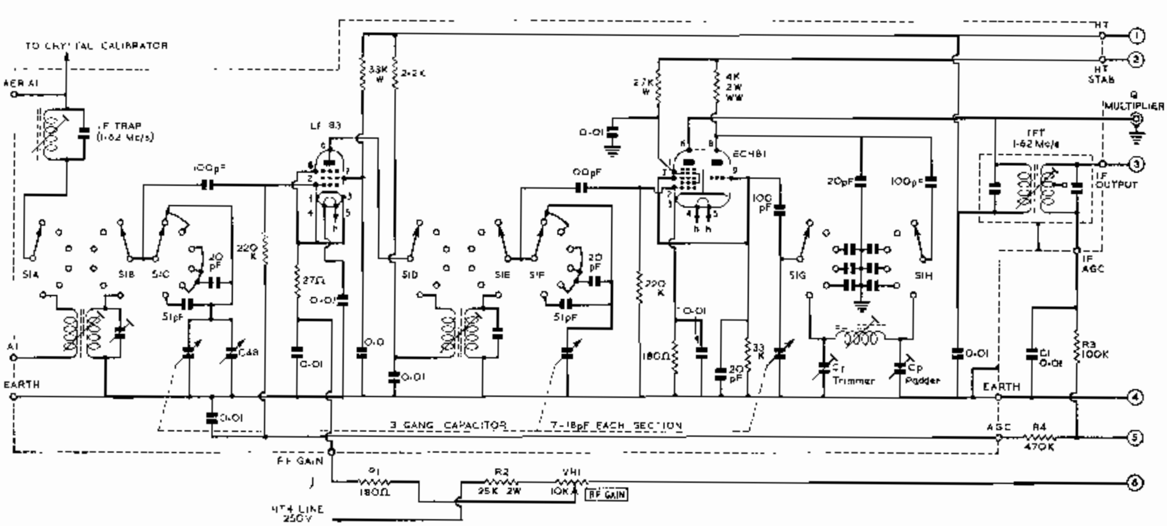


Fig. 17. The front-end of the receiver (Electroniques type QP166). The bandswitch is shown in the 1·8 Mc/s position. Only the coils and trimmers for 28 Mc/s are shown; the others occupy corresponding positions on the other bandswitch contacts. The oscillator switch section S1C is fitted with shorting contacts.

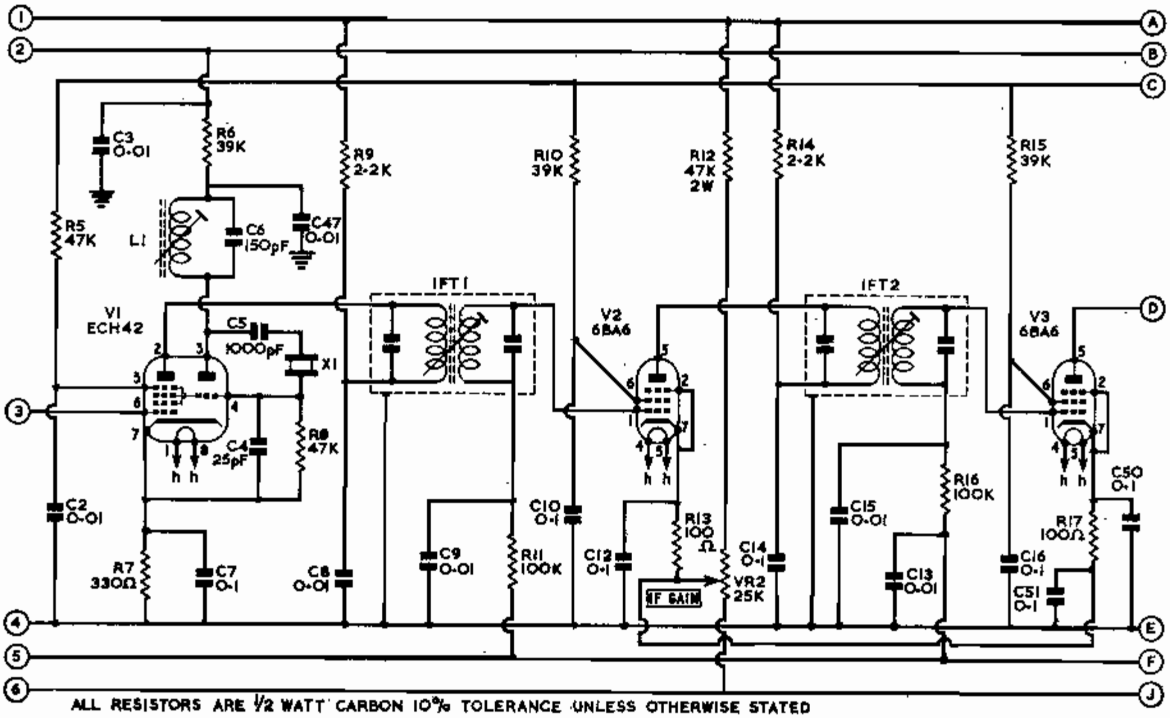


Fig. 18. The second frequency changer and 85 kc/s i.f. strip.

COMPONENTS LIST

B.F.O. Unit, HSO85 (Electroniques (STC Ltd.)).
C1, 2, 3, 8, 9, 13, 15, 22, 24, 29, 37, 41, 42, 44, 45, 47, 49, 0.01 μF, 500 volt wkg., disc ceramic.
C4, 25pF silver mica.
C5, 1000pF silver mica.
C6, 150pF ceramic.
C7, 10, 12, 19, 50, 51, 0.1μF paper.
C11, 14, 16, 17, 18, 0.1μF 400 volt wkg., paper.
C20, 39, 46, 50pF silver mica.
C21, 8μF, 400 volt wkg., electrolytic.
C23, 30, 31, 500pF ceramic.
C25, 1000pF ceramic.
C26, 27, 25μF 25 volt wkg., electrolytic.
C28, 32μF 400 volt wkg., electrolytic.
C32, 33, 2000pF ceramic.
C34, 100pF silver mica.
C35, 50pF variable (J.B. type C804).
C36, 5pF silver mica.
C38, 30pF trimmer.
C40, 250pF ceramic.
C43, 24 + 16μF 450 volt wkg. electrolytic.
C48, 4-13pF (Eddystone type 588), aerial trimmer if required.
C52, 0.5μF.
CR1, 4, 5, OA81.
CR2, 3, OA79.
Cabinet, 16 in. x 10½ in. x 8 in. (Philpotts' Metalworks).
Chassis, 15 in. x 10 in. x 2½ in., 16 s.w.g. aluminium.
Dial and Drive, Eddystone type 898.
Front End, QP166 Amateur Bands Bandspread Qoilpax (Electroniques (Felixstowe) Ltd.).
F1, 2, 1 amp fuses.
F3, 250mA fuse.
IFT1, 2, 85 kc/s type DIF1 Series II (Electroniques (STC Ltd.)).
IFT3, 85 kc/s type DIF1/D Series II (Electroniques (STC Ltd.)).
L1, 50–75μH type DLM14 (Electroniques (STC Ltd.)).
L2, 3, 10H 150 mA.
M1, 0-1mA moving coil meter.
MR1, 2, 1000 p.i.v., 500mA silicon diodes.
R1, 180 ohms.
R2, 25K ohms 2 watts.
R3, 11, 16, 26, 33, 42, 43, 44, 100K ohms.
R4, 29, 31, 37, 470K ohms.
R5, 8, 22, 30, 35, 39, 47K ohms.
R6, 10, 15, 40, 39K ohms.
R7, 330 ohms.
R9, 14, 19, 2.2K ohms.
R12, 47K ohms 2 watts.
R13, 100 ohms.
R17, 100 ohms.
R18, 1.8K ohms.
R20, 28, 27K ohms.
R21, 41, 220K ohms.
R23, 3.3K ohms.
R24, 36, 1 Megohm.
R25, 750 ohms (see text).
R27, 150K ohms.
R32, 820 ohms.
R34, 10K ohms.
R38, 22K ohms.
R45, 3.9K ohms 4 watts.
R46, 100K ohms 2 watts.
R49, 6.8 Megohms.

All resistors are ½ watt carbon unless otherwise stated.

RFC, 2.5mH 150mA.
S1, bandswitch incorporated in coil pack.
S2, s.p.s.t. toggle (calibrator on/off).
S3, d.p.d.t. toggle (transmit/receive).
S4, s.p.s.t. toggle (a.g.c. on/off).
S5, d.p.d.t. heavy duty toggle (mains on/off).
S6, 3 way 3 pole Yaxley, only 2 positions used (a.m./s.s.b./c.w.).
S7, s.p.s.t. toggle (a.g.c. time constant—slow/fast).
T1, 250-0-250 volts, 150mA; 6.3 volts, 3.5 amps.
T2, output transformer to suit valve (For EL91, 6000 ohms/3 ohms, 2 watt type).
V1, ECH42.
V2, 3, 6, 6BA6 (EF93).
V4, 6AT6, EBC90.
V5, 6AM5, EL91 (see text).
V7, 6AM6, EF91.
V8, 12AU7, ECC82.
V9, VR150/30 (OD3).
VR1, 10K ohms (r.f. gain).
VR2, 25K ohms (i.f. gain).
VR3, 3K ohms (Radiospares pre-set for S meter set zero).
VR4, 1 Megohm (a.f. gain).
VR5, 25K ohms (Radiospares pre-set for adjusting standby sensitivity).
VR6, 25K ohms (noise limiter).
X1 (see text).
X2, 100 kc/s crystal.
Other components required are fuseholders, knobs, pilot lamp, plug, sockets, tag board, tag-strips, valveholders, screening cans, flexible coupler and grommets.

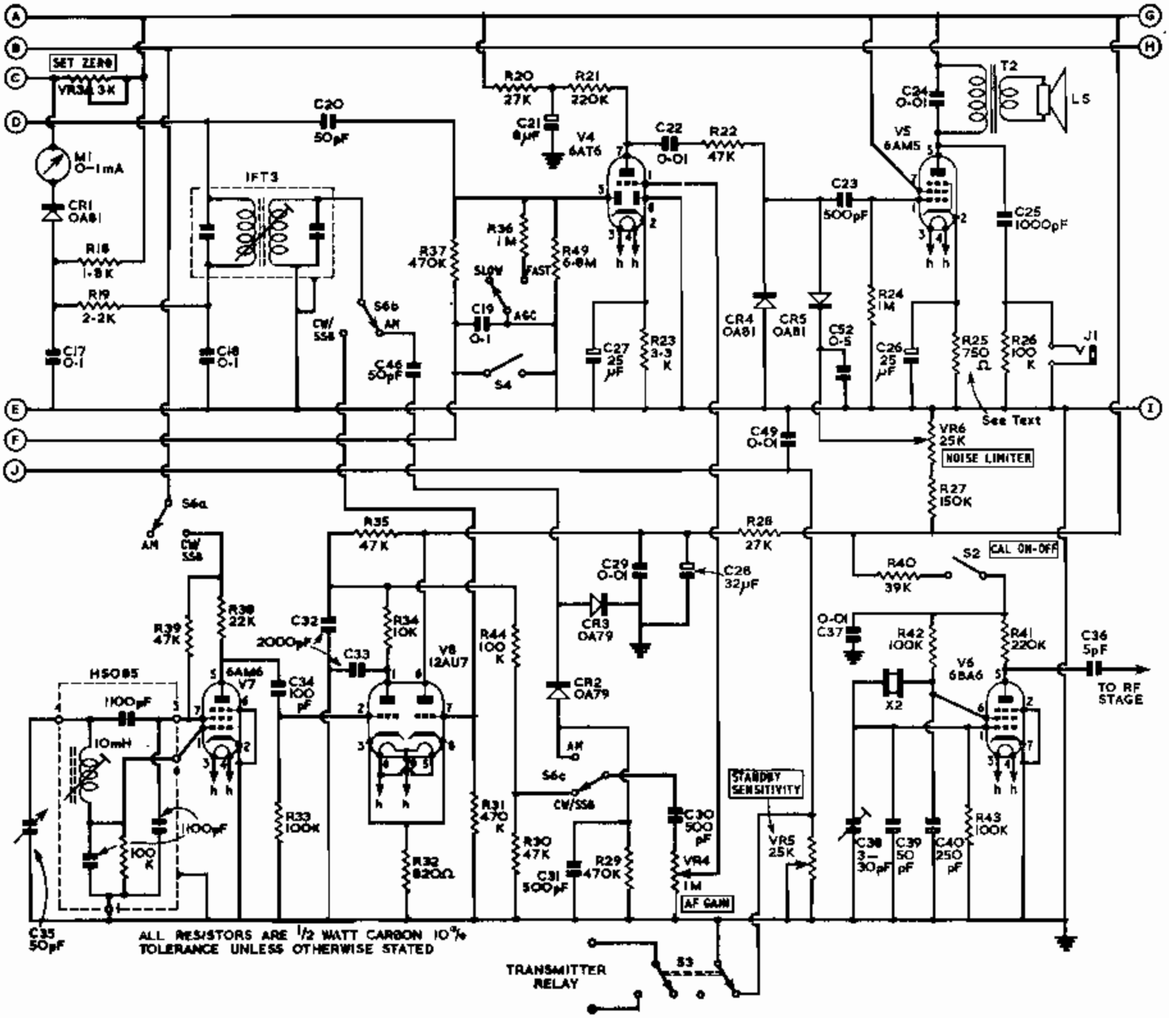


Fig. 19. The S meter, crystal calibrator, a.g.c., detectors and a.f. sections. C35 is the b.f.o. pitch control.

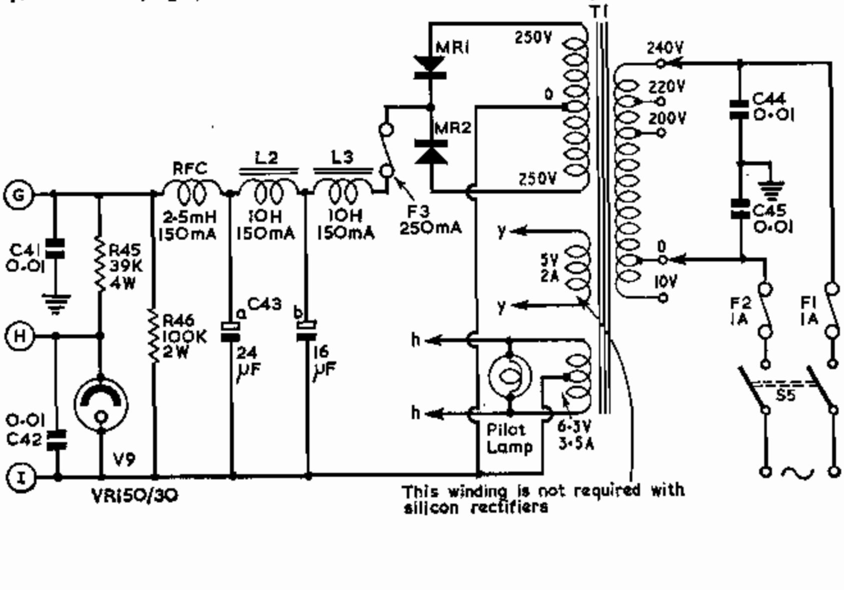


Fig. 20. The power supply.

built front-end. The 1620 kc/s signal from this sub-unit goes to V1 (ECH42), the second frequency changer with crystal-controlled oscillator. V2 (6BA6) and V3 (6BA6) are both 85 kc/s i.f. amplifiers. V4 (6AT6) is a diode a.g.c. rectifier with delay, and a.f. amplifier. V5 (6AM5) is the audio output stage. V6 (6BA6) is the 100 kc/s calibrator; and V7 (6AM6) the high-stability beat frequency oscillator covering about 84–86 kc/s. V8 (12AU7) is the product detector. The crystal diode CR1 (OA81) is used to protect the S-meter (M1) from flow of reverse current. CR2, 3 (OA79) form the voltage-doubling diode integrator detector; CR4, 5 (OA81) is an adjustable peak noise clipper.

Values shown for R25 and T2 are suitable for use with 6AM5 output valve which provides about 0.5 watt. For higher output power a 6BW6 or EL84 is suggested with modification of these components.

The crystal (X1) used in conjunction with V1 is 1537 kc/s, though since the 85 kc/s i.f. transformers can be tuned over the range 80–90 kc/s, the crystal can be anywhere in the range 1530–1540 kc/s without changing the first i.f. from the factory figure of 1620 kc/s. Suitable crystals are usually available in the "surplus" market. The tuned circuit in the anode circuit of this stage is resonated to the crystal fundamental frequency to reduce harmonic content. A standby sensitivity control VR5 allows the receiver to be used to monitor strong signals from the transmitter.

If a crystal calibrator is already available, V6 and its associated components could be omitted, but otherwise this will prove a most useful accessory. For highest accuracy the second harmonic of the 100 kc/s crystal may be zero beat by adjusting C38 against the 200 kc/s BBC Light Programme high stability transmitter while using a separate broadcast receiver.

Construction: The final layout is shown in Fig. 21; this differs slightly from the photographs which were taken at an earlier stage of development. It is recommended that 16 s.w.g. aluminium is used for the chassis work, which should be well braced.

Care should be taken throughout construction to ensure that components and wiring are as rigid as possible, especially any affecting the frequency stability. Ventilation should be arranged to keep operating temperature low, without erratic air currents passing through the oscillators. The front-end unit should be well braced, in the $6\frac{1}{16}$ in. square cut-out. It may be found worth fitting a screen over the oscillator section of the front-end. The crystal-controlled oscillator of V1 should be well screened to minimize spurious responses. The b.f.o. should be constructed using 16 s.w.g. tinned copper wire for stability, and should preferably be screened.

Screening cans fitted to all valves should be painted black to assist heat radiation. Low loss skirted valveholders of either the ceramic or nylon loaded types should be used. A B7G valveholder is fitted to the rear of the chassis and supplies power for a *Q* multiplier or other external units. Disc ceramic 0.01 μF capacitors are used extensively because of their small size, low inductance and relatively high working voltages. With paper capacitors the plastic case type is to be preferred to those with waxed paper containers. Any long wires carrying i.f. or a.f. signals should be screened. All a.g.c. and h.t. line connections are made via the long tapstrip mounted along the rear of the i.f. stages.

Alignment Procedure: Alignment is relatively simple, owing to the use of the pre-aligned front-end. Several methods are possible, but the original model was readily aligned by the following method.

For alignment one requires a test signal within 5 kc/s of 1620 kc/s. If no accurate signal generator is available, the test signal is best obtained by replacing the 100 kc/s crystal of V6 by one of 1620 kc/s or a sub-harmonic of the frequency. A readily obtainable "surplus" crystal is the FT241A 54th harmonic type marked 29.1 Mc/s (Channel 19). This has a fundamental of 405.5 kc/s and will usually provide a fourth harmonic on about 1622 kc/s.

The output from V6 is temporarily removed from the aerial socket, and taken to the "i.f. out" lead-through on the front-end, via a 1000 pF capacitor. Calculate what will be the second i.f. (i.e. 1622 kc/s minus the conversion crystal frequency).

Now switch the receiver on, and allow it to thoroughly warm up. Switch on crystal calibrator. Turn i.f. gain to maximum; a.g.c. switched on and the S-meter zero-control turned to give quarter scale deflection on S meter. Should a small a.f. oscillator be available it can be used to modulate V6 crystal output so that an audible check is available, but this is not essential. Remove the two front-end valves.

The i.f. transformers are preset to 85 kc/s on the outer resonance. Then if calculated second i.f. is less than 85 kc/s tune cores slightly inwards; if greater than 85 kc/s tune cores slightly outwards. Adjust each core only by half a turn at a time, starting with i.f.t. 1 and work towards the detector. Repeat the entire sequence with a further half-turn adjustment and so on until S meter reading begins to rise. Then peak each core for maximum reading, readjusting the gain control and set zero control as the alignment proceeds so that the S meter reading is kept reasonably low.

Reconnect the crystal calibrator to its normal position and reinsert 100 kc/s crystal. Set to Band 1, replace front-end valves and allow to thoroughly warm up, with aerial still disconnected. With gain controls at maximum a kick in the S meter reading should be observed as the receiver is tuned over the centre of the band; this should be 1900 kc/s and should be carefully tuned for peak S meter reading. At this stage all the i.f. circuits should be finally peaked up, the b.f.o. switched on and, with the pitch control set at mid-scale, adjusted for zero beat.

The aerial may then be connected and the trimmers on the r.f. coils (front compartment of the front-end) carefully peaked at the centre of the band, with the aerial trimmer if fitted set to mid-scale. This can be done using external signals, or for example a signal from a transmitter v.f.o. Work carefully, and avoid making large haphazard changes.

Aerial connection will depend upon the type to be used:

75 ohms balanced input: terminals A and A1;

75 ohms unbalanced (e.g. co-ax feeder): terminals A and E with A1 strapped to E.

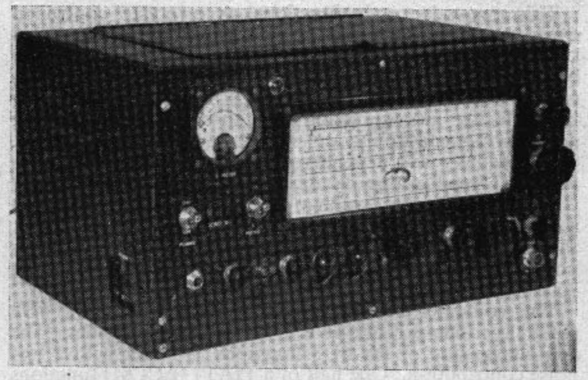
Single-ended: terminal A with A1 strapped to E.

To provide an accurate impedance match, it is possible to use an aerial tuning unit of the type shown in Fig. 22.

Stability: Probably the greatest problem facing the constructor will be that of achieving maximum frequency stability. Should any sudden changes in frequency be noted, the receiver oscillators should be carefully inspected. If the same amount of shift occurs on all bands the trouble is probably in the crystal conversion oscillator or the b.f.o. If the shift is greater on the higher frequency bands suspect the front-end.

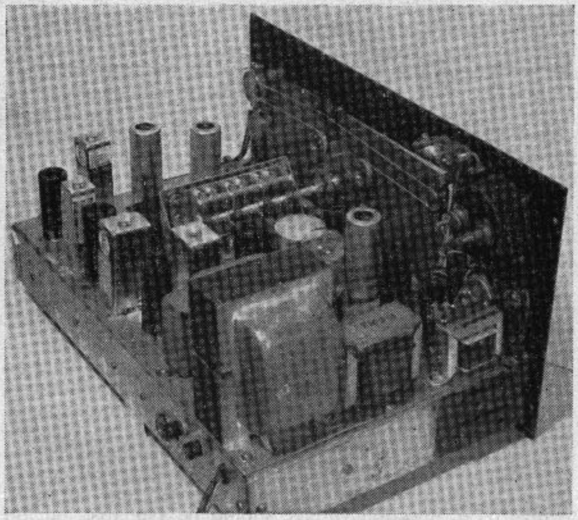
Note that the front-end is fitted with negative temperature coefficient capacitors in the oscillator circuit to provide thermal compensation. For optimum stability this thermal compensation must be in accord with the normal operating temperature, and this will be affected by the ventilation. It may therefore be necessary to adjust the ventilation, after carefully checking stability on a stable signal in the 21 to 28 Mc/s band (allow receiver to warm up for at least 30 minutes). Adjust b.f.o. for zero beat.

If tuning control capacitance has to be consistently increased (plates further in mesh) the oscillator is drifting higher in frequency, suggesting that there may be excessive ventilation, and vice versa. In the prototype model optimum stability was achieved with the lid of the cabinet open and a few suitably placed ventilation holes drilled in the chassis.



The receiver in its cabinet showing the arrangement of the controls.

When operating, the setting of the gain control knobs will affect performance. For best signal-to-noise ratio, the r.f. gain should be maximum; a.f. gain about half-travel and gain kept under control by altering i.f. gain control. If very strong local stations cause cross-modulation or blocking, the r.f. gain should be reduced, and i.f. and a.f. gain increased.



The chassis removed from the cabinet. The terminals on the rear drop of the chassis are for the loudspeaker and transmitter relay.

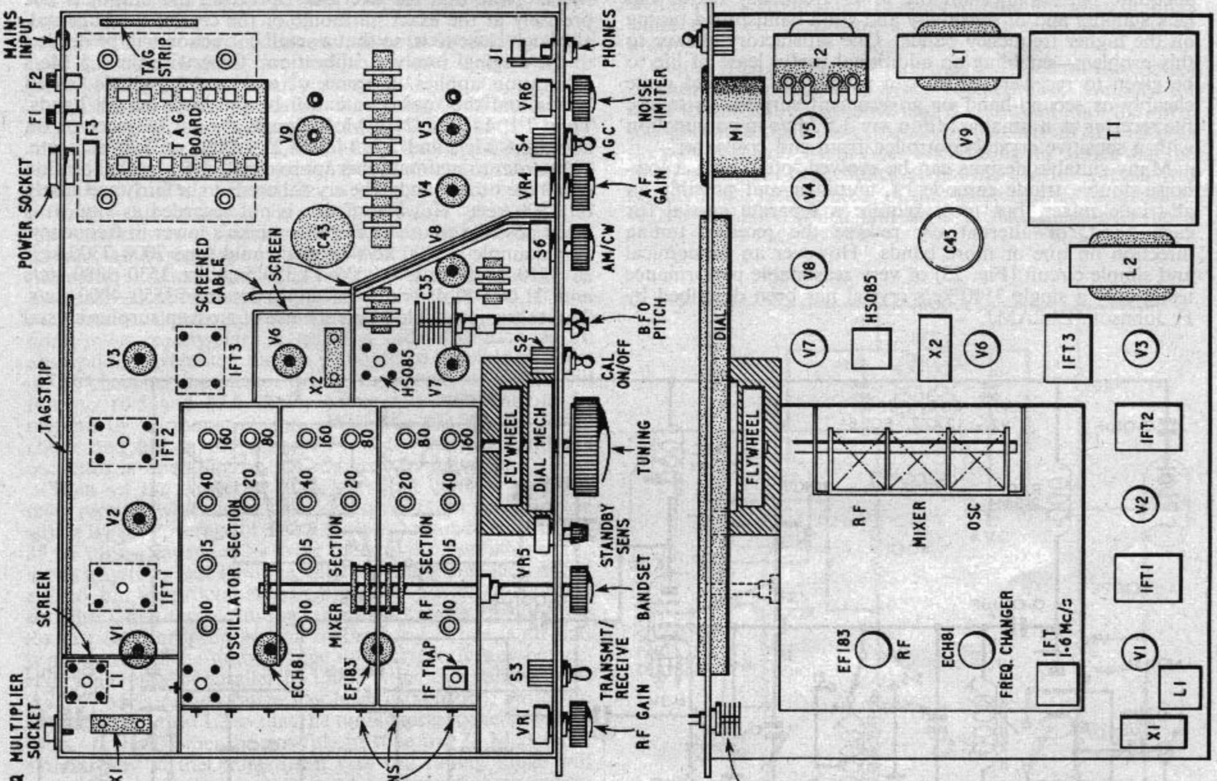


Fig. 21. The layout of the receiver showing the positions of the major components.

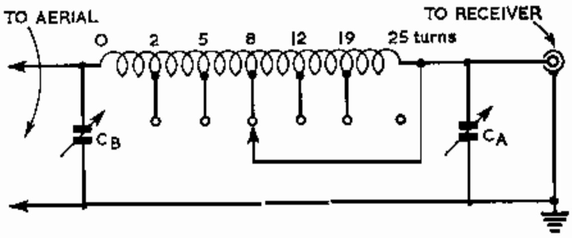


Fig. 22. An aerial tuning unit. C_A should be 500pF, C_B will depend upon the type of aerial in use, but 300pF is a good basis for experiment. The coil consists of 25 turns on a 1 in. diameter former, tapped at 2, 5, 8, 12, and 19 turns and occupying a space of 1 in. 28 s.w.g. wire is suitable.

For reception of s.s.b., the b.f.o. pitch control should be set to a point near the extremity of its travel, corresponding to upper or lower sideband reception. The main control is then rotated until the speech becomes intelligible, possibly with a slight final adjustment of the b.f.o. It should not be necessary to switch off the a.g.c. except on very weak signals but a.g.c. should be switched to the longer time constant. Ample b.f.o. injection voltage should be available, but on very strong s.s.b. signals it may be necessary to reduce the i.f. gain slightly to avoid distortion.

High Stability H.F. Converter

Many of the older communications receivers provide very adequate performance on the lower frequency bands but lack stability and/or sensitivity and good bandspread tuning on the higher frequency bands. One satisfactory answer to this problem—enabling an additional useful lease of life to be given to receivers which can usually be acquired quite cheaply as second-hand or government surplus—is to use the receiver as a tunable i.f. on say 3.5 Mc/s in conjunction with a sensitive crystal-controlled front-end converter.

Many suitable designs can be evolved, often with a low-noise double triode cascode r.f. amplifier and possibly an all-triode mixer, but most require a separate crystal for each band, or alternatively reverse the receiver tuning direction on one or more bands. However an economical and simple circuit (Fig. 23) of very reasonable performance using only a single 3500 kc/s crystal has been described by F. Johnson, ZL2AMJ.

This two-valve unit functions as a crystal-controlled converter on the 7, 14 and 21 Mc/s amateur bands and as a straight pre-amplifier on 3.5 Mc/s. The converter provides a broad-band output on the 3.5 Mc/s band, and all tuning is carried out on the main receiver. It should prove particularly effective in conjunction with an older receiver having good bandspread tuning and stability on the 3.5 Mc/s band. The selectivity will depend entirely upon that of the main receiver when functioning upon 3.5 Mc/s.

One possible disadvantage is that the unit produces a strong spurious marker signal on 7000 kc/s which can block the first few kilocycles of the 7 Mc/s band, although this does not occur if the crystal is slightly lower in frequency than 3500 kc/s as described later.

The converter comprises the triode section of a 6U8 (ECF82) triode-pentode as a grounded-grid amplifier. The pentode section of the 6U8 functions as mixer with a low noise contribution. One half of a 12AT7 (ECC81) functions as crystal oscillator; the other section as a cathode follower output stage following the mixer. There are no tuned circuits at the broadband i.f. of about 3.5–4 Mc/s so that no ganged tuning circuits are involved.

For 3.5 Mc/s reception the oscillator is switched off and the other stages act as a pre-amplifier. On other bands the crystal oscillator frequency is always 3.5 Mc/s lower than the band being received, so that the signal frequency rises as the main receiver is tuned higher across the 3.5 Mc/s band. For 7 Mc/s the crystal oscillates on its fundamental frequency of 3500 kc/s; for 14 Mc/s on its third "overtone" of about 10.5 Mc/s; and for 21 Mc/s on its fifth "overtone" of 17.5 Mc/s. Note that for overtone operation the output is not precisely at the exact harmonic of the crystal fundamental, although close to it, so that a small correction will be needed to the original receiver calibration. Otherwise the 3.5 Mc/s calibration applies in terms of tens and hundreds on all bands, and the tuning rate will be the same on all bands. Thus 7.1, 14.1 or 21.1 Mc/s signals should be received on about 3.6 Mc/s and 7.2, 14.2 or 21.2 Mc/s on 3.7 Mc/s, etc.

In order to maintain this approximate 3.5 Mc/s calibration on all the other bands, the crystal needs to be fairly accurately on 3500 kc/s. However if this is not regarded as vital, it is often possible to use a crystal some kc/s lower in frequency. For example a 3490 kc/s crystal would tune 7000–7300 kc/s as 3510–3810 kc/s, 14,000–14,350 kc/s as 3530–3880 kc/s and 21,000–21,450 kc/s as approximately 3550–4000 kc/s. This tolerance would allow the use of a cheap surplus crystal

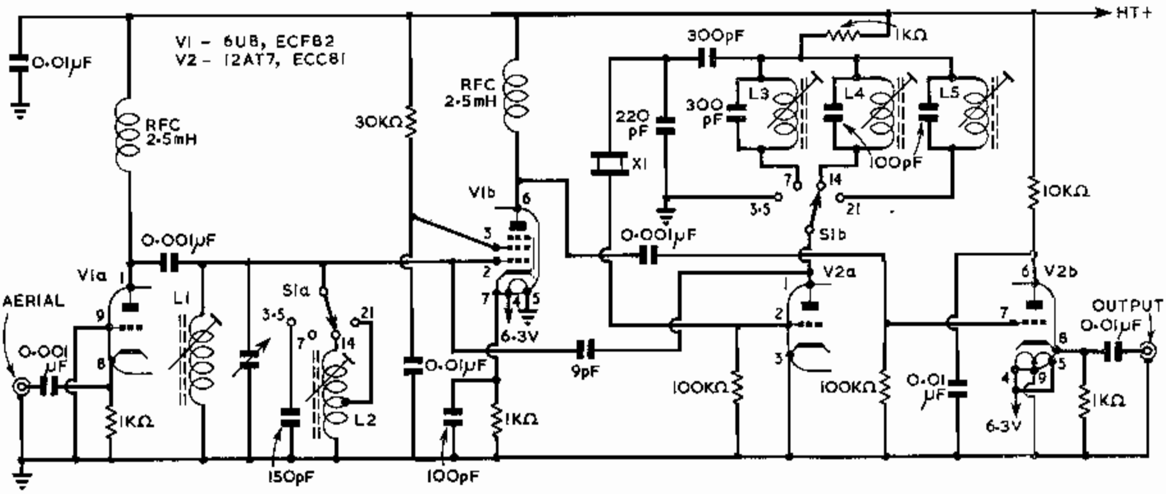


Fig. 23. Circuit diagram of the high stability converter.

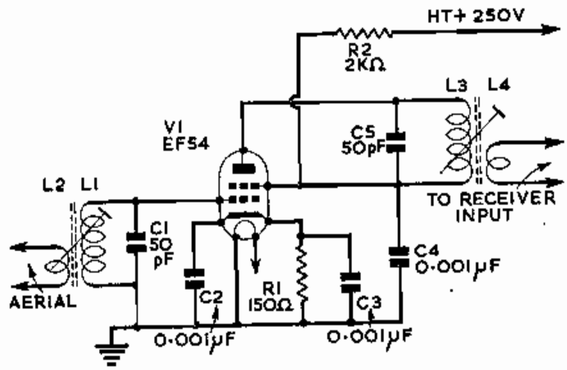


Fig. 24. Circuit diagram of a simple 14 Mc/s pre-amplifier designed by G3ESV. A unit of this type will improve the sensitivity of all but the best of communications receivers. L1, L3 are 13 turns 26 s.w.g. enamel spaced to occupy ¼in. L2 is 5 turns 34 s.w.g. enamel or silk covered, interwound with the bottom 5 turns of L1. L4 is 4 turns 34 s.w.g. enamel or silk covered, interwound with the bottom 4 turns of L3. Coils wound on 7/16" diameter, slug-tuned formers. Wire sizes are not critical; and the slug can be adjusted to cover minor variations in windings. Slightly better results can be obtained from the EF85, 6BA6 with slight component changes.

provided that it is sufficiently active to oscillate readily on its fifth overtone.

Note that only two adjustable coils are used to tune the four bands with L1 left in parallel with L2 on 14 and 21 Mc/s bands.

Construction and layout are not particularly critical provided that r.f. leads are kept short, and output circuits placed well away from input circuits.

All coils are wound on ¼-in. diameter slug-tuned unshielded formers using 30 s.w.g. enamelled wire: L1 42 turns; L2 26 turns, tapped at 17 turns from the "earthy" end; L3 35 turns; L4 13 turns; L5 8 turns, spaced over ⅜ in. Formers could be 0.3 in. diameter with a slight reduction in numbers of turns—this can easily be determined if a calibrated grid dip oscillator is available. The formers can be mounted around the Yaxley-type bandswitch.

Alignment: After completing and checking all wiring, the oscillator circuits must be adjusted so that the crystal oscillates on the correct overtone frequencies. This can be done most readily with a grid-dip oscillator used as an absorption wavemeter, though it should be possible to make do by checking the output on the main receiver if this will tune to 10.5 and 17.5 Mc/s and care is taken not to be mislead by harmonic output. With the absorption device check and adjust the cores of L3, L4 and L5 until the oscillator is operating on the required frequencies.

Then set the converter to 7 Mc/s and connect it to the main receiver which is set to 3.5 Mc/s. Without switching on adjust L1 for coverage of 7–7.5 Mc/s in conjunction with the 35 pF tuning capacitor by using the grid dip oscillator in the usual way (this can be done with incoming signals without a g.d.o. but the process is more difficult). Switch to 3.5 Mc/s and check that the r.f. tuning range now covers 3.5–4.0 Mc/s (or just the European section of the band if this is all that is required). If the tuning range is incorrect, it may be necessary to replace or parallel the 150pF with other values. Once the 3.5. Mc/s tuning range has been established, switch to 14 Mc/s and adjust L2 so that the tuning range covers 14–14.5 Mc/s. It should then be possible to tune the 21 Mc/s band without any further adjustment (the full tuning range will probably exceed the amateur band but this is of no consequence. In practice it will probably prove necessary to change the converter tuning only when tuning right across the band; when searching around only a small section of the band the control can be left unaltered.

Once the tuning ranges have been adjusted, the unit should then be ready for use; signals can be peaked with the converter tuning control when necessary; otherwise all tuning is done on the main receiver. If the gain of the h.f. converter should be excessive on some signals it would be possible to fit a gain control on the cathode follower stage.

One possible difficulty is that there may be i.f. breakthrough from strong local 3.5 Mc/s signals when receiving on the other bands. Screening of the converter and the use of co-ax line with screened connectors between converter and receiver may be sufficient to overcome any difficulties. Should this not be the case, it may in some cases be necessary to fit a further tuned circuit in the form of an aerial tuning unit between aerial and converter.

Provided that the main receiver is efficient on 3.5 Mc/s this combination should provide excellent sensitivity and stability on all the bands concerned.

Simple Q Multiplier

A simple circuit for a *Q* multiplier for selectivity peaking only (i.e. with no rejection notch facilities) and not requiring any additional high-*Q* coils has been described by W3FYG. This arrangement can be incorporated fairly easily in an existing receiver should it be desired to increase selectivity, particularly for c.w. reception; see Fig. 25.

This uses a single additional double triode such as 12AT7 or 12AX7 multi-vibrator oscillator using the existing i.f. transformer in the receiver as the tuned circuit. The device is most effective with single-conversion receivers of only moderate selectivity, such as those without any form of filters other than i.f. transformers on 465 kc/s or 1600 kc/s or above.

Coarse (R2) and fine (R1) controls are fitted for the control of cathode coupling and hence regeneration. Initially R1 is set to minimum resistance and R2 adjusted until the valve just goes into oscillation, then R1 is backed off and used as the panel control. Remember when fitting the device that the small additional capacitance across the i.f. transformer will require slight re-alignment of this winding after installation.

One difficulty which can arise is that there may be a

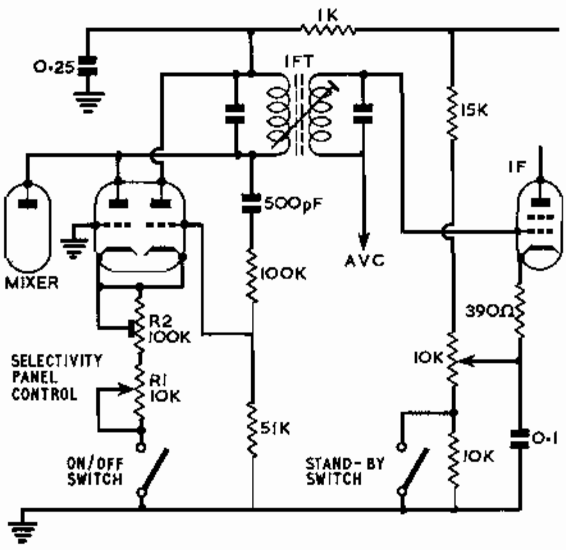


Fig. 25. Q-multiplier without additional coils. The valve is a 12AT7 or equivalent.

tendency for the subsequent i.f. stage to go into oscillation. This can be overcome, as shown in the diagram, by the removal of the bypass capacitor from across this valve's cathode-bias resistor; the slight loss of gain is more than compensated for by the effect of the Q multiplication.

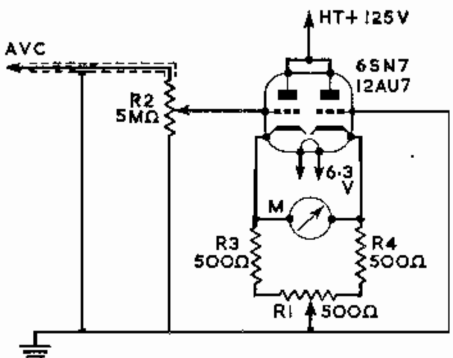


Fig. 26. Circuit diagram of the "S" meter described by W3BLC. The meter M should be 0-200 μA full-scale deflection. R3 and R4 should be 10 per cent tolerance type.

Adding an "S" Meter

An "S" meter is a very useful receiver accessory but many of the simpler circuits suffer from practical disadvantages. The S meter circuit shown in Fig. 26 was described recently in the R.S.G.B. *Bulletin* by Mr. H. O. Lorenzen (W3BLC) and is applicable to almost any receiver utilising a conventional a.g.c. line. R1 is the zero adjustment to compensate for different levels of receiver noise. The input voltage taken from the receiver a.g.c. line is controlled by R2. The calibration scale on the meter provides adequate spread for the lower S units but also accommodates readings up to about 20 dB over S9. Mid-scale usually represents about S8-9 but the scale should be calibrated to suit the receiver concerned.

Transistorized Receivers

During recent years, h.f. communications receivers and v.h.f. converters using no valves but based entirely upon transistors and other semiconductor devices have been developed both commercially and by amateur constructors. These offer the advantages of compact size, greater reliability (provided the transistors are operated under correct conditions); and since they draw only low power, from low voltage supplies, they can be optionally operated from dry batteries or car accumulators. Simple sets—such as the RSGB Transistor Four (described later)—can be made at considerably less cost than a mains-operated valve set of comparable performance.

Not only are semiconductors significantly more reliable than valves and less subject to ageing, but modern types can have better noise characteristics right up to u.h.f. and the low operating voltages and reduced heat make for more reliable and consistent performance of the associated components. The small size of the semiconductors and the complete absence of heater wiring and large holes for valveholders simplify the construction of receivers and converters; alternatively much more complex circuits can be put into a similar sized cabinet in order to improve frequency stability, etc. Battery sets will usually prove a good deal cheaper, due to the omission of the mains transformer and other power supply components, especially since new and surplus transistors are available at much the same cost as valves. This also means that there are none of the safety problems associated with the construction and testing of a first mains-operated receiver.

Thus simple h.f. and v.h.f. transistorized receivers and converters can be built easily and cheaply, and are increasingly used for mobile and portable work, and are beginning to find favour for fixed station use. There is also growing use of "hybrid" designs in which some transistors and some valves are incorporated.

With the many apparent advantages of transistors it may be asked why in fact the majority of high-grade amateur communications receivers are still based on valves, and whether this is likely to continue. Undoubtedly there will be a trend towards many more all-semiconductor receivers and converters, but it must be recognized that there are still some important problems in the design of really high-grade transistor receivers and that although ways of overcoming these have been developed some of the techniques result in sets of great complexity and hence high cost. It is only now that designs are beginning to appear which offer performance equivalent to that of the best valve sets, and some of these are rather beyond the pocket of most amateurs.

The main problem with readily available transistors is that of achieving a really wide dynamic range of the front-end of the receiver—that is to say a front-end to a receiver which will handle both very weak and very strong signals without introducing various forms of cross-modulation and blocking. This is partly because there is no near equivalent among conventional bipolar transistors to the variable-mu pentode valve and this makes it difficult to obtain really effective automatic gain control characteristics unless one uses unipolar devices such as the FET mentioned below.

Other problems include increased circuit loading due to lower input impedances; feedback capacitances that may require neutralizing; the variation of semiconductor characteristics with temperature; the fact that, unless protection circuits are fitted, transistors can be damaged by large input voltages due to static build-up on the aerial, impulse interference or a near-by transmitter; the greater spread of characteristics between devices bearing the same type number than we are used to with valves; and the need to pay greater attention to accurate impedance matching through all stages of the receiver.

This may seem a formidable list, but in fact many of these problems are being overcome; for instance some are alleviated by the use of silicon rather than germanium devices (though these tend to be a little more noisy). A fairly recent development, which may considerably affect the design of the front-end of receivers, is the growing availability of low noise "field effect transistors" (FETs) and the special forms of these known as IGFETs (insulated-gate FET) or MOSTs (metal-oxide semiconductor transistor). These devices have extremely high input impedances and have characteristics which make them much less susceptible to cross-modulation and resemble vari-mu pentode valves in this respect. They can also act as extremely efficient low-noise mixers (unlike valves, they give almost as low noise as mixers as they do as amplifiers).

But at the time this edition is being prepared, suitable FET devices (such as the Texas Instruments 2N3823 n-channel FET) cost several pounds each, although cheaper FET devices such as the 2N3819 are becoming available, and appear to have an important role to play. A single FET receiver can be as effective as the once popular O-V-I. All semiconductors, of course, have to be treated with some care and the precautions listed on pages 20-21 should always be observed.

An alternative technique to overcome the problems of transistor front-ends is in fact to use the miniature Nuvistor valves, with their low power consumption, for this section of the receiver.

The development of good semiconductor receivers and converters for amateur operation is thus a good example of the type of interesting constructional and design work which is still open to experienced amateurs—even if it still seems likely that there will be many valves used in communications receivers for some time to come.

RSGB Transistor Four

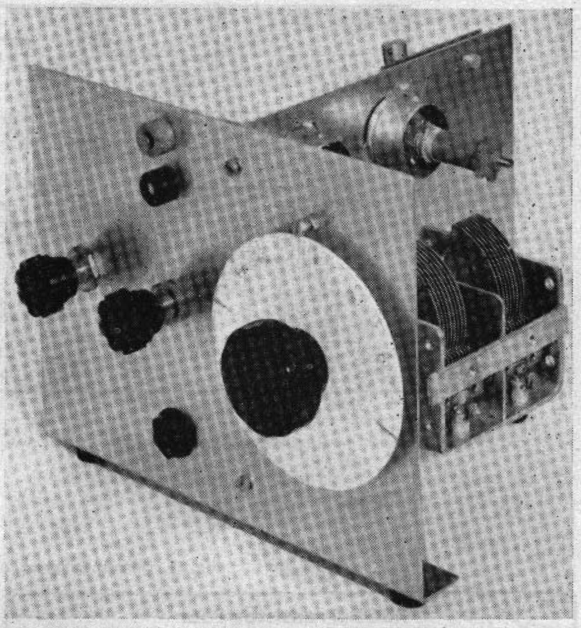
A simple, low-cost transistorized superhet receiver, using commercially available plug-in coils can be built for about £5 and can give many hours listening for each small 9-volt (PP3) battery, as well as giving the constructor a useful insight into small communication receivers.

A receiver of this type can be built for appreciably less cost than a mains-operated valve receiver, and the complete absence of the mains power pack is an attractive safety feature when the set represents an initial constructional project.

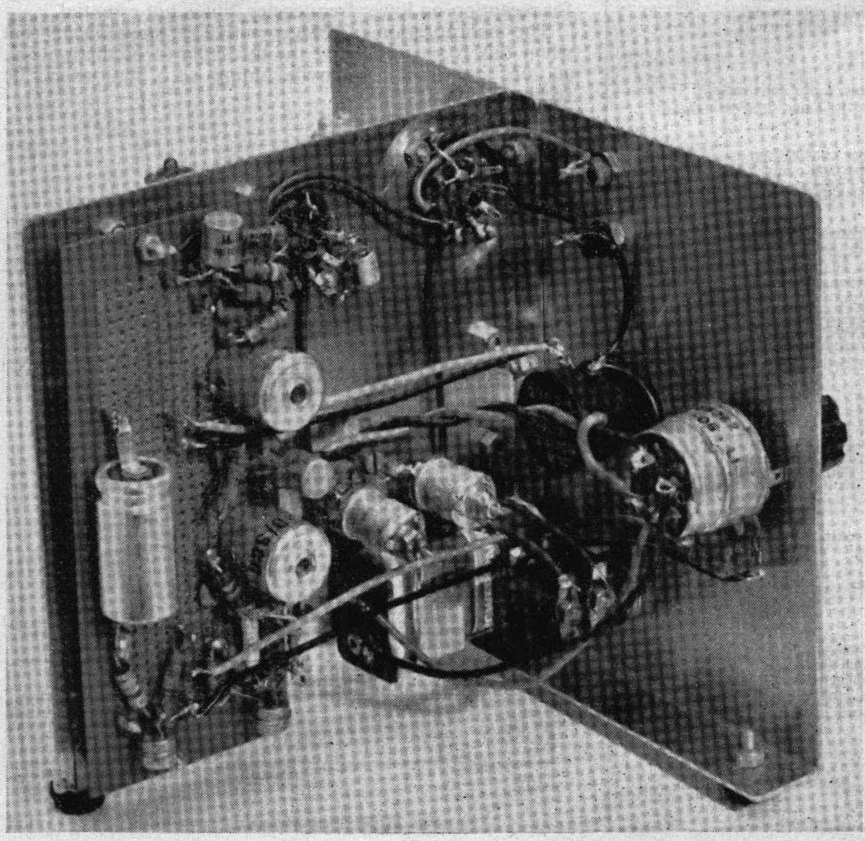
The receiver described below is based on a design prepared by A. L. Mynett, G3HBW for the RSGB.

It is intended primarily for the headphone reception of amateur stations in the 1·8 and 3·5 Mc/s bands using a single pair of coils (1·8–5 Mc/s) but is capable of receiving amateur and broadcast signals throughout the range 515 kc/s (580 metres) to 31·5 Mc/s (9·5 metres) with the appropriate plug-in coils.

The receiver uses an OC170 (or AF115) h.f. transistor as a self-oscillating mixer (TR1) providing an i.f. output on about 470 kc/s. A second OC170 (TR2) is used as a regenerative i.f. amplifier, with the gain/regeneration controlled by VR1 which adjusts the amount of negative feedback in the stage to balance the positive feedback resulting from the effects of C13 and the internal capacitive feedback of TR2.



The RSGB Transistor Four designed by G3HBW as a low-cost superhet.



The amplified i.f. signal is demodulated by the diode envelope detector (CR1), followed by two stages of a.f. amplification (TR3, TR4) which can conveniently be OC71 or almost any similar a.f. transistors. Control of the a.f. gain is governed by adjustment of VR2 which varies the amount of negative feedback in the final stage.

Low-impedance headphones are connected directly in the collector circuit of TR4, and although this may appear bad practice (in general the direct current component should not flow through a good pair of headphones since this can cause changes in magnetization) in this case the collector current is too small to change appreciably the d.c. magnetic field. Although only two tuned circuits are used in the i.f. section, selectivity is aided by the use of a regenerative stage, and should show considerable improvement over that of a simple straight receiver.

Sensitivity is limited by the absence of an r.f. stage though this will be less important on the lower frequency bands where external noise is high; with only one tuned signal frequency circuit—damped by

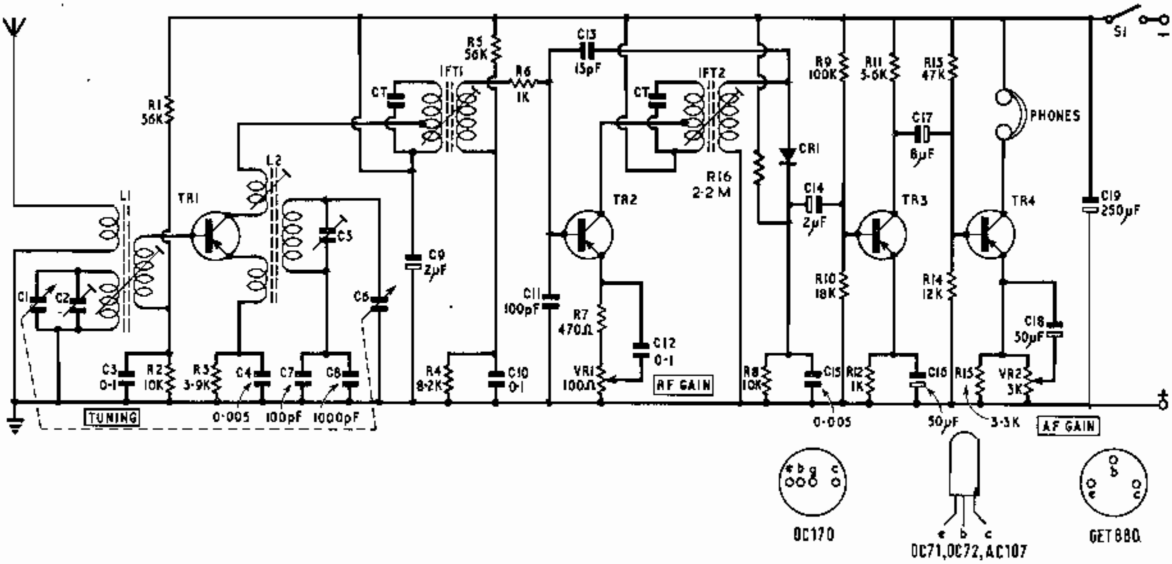


Fig. 27. Circuit Diagram of the RSGB Transistor Four.

RSGB Transistor Four

PARTS LIST

Capacitors

Two 2µF sub-miniature electrolytics (15 volt rating).
One 8µF sub-miniature electrolytic (15 volt rating).
Two 50µF sub-miniature electrolytics (15 volt rating)
One 250µF sub-miniature electrolytic (15 volt rating).
Two 0.005µF paper (150 volt rating).
One 100pF tubular ceramic.
One 15pF tubular ceramic.
One 100pF Suflex polystyrene (350 volt, 5 per cent rating).
One 1000pF Suflex polystyrene (500 volt, 2 per cent rating).

Resistors

All Radiospares type RS, ½-watt, 10 per cent rating.
One 470 ohms; two 1K; one 3.3K; one 3.9K; one 5.6K; one 8.2K; two 10K; one 12K; one 18K; one 47K; two 56K; one 100K.

Miscellaneous

The following parts can be obtained from Home Radio of Mitcham:
One 12 yard reel Z8A connecting wire, any colour.
One 6 yard reel Z8B connecting wire, any colour (miniature).
One VC12 310 plus 310pF, 2 gang condenser.
One DL50A epicyclic drive, with flange.
One Maxi-Q Coil, transistor tuning, Range 3T, red.
One Maxi-Q Coil, transistor tuning, Range 3T, blue.
One VR25 100 ohm wirewound potentiometer, 1 watt.
One VR82 3K ohm log potentiometer, with D.P. switch.
One JH6 Igranic P27 c/c jack socket.
One PK4 Clix Socket, red.
One PK4 Clix Socket, black.
Two VC62 Mullard trimmers, 3–30pF.
Two VH3 B9A valveholders, nylon (used as coil holders).
One TRC72 Weyrad I.F. transformer, P50/3CC.
One TRC73 Weyrad I.F. transformer, P50/2CC.
Two ¾ in. dia. black fluted knobs.
One 1⅜ in. dia. black fluted knob.
One PP3 battery.
One LK141 Chassis plate No. 4, Lektrokit.
One LK2311 Bracket No. 1, Lektrokit.
50 LK3011 Pins soldering, Lektrokit.
Three Z40 Grommets to fit ¼ in. holes.
One Battery connector for PP3.

Nuts and Bolts

Three ⅜ in. long 4 B.A. ch. hd. cad. steel screws.
Three ¼ in long 4 B.A. ch. hd. cad. steel screws.
Two ¾ in. long 6 B.A. ch. hd. cad. steel screws.
One doz. ¼ in. long 6 B.A. ch. hd. cad. steel screws.
Two 3/16 in. long 8 B.A. csk. hd. cad. steel screws.
Three 2 B.A. cad. steel half-nuts.
Six 4 B.A. cad. steel nuts.
Two doz. 6 B.A. cad. steel nuts.
Six 6 B.A. soldering tags.
One 4 B.A. star tag.
Six 6 B.A. cad. steel washers.

the aerial—there will inevitably be image responses, particularly on higher frequencies. Nevertheless a surprisingly large number of amateur phone and c.w. signals can be received satisfactorily, particularly when used with a reasonably high aerial some 30-60 ft. long; an earth is preferable, particularly for reception on lower frequencies, but is not essential.

The incorporation of a regenerative i.f. stage means that when this is set just above the threshold of oscillation c.w. stations and (with very careful tuning) s.s.b. stations can be received.

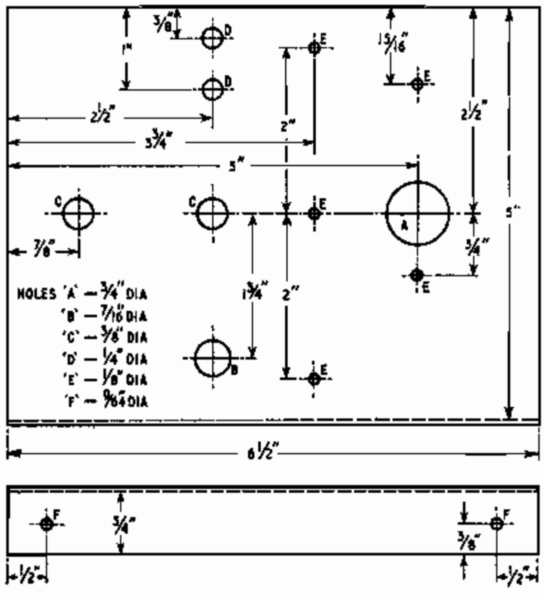
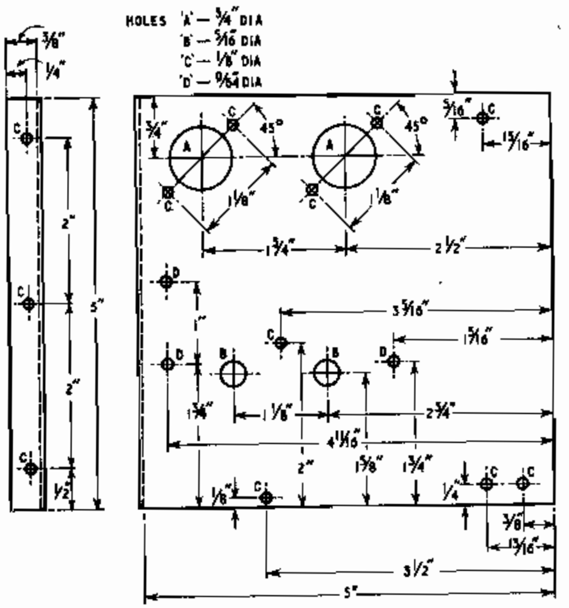


Fig. 28. Drilling diagram Front Panel.



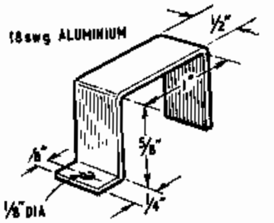


Fig. 29. Drilling diagram of Vertical Chassis. (*left*) Battery clip.

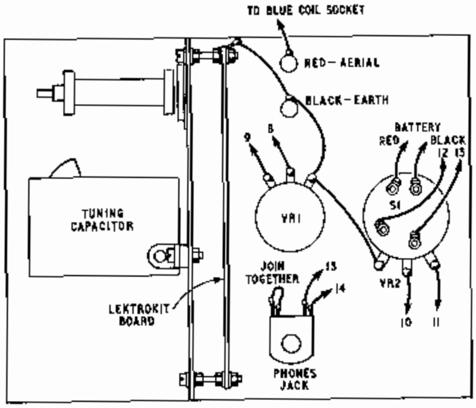


Fig. 31. Main components on Front Panel.

Since transistors can be damaged or destroyed by excessive heat or by incorrect polarity of the supplies, it is necessary to be most careful not to leave a hot soldering iron in contact with the transistor leads longer than necessary,

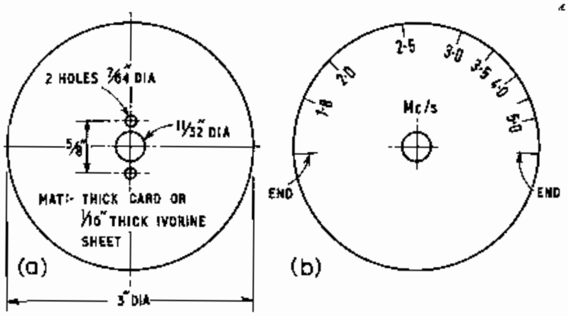


Fig. 32. Tuning scale and approximate calibration for 1·8 to 5·0 Mc/s band.

The receiver is constructed in the form of a front panel, consisting of a bent sheet of 18 s.w.g. aluminium, with a similar piece of aluminium to form a vertical chassis. Three rubber grommets are used as "feet". Most of the detailed wiring is carried out on half of a Lektrokit (LK141) perforated wiring board.

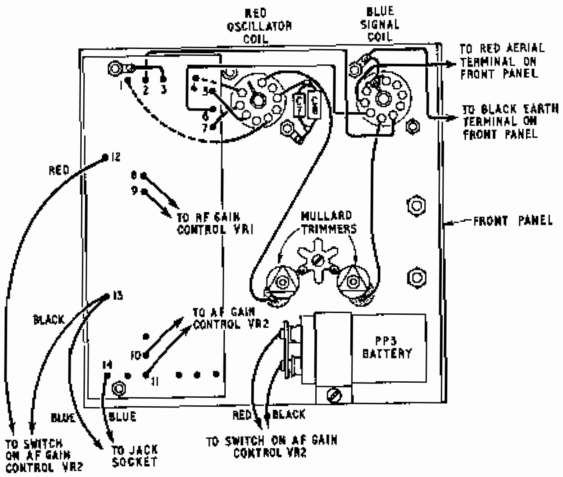


Fig. 30. Main components on Vertical Chassis.

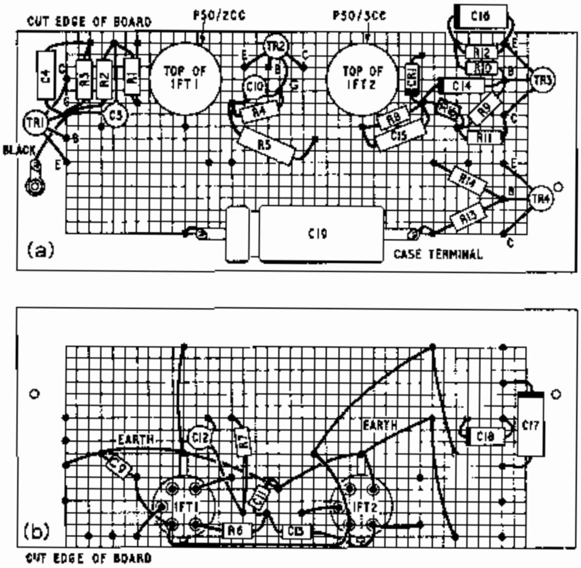


Fig. 33. Layout of Perforated Wiring Board (a) Top; (b) Below.

and to check all wiring including the battery clip connector and switch; do not clip the battery connector on to the battery until all wiring has been completed and carefully checked against the diagrams. Care should also be taken not to allow the hot soldering iron to come into contact with the casing of the polystyrene capacitors.

Adjustment and Alignment

When the receiver has been completed, and all wiring most carefully checked, plug-in the Denco coils (3T red and 3T blue), the blue coil being inserted in the socket nearer the front panel. Turn both coil core-adjusting screws until about ⅛-in. protrudes, and set both the Mullard trimmers to half-mesh. Plug in a pair of low resistance headphones (for example type DLR), connect the battery clip, turn the a.f. gain control fully clockwise, r.f. gain fully anticlockwise and switch on.

A faint hiss should be heard in the 'phones. Advance the r.f. gain and the i.f. stage should go into oscillation with a louder hiss. If this does not happen, advance the r.f. gain fully clockwise and adjust the core in one (either) i.f. transformer, first in one direction and then the other using a nylon trimming tool or chisel-pointed matchstick for this operation; do not use a metal screwdriver since this may crack the core. When the i.f. stage does oscillate, alternatively adjust the i.f. transformer core and reduce the r.f. gain until finally the i.f. stage oscillates at the lowest possible setting of the r.f. gain control.

Should a signal generator be available, the receiver input circuits may be aligned and the dial calibrated, using the following procedure:

Turn the tuning knob clockwise until the gang capacitor vanes are completely meshed; set the signal generator to provide about 50 microvolts output (i.e. fairly weak signal) at a frequency of 1·62 Mc/s, feeding this into the aerial and earth terminals of the receiver. Turn the receiver's r.f. gain until the i.f. just oscillates and then adjust the red coil core until the signal is received.

Then turn the tuning control anticlockwise until the ganged capacitor vanes are completely out of mesh, tune the signal generator to 5·25 Mc/s and adjust the Mullard trimmer on the red (oscillator) coil side until the signal is again heard. If you now retune the set and generator to 1·62 Mc/s the setting may no longer be quite correct. Repeat the two adjustments at 1·62 Mc/s and 5·25 Mc/s until both ends are right at the same time. Then tune in the 1·62 Mc/s signal and adjust the blue coil core for optimum signal strength; and adjust the Mullard trimmer associated with the blue coil for maximum signal strength at 5·25 Mc/s. At this stage the receiver will be aligned and accurate calibration marks can be made on the dial by tuning the signal generator to 5·0, 4·5, 4·0 Mc/s, etc. Indian ink or a ball-point pen may be used to mark the dial.

Where (as will often be the case) no signal generator is available, the set can still be aligned quite easily without one. If the coil cores and trimming capacitors have been set as suggested earlier in this section, the receiver will probably not be far out of alignment. The scale of Fig. 32 can be copied on to the dial and should prove reasonably accurate. Then with an aerial plugged in, turn the tuning control clockwise until the vanes are meshed and then adjust the core of the blue coil for loudest signals at this end of the wave-range; then turn the tuning knob until the capacitor vanes are almost completely out of mesh, and adjust the Mullard trimmer associated with the blue coil until signals are loudest; repeat these adjustments until optimum results over the band are obtained.

Frequency calibration may be accurately checked by listening for the frequency standard station MSF on 2·5 Mc/s and 5·0 Mc/s (this usually transmits a carrier modulated with distinctive one second "ticks"); another useful identification signal is the strong "Loran" navigational signals which can be heard at night transmitting a characteristic "buzzing" signal occupying a broad channel on about 1·95 Mc/s. Amateur stations should, of course, be heard between 1·8 and 2·0 Mc/s and also between 3·5 and 3·8 Mc/s, as well as many small ships transmitting phone in the range 2·0 to about 3·0 Mc/s.

Simple Transistor H.F. Converter

Quite often newcomers wish to listen to amateur stations on broadcast receivers which either do not have a short-wave band or alternatively which do not cover the band(s) they are interested in. If the receiver has plenty of gain and preferably is intended for use with an external aerial rather than with an internal ferrite-rod type aerial, use can be made of an extremely simple crystal-controlled converter of the type shown in Fig. 34. This consists of a single transistor (types OC170, OC171, AF115, AF105, 2N247 or any other high frequency transistor would be suitable) which acts as a combined oscillator and mixer, with all tuning carried out on the main receiver.

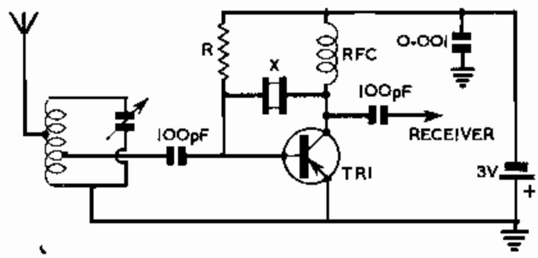


Fig. 34. Simple crystal-controlled converter.

To show how to choose a suitable frequency for the crystal, say one wanted to listen between 3·5 and 3·8 Mc/s (80 metre amateur band) with the broadcast receiver on the medium waves. Then if a crystal of 4400 kc/s were used, a signal on 3500 kc/s should be receivable with the set tuned to 4400–3500 kc/s, that is 900 kc/s (334 metres) and the band received as one tunes down to 600 kc/s (500 metres), since 4400–3800 is 600 kc/s. It can easily be seen that the crystal does not have to be exactly 4400 kc/s but almost any frequency in that region; and similarly for other bands.

With only a single aerial tuning circuit (and this will be damped to some extent by the aerial, even when this is tapped towards the earthy end of the coil) there is almost bound to be some interference from stations on the "image" frequencies, and it may be that very loud broadcasting stations will also continue to break through (this will be minimized by keeping the lead between the converter and the receiver aerial socket very short); nevertheless this often proves a quite useful and economical way of listening to additional amateur bands, since surplus crystals can be obtained for a very few shillings. The resistor R is best adjusted by trial and error for optimum results on the particular transistor used; it will normally fall between 100 K ohms and 1 Megohm. This type of converter can also be used to convert a car radio for amateur frequencies.

CHAPTER FOUR

Amateur Transmitters

This chapter describes the practical problems encountered in the design and construction of amateur transmitters for telegraphy and telephony, frequency measurement and transmitting aerials. It is based, with additional material, on a series of articles by Lorin Knight, A.M.I.E.E., published originally in the *RSGB Bulletin*.

The Master Oscillator

To start this introduction to amateur transmitter design and practice it is intended to go straight to the heart of the transmitter, the master oscillator. Before delving into actual circuits, however, let us refresh our memories about the working of the parallel tuned circuit shown in Fig. 1.

In the figure it is assumed that the capacitor has just been charged. There is a surplus of electrons (or a negative charge) on the upper plate and a corresponding deficit of electrons (a positive charge) on the lower plate. Now the coil possesses inductance which tries to stop the current through it changing. Thus there will not be an immediate avalanche of electrons from the upper plate through the coil to the lower one. The electron flow will instead gradually increase in intensity.

Eventually the charge on the capacitor will be reduced to zero but by now the electron current will be quite strong and the inductance will not allow it to stop suddenly. In consequence, the capacitor will begin to charge up in the opposite direction. As it charges up the current will gradually diminish and eventually cease. The direction of current flow will then reverse and start to discharge the capacitor again. This cycle of events will continue, the voltage across the capacitor periodically alternating from positive to negative. The current through the coil will alternate also, being at a maximum when the voltage is zero and being zero when the voltage is at a maximum. The frequency of these oscillations, that is to say, the number of complete cycles per second, is governed by the inductance of the coil and by the capacitance. By choosing suitable values, oscillations can be obtained at any frequency.

If there were no losses anywhere the oscillation would continue indefinitely. In practice, of course, there will

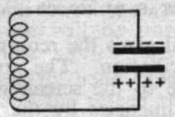
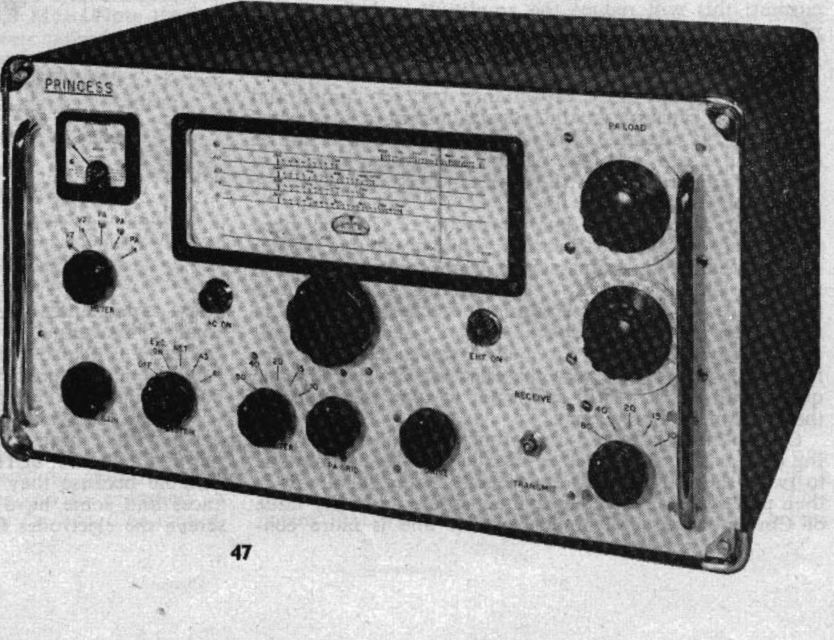


Fig. 1. The parallel tuned circuit

be a loss of energy, the main cause being the dissipation of heat by the resistance of the coil. If the circuit is to be kept in oscillation the lost energy must be replaced.

We can think of the tuned circuit as rather like an electrical equivalent of the pendulum. Just as a pendulum needs a small mechanical push now and then to keep it going, so the tuned circuit needs a small electrical push now and then. Most of the oscillator circuits which we use in Amateur Radio are, in spite of their fancy names, only different ways of providing pushes to a tuned circuit.



G3JJG's fine example of an amateur-built table-top transmitter. The main cabinet contains the r.f. circuits for a five-band, 150-watt transmitter designed for TVI-proof operation.

The Electron-Coupled Oscillator

For a transmitter it is extremely important that the frequency should be stable and thus the choice of an oscillator circuit must be guided by this criterion. A circuit which has proved very useful in this respect is the electron-coupled oscillator, a typical version of which is given in Fig. 2. L1 and C1 form the tuned circuit and the alternating voltage across it is fed *via* C3 to the grid of a pentode. The consequent alternating cathode current flowing through the lower part of the

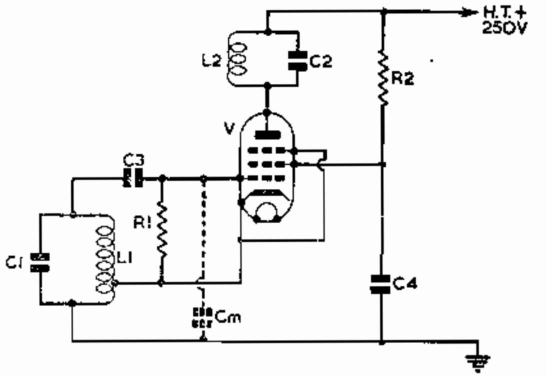


Fig. 2. A typical electron-coupled oscillator. C3, 100 μμF; C4, 0.005 μF; R1, 100,000 ohms; R2, 47,000 ohms; V, 6AC7 or EF80.

coil gives the required energy reinforcement to maintain oscillation. The great advantage of this circuit is that, due to the screen grid being virtually earthed at radio frequencies by the capacitor C4, the anode is screened from the control grid. Thus we can load up the anode without worrying about the effect this will have on the grid circuit.

The most obvious way of developing the output voltage is to tune L2C2 to the fundamental frequency, *i.e.*, to the frequency of the L1C1. The anode current, which alternates in sympathy with the grid voltage, will then maintain an oscillating current in L2C2. Since the anode circuit is being driven by the valve the frequency of the oscillation there will be locked to that of the grid circuit. Off-tuning the anode circuit will cause the natural oscillation to be partially cancelled by the anode current; this will reduce the amplitude and change the phase relative to the grid but it will not affect the frequency.

In practice this does not work out quite as perfectly due to the small stray capacitance between anode and grid, which causes a small feedback current to be injected into the grid circuit. This feedback current will not be exactly in phase with the natural oscillatory current in the grid circuit and will normally try to slow the oscillation down.

It is, in fact, as if a small capacitance Cm has been added between grid and earth. This would not matter if the value of this capacitance were constant. Unfortunately, slight changes in the tuning of the anode circuit near to resonance cause appreciable changes in the phase of the feedback current and consequent changes in the value of Cm. With valves having a very low anode-grid capacitance the effect of Cm can be made quite small but it is still safest not to tune the anode to the fundamental frequency.

One solution is to use an untuned anode load consisting of a resistor but a better method is to tune the anode to twice the fundamental frequency. The grid circuit is then practically unaffected by the anode circuit; the value of Cm is consequently much smaller and is more constant. The anode circuit now only receives one push per two cycles but this is quite sufficient to maintain a strong oscillatory current. The output frequency is exactly twice that of the fundamental oscillation and if, for example, the desired output frequency was 3.8 Mc/s L1C1 would have to be tuned to 1.9 Mc/s.

Having seen how the effect of the output circuit can be reduced let us look at the grid itself and the cathode. Each of these imposes a small capacitance across the tuned circuit and these capacitances are liable to vary. Their effect, together with the effect of Cm, can be minimised by tapping the grid and cathode as far down the coil as possible. The coil, it must be remembered, is an auto-transformer and any impedance placed across a tap is equivalent to a smaller impedance placed across the whole. With a grid capacitance of 10μμF, for example, and assuming a perfect coil, tapping the grid half way up the coil would only impose $(\frac{1}{2})^2 \times 10$ μμF, or 2.5 μμF, across the coil. Tapping the grid one third up would only impose $(\frac{1}{3})^2 \times 10$ μμF, or 1.1 μμF (1 μμF = 1 pF).

We can see now that it is advantageous to have a low loss tuned circuit or as it is usually expressed, one with a high Q factor, for the higher the Q the less reinforcement will be required from the valve and the lower the taps can be. In order therefore, to keep the losses in the coil low we can (a) wind the wire in a single layer on a circular former of as large a diameter as practicable; (b) use good quality enamel covered wire of such a gauge that the length of the coil is about 1½ times its diameter; (c) use a former made of a low-loss material such as polystrene, "frequelex" or "mycalex"; (d) keep the coil at least one diameter away from any other metal. To keep the size of the oscillator within reasonable dimensions the maximum practical coil diameter will usually be about ¾in. to 1in.

The effect of the grid and the cathode can be further reduced by choosing a large value for C1 so that the

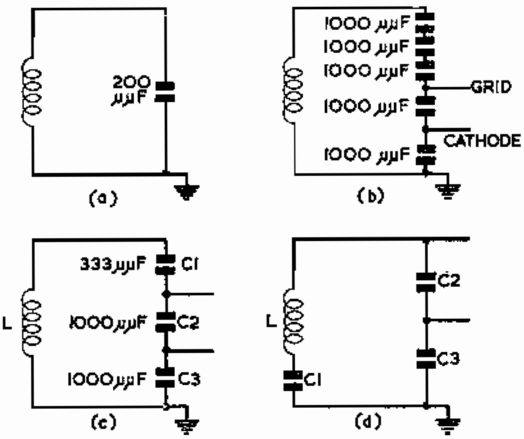


Fig. 3. Evolution of the Clapp oscillator circuit.

stray capacitances are only a small percentage of the total. This cannot be carried too far because decreasing the ratio L/C also reduces the Q. In an oscillator whose fundamental frequency is 1.9 Mc/s the optimum value of C1 might be about 300 μμF.

We can also help to make the taps low by using a valve with a high mutual conductance. Types such as the 6AC7, 6AG7, 6CH6, EF80 and EF50 are particularly suitable because they also have low anode-grid capacitances and some have metal exteriors which completely screen the electrodes from any external circuits.

The Clapp Oscillator

It is not very convenient to experiment with tapping points on a coil and in any case the finished result is not usually very elegant. An alternative which has come into favour is to tap the capacitance instead. Taking the tuned circuit in Fig. 3(a) the 200 $\mu\mu$F capacitor can be considered as consisting of five 1000 $\mu\mu$F units in series. It is therefore possible to tap into the capacitance as in Fig. 3(b). Simplifying this we get (c).

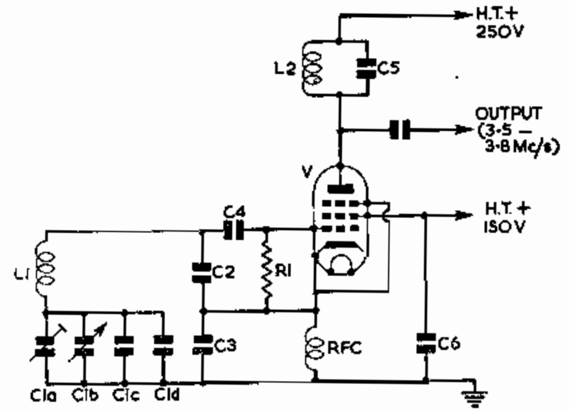


Fig. 4. Typical Clapp Oscillator. C1a, 50 $\mu\mu$F preset; C1b, 100 $\mu\mu$F (tuning); C1c, 200 $\mu\mu$F silver mica; C1d, 20 $\mu\mu$F neg. temp. coef. type; C2, 2000 $\mu\mu$F silver mica; C3, 3000 $\mu\mu$F silver mica; C4, 100 $\mu\mu$F; C6, 0.005 μF; L1, 46 turns, 26 s.w.g. enam. on 1 in. diam. former; L2C5, tuned to 3.5 Mc/s band; R1, 100,000 ohms; RFC, 1 mH; V, 6AC7, EF80, etc.

If the frequency of the oscillator is to be varied we must have some facility for varying the total capacitance. C2 and C3 will only have minor effects on the total and it is better to vary C1. This would be inconvenient with neither side of C1 earthed and so it must change positions with L as in Fig. 3(d).

This arrangement is used in what is commonly known as the Clapp oscillator, an electron-coupled version of which is given in Fig. 4. C1a is used to set the lowest frequency to 1.75 Mc/s. C1b then allows the oscillator to be tuned from 1.75 Mc/s to 1.9 Mc/s and the resulting output frequency is 3.5 Mc/s to 3.8 Mc/s. Note that an r.f. choke has been included between cathode and earth to provide the necessary d.c. connection. Having a relatively high inductance it will pass very little r.f. current and thus have very little effect on the tuned circuit.

Practical Considerations

There are a number of other oscillator circuits capable of excellent stability, including the Tesla (Vackar), the Franklin, and Mixer (frequency synthesizer) circuit. The transistorized v.f.o. shown on page 20 has been adopted by many amateurs despite the low output.

The fact that we have chosen a good circuit is not in itself a guarantee that we are going to have a stable oscillator. Our efforts will all be in vain unless care is taken with the physical construction. We have seen how by suitable techniques the frequency can be made almost entirely dependent on the actual oscillator tuned circuit. The main consideration, therefore, must be to ensure that this itself is stable.

All the components comprising the tuned circuit should be housed in a metal box to prevent any coupling from external circuits. The valve holder can be mounted on the box so that the valve is outside the box. The mounting and the wiring of all the critical components must be rigid so that the freqency is unaffected by mechanical vibration. The tuning capacitor should preferably have ceramic insulation and should have good bearings at either end.

To enable the oscillator to be accurately reset to a given frequency the tuning scale should have as large a diameter as possible and a slow motion drive which is free from backlash. It is advisable to use a flexible coupler between the drive and the capacitor to prevent any undue strain on the bearings of either due to imperfect alignment.

Fixed capacitors in the actual oscillator tuned circuit must have high stability and little better can be done than to use silvered mica types. **Paper dielectric, high-K ceramic and the normal moulded mica types should certainly be avoided.**

The use of a coil former having a low coefficient of expansion will be helpful in making the inductance less dependent on temperature.

Even when all precautions have been taken it is usually found that the frequency decreases slightly for the first half-hour or so after switching on as the components warm up.

If we are using an electron-coupled type of oscillator it must not be forgotten that we are taking advantage of the fact that the anode-grid capacitance is small and we must ensure that the grid and anode circuits are shielded from each other. Our efforts in choosing a valve with 0.005 $\mu\mu$F grid-anode capacitance will be wasted if we introduce 0.05 $\mu\mu$F in the wiring.

The effective values of the grid and cathode capacitances are influenced by the anode and the screen voltages. With electron-coupled oscillators there is usually an optimum value for the screen voltage which gives minimum frequency change for a change in h.t. voltage but for maximum stability it is advisable to stabilise the anode and screen voltages

It must be appreciated that the percentage of frequency drift which can be tolerated depends on the output frequency of the transmitter. A drift of 0.05 per cent, for example, is equivalent to 0.9 kc/s at 1.8 Mc/s and, provided that the rate of drift was slow, might be acceptable. At 28 Mc/s, however, it is equivalent to 14 kc/s and much more serious.

The following table gives a rough guide to the values of inductance and capacitance required to tune to various amateur bands.

Band	*L (μH) x C (μμF).*
1.8 Mc/s	7000
3.5 Mc/s	1900
7 Mc/s	500
14 Mc/s	130
21 Mc/s	55
28 Mc/s	30

The approximate inductance of a single layer coil is given by:—

$$L = \frac{a^2N^2}{9a + 10l}$$

where a=radius of former + radius of wire (in inches)
N=number of turns
l=length of winding (in inches)

The Crystal Oscillator

A simpler method of obtaining a stable source of one spot frequency is to use a quartz crystal instead of a tuned circuit. Quartz is said to be piezo-electric. This means that when an electrical potential is placed across

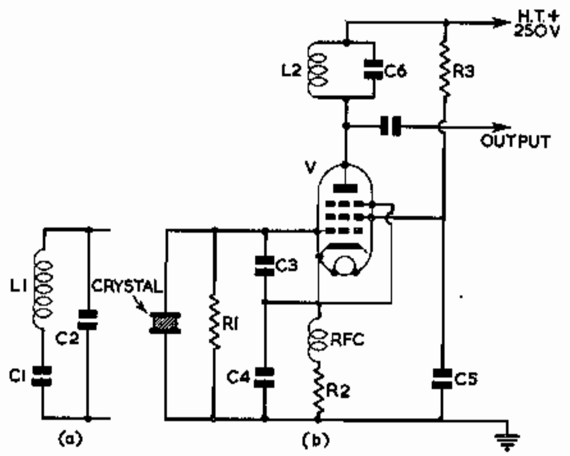


Fig. 5. Crystal oscillator. (a) Approximate equivalent of 1.9 Mc/s crystal. C1, 0.004 μμF; C2, 5 μμF; L1, 2 H. (b) Typical crystal oscillator for 1.9 Mc/s. C3, 75 μμF; C4, 250 μμF; C5, 0.005 μμF; R1, 25,000 ohms; R2, 250 ohms; R3, 47,000 ohms; V, 6AG7.

a suitably cut plate of quartz the plate will be deformed and, conversely, if the plate is deformed an electrical potential will be produced across the two faces.

Thus if a mechanical vibration is set up within the quartz a corresponding alternating electrical voltage will appear across the two faces. Normally this vibration would soon die out but, by using a valve to supply suitably timed electrical impulses to the plates, the oscillation can be maintained. In behaviour, therefore, the crystal behaves somewhat similarly to an LC circuit but the frequency is almost entirely dependent on the physical dimensions of the quartz.

The electrical equivalent of a 1.9 Mc/s crystal is something like that in Fig. 5(a). A circuit such as Fig. 5(b) is usually recommended for modern crystals. The anode may be tuned to either the crystal frequency or to the second harmonic, *i.e.,* twice the crystal frequency. It will be realised that this circuit is virtually the same as that in Fig. 3. The crystal, however, has a Q very many times greater than could be obtained by a practical LC circuit and the effective capacitance tap is so low down that the external circuits have very little effect.

For 144 Mc/s and higher, where a frequency stability of something like one part in a million is desirable, crystal control is almost essential. Crystals for frequencies above 10 Mc/s, however, become exceedingly thin.

It is therefore common practice to operate with a crystal in the 5-10 Mc/s range and use a number of frequency multiplying stages to obtain the desired frequency. By using suitable circuits some of the necessary multiplication can be performed by the oscillator itself. Transmitters for 144 Mc/s, for example, often have an oscillator which gives 24 Mc/s output from an 8 Mc/s crystal operating on its third overtone.

The characteristics of crystals differ widely, dependent on how the quartz is cut and how the crystal is manufactured. It is always advisable, therefore, to use the oscillator circuit recommended by the manufacturer.

Variable crystal oscillators (v.x.o.) are becoming popular which allow the crystal frequency to be "pulled" over a small range by adding series reactance.

THE POWER AMPLIFIER

In all amateur work it is always advisable to use a low power master oscillator, as this ensures low heat dissipation and, in consequence, produces better frequency stability. With a crystal oscillator it also avoids any risk of fracturing the crystal. Because of this desirable condition the transmitter output must be brought up to the required power level by one or more radio-frequency power amplifiers. A typical circuit is shown in Fig. 6. In this arrangement the valve is a pentode or beam tetrode. For a 10 watt transmitter a normal receiving type such as a 6AQ5 will be satisfactory. But for a more powerful transmitter a special transmitting type such as an 807, 6146, TT21 or an 813 will be necessary.

In order to appreciate fully the operation of a power amplifier we should look at the operating characteristic of a typical tetrode such as is shown in Fig 7(a). If the valve is operated under class A conditions the grid would be biased to about —15 volts. Then, provided that its amplitude is not excessive, a sine-wave input voltage would produce a corresponding sine-wave anode current as shown in Fig. 7(b).

If the grid bias were increased to —30 volts the anode current, with no r.f. input applied, would be practically zero and the bias would be said to be at the cut-off point. Under these conditions, when a sine-wave voltage is applied to the grid, anode current flows only for half of every cycle. We can now drive the grid positive for part of the cycle and obtain higher peaks of anode current for the same average anode current as we obtained in Fig. 7(b). Greater efficiency has been achieved in the sense that more r.f. output power is being obtained for a given power consumption from the h.t. supply. It should be noted, however, that a much larger r.f. input power is required. Not only must the amplitude of the r.f. voltage be greater, but the grid will have a low resistance to earth when it is positive and power will be required to drive it above earth on the positive

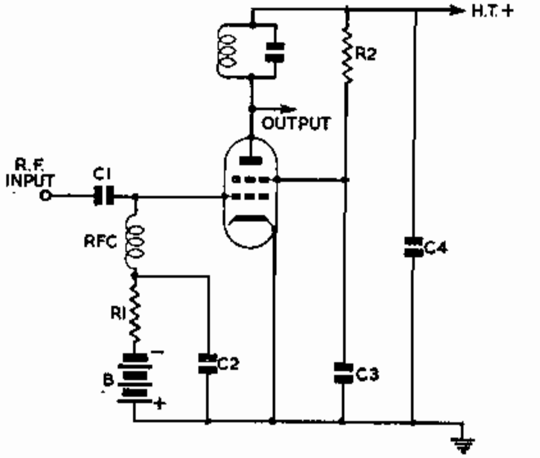


Fig. 6. A typical r.f. power amplifier. Values for an 807 would be 400 volts h.t.; B, 45 volts; C1, 0.001 μF; C2, 3, 4, 0.005 μF; R1, 10,000 ohms; R2, 10,000 ohms.

peaks. Used under these conditions the amplifier is said to be operating in class B.

If the grid bias is increased still further, say to about 2 or 3 times the cut-off value, the anode will conduct for considerably less than half a cycle, as shown in Fig. 7(d). Under these conditions the grid can be driven even more positive before the average value of the anode current becomes excessive and an even greater r.f. output power can be obtained for a given h.t. input power. This fact makes class C operation, as it is called, particularly attractive for an amateur transmitter where the power limitation is imposed on the d.c. input to the anode of the final power amplifier.

Class B is, however, occasionally used in preference to class C, because it has the advantage that its output can be made to be directly proportional to the r.f. input. This, as we shall see later, is extremely useful for single sideband transmission.

With a maximum input power of 150 watts a typical class C amplifier might give 110 watts of r.f. power. In class B the output would be less than 100 watts and in class A less than 50 watts.

Grid Bias

There are various ways of providing grid bias but that shown in Fig. 6 is one of the best for class C operation. The battery (or small power supply) B provides about 1½ times the cut-off voltage; the extra voltage required is produced by the r.f. input itself. For a short period every cycle, the grid is driven positive and during this time it draws electrons from the cathode. These then return to earth through the resistor R1 and the battery. The current flow through R1 is smoothed out by the capacitors C1 and C2 so that there is a steady voltage developed across R1 which provides the extra bias. Since this voltage is dependent on the r.f. excitation it is self-adjusting, becoming high for over-excitation and low for under-excitation.

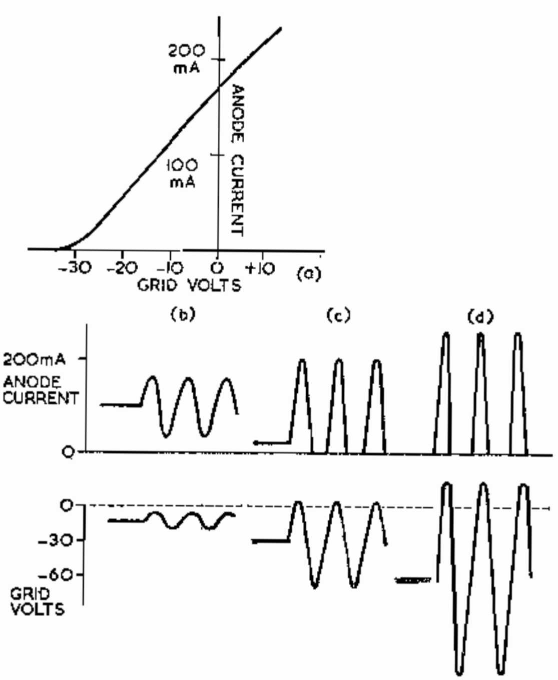


Fig. 7. (a) Characteristics of a typical transmitting tetrode. (b) Class A operation. (c) Class B operation. (d) Class C operation.

It is possible to dispense with the battery and use grid current bias entirely but this introduces the danger that if, for any reason, there is no excitation the bias will disappear and the valve will draw excessive anode current. A popular method of preventing this happening is to use a second valve—commonly called a clamp valve—to prevent excessive anode dissipation in the absence of drive by reducing the screen voltage of the p.a. valve to a low value. The arrangement is illustrated in Fig. 8.

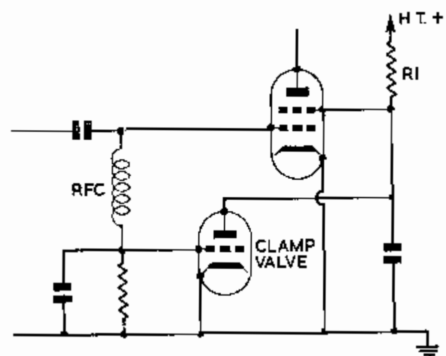


Fig. 8. Clamp valve circuit.

During normal operation the p.a. grid current bias causes the clamp valve to be cut off and to have no effect. Should the excitation fail, the grid of the clamp valve will rise to earth potential. The clamp valve will then conduct heavily and the resulting voltage drop across R1 will reduce the screen voltage of the tetrode, thus preventing the latter from taking excessive anode current.

The grid current of a power amplifier gives a very useful indication of the amplitude of the excitation being applied to the grid and thus it is common practice to make provision for connecting a d.c. milliammeter in series with the bottom of the grid resistor. There is no advantage in increasing the current beyond the figure recommended by the valve manufacturer; it will give no worth-while increase in efficiency and is quite liable, by overheating the grid and liberating gas, to have the reverse effect.

Interstage Coupling

It has been assumed so far that the anode of the driver valve would be tuned and would be capacitance coupled to the grid of the amplifier as shown in Fig. 9(a). The capacitor C1 isolates the grid from the h.t. supply but provides a low impedance path for the transfer of r.f. energy from the driving anode. The r.f. choke RFC gives a d.c. path for the grid bias but its high r.f. impedance prevents it from absorbing any appreciable r.f. energy.

An alternative system which is very popular is that shown in Fig. 9(b). In this arrangement the grid circuit also is tuned and is inductively coupled to the anode of the driver. One advantage of this method is that by suitably adjusting the coupling between the two coils it is possible to obtain a band-pass characteristic. This means that it is possible to obtain an efficient transfer of energy over the whole frequency range of one amateur band without any retuning being necessary.

A modified version of inductive coupling is the link coupling method shown in Fig. 9(c). Here each coil has a small coupling winding, the two coupling windings

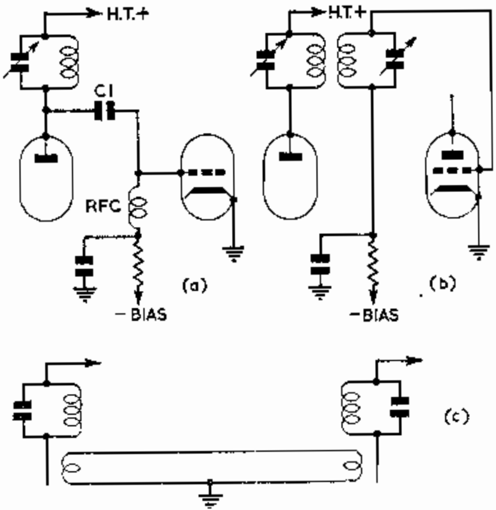


Fig. 9. Interstage coupling. (a) Capacitive coupling. (b) Inductive coupling. (c) Link coupling.

being linked by a length of coaxial cable or twin p.v.c.-covered wire. An advantage of this method is that the two tuned circuits can be some distance apart.

Anode Current

It has already been shown that when r.f. excitation is applied to the grid the anode will take pulses of current. If the anode circuit is off-tune the reading given by a d.c. milliammeter connected in the h.t. supply to the anode will indicate a high current. If the anode circuit is tuned to resonance a large sine-wave voltage will appear across it. The phase of this voltage will be such that the anode potential will be very high when the grid is very negative and nearly zero when the grid is positive. In consequence, the average anode current will be very low.

If a load such as an aerial or a succeeding power amplifier is coupled to the anode circuit, energy will be drawn from the tuned circuit. This will damp the oscillatory current there and the r.f. voltage across the coil will fall. The anode will, consequently, be more positive at the instant the grid potential is high and more anode current will flow.

It is quite easy, therefore, to bring the anode circuit into resonance by tuning for minimum anode current. When an external load is coupled to the anode the increase in anode current will give an indication of the amount of energy being extracted. Ideally the effect of the external circuit should be the same as if a resistance had been introduced into the tuned circuit. In practice some capacitance or inductance may also be introduced and a slight readjustment of the tuning may be required to compensate for this condition.

If there is no load on the anode circuit it is inadvisable to run an amplifier with full anode and screen voltages because of the high r.f. voltage which may be developed. Furthermore, because the anode potential will be so low during the time that the grid is positive, most of the electrons from the cathode will flow to the screen and as a consequence the screen current may become excessive. When first adjusting a power amplifier the h.t. voltage should be reduced to at most 50 per cent of its normal value. With a tetrode it is sufficient to lower the screen voltage only.

When adjusting the anode circuit a useful indication of the presence of a r.f. voltage can be obtained by a small neon bulb. When held in the hand near a point of high r.f. potential the small r.f. current which passes through the capacitance of the air gap, *via* the neon and thence through the body to earth, is sufficient to make the neon glow.

Feedback

It must not be forgotten that a power amplifier has its grid and anode circuits tuned to the same frequency and that stray coupling between the two may cause oscillation. Most power tetrodes designed for r.f. use have a top-cap anode and in such cases it is sound practice to mount all the anode circuit above and all the grid circuit beneath the chassis. It is advisable also to place an earthed cylindrical metal screen around the lower half of the valve to shield the grid assembly from the anode circuit. To prevent overheating of the valve, allowance should be made for air from beneath the chassis to pass up between the valve and the cylinder. All leads should be kept short and direct, earth connections for any one stage being taken to points on the chassis which are as close to each other as is practicable. On no account should a length of wire be used to serve as the common earth lead for the grid and anode circuits. Such a lead would have some inductance and the r.f. voltage developed across it by the anode circuit, although very small, might introduce sufficient feedback into the grid circuit to cause trouble.

On very high frequencies, with a poor transmitter layout or with tetrodes having very poor internal screening, the stray anode to grid capacitance may be high enough to cause undesirable interaction between the anode and grid circuits, if not actual oscillation. It will then be necessary to neutralize this capacitance. If, as was common some years ago, a triode is used, it will be essential to take this step.

Neutralizing

A popular neutralizing circuit is shown in Fig. 10. In this arrangement the anode coil is centre-tapped and tuned by a split-stator capacitor. The voltage at the upper end of the anode coil is 180° out of phase with the anode and the feedback through Cn can therefore be made to cancel out the anode-grid capacitance. The required value of Cn will be approximately equal to the anode-grid capacitance. With a triode this might be of the order of 5 μμF; with a tetrode it will be of the order of 0.1 μμF and will require nothing more than the suitable positioning of a short piece of stiff wire.

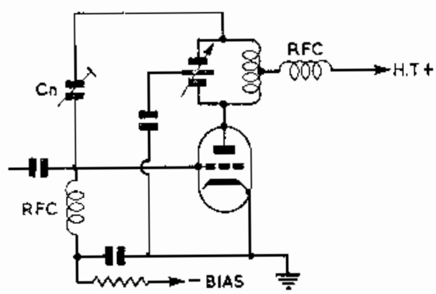


Fig. 10. Neutralization.

Neutralizing is adjusted with all h.t. removed from the amplifier. Grid excitation is applied and Cn set so that tuning the anode circuit through resonance produces no kick on the grid current meter.

Frequency Multipliers

The anode circuit can, of course, be tuned to a multiple of the excitation frequency. It will not then receive a driving pulse during every cycle of its resonant frequency but its own pendulum action will maintain a circulating sine-wave current. This arrangement is most commonly used to give twice or three times the input frequency. The amplifier is then said to be a doubler or a tripler and the output frequency the second or the third harmonic of the input frequency. Because the anode and grid are tuned to different frequencies there is less danger of feedback and no need for neutralization.

A frequency multiplier is less efficient than a straight r.f. amplifier and is generally only used as an intermediate stage between the master oscillator and the final power amplifier.

Since many of the amateur bands are harmonically related to each other it is possible to obtain outputs on a number of bands by using one master oscillator followed by different arrangements of frequency multipliers. The more ambitious transmitters, for example, often have a v.f.o. giving an output in the 3.5 Mc/s band followed by switchable frequency multipliers which enable the input to the final amplifier to be in the 3.5, 7, 14, 21 or 28 Mc/s bands.

THE TANK CIRCUIT, HARMONICS and PARASITICS

Regardless of the actual method by which power is absorbed from a tuned circuit it is always convenient to suppose that it is being used to heat up a fictitious resistance which is in series with the coil and the capacitor. Thus we can regard the anode circuit of a power amplifier, the tank circuit as it is often called, as being as shown in Fig. 11(a) where R_L accounts for all the losses in both the coil and the capacitor. When the aerial is coupled to the tank circuit another resistance R_A can be imagined as appearing in series with the coil as in Fig. 11(b). The value of this resistance will grow as the coupling is increased; the power supposedly dissipated as heat by R_A will in fact be that supplied to the aerial for radiation as radio waves.

Now, if the transmitter is to operate efficiently, R_L must be low and R_A high. Only a small fraction of the available power will then be dissipated as heat in the tuned circuit and the major part will be passed to the aerial.

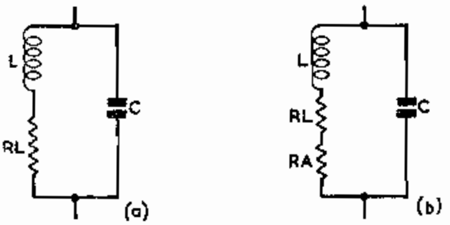


Fig. 11. The tank circuit.
(a) Equivalent circuit unloaded. (b) Equivalent circuit loaded.

R_L will be low if a high Q coil and a good quality capacitor with ceramic, p.t.f.e. or polystyrene insulation are used. There is a limit to how high we should make R_A. If it is too high the tuned circuit will be damped too drastically and its "pendulum" action spoilt. The aerial current waveform, instead of being a pure sine wave, will then be considerably distorted. A distorted sine wave of, say, 14 Mc/s is equivalent to a pure sine wave of that frequency plus smaller sine waves of some or all of the harmonic frequencies, 28 Mc/s, 42 Mc/s, 56 Mc/s, etc. To feed these harmonics into the aerial would almost certainly result in the radiation of signals at these frequencies and interference to television reception.

The value of R_A must therefore be something of a compromise and it is generally agreed that the best value is that which reduces the Q of the tuned circuit to 12†. The amateur usually has no facilities for accurately assessing Q and it is therefore safer to aim for a value of 15, thereby erring on the side of lower efficiency rather than that of increased harmonic output.

At resonance the tuned circuit will be equivalent to a resistance ($=2\pi fLQ$), the value of which will be dependent on those of L and Q. This resistance is in effect the anode load of the p.a. valve and must have some definite value if the valve is to operate at maximum efficiency.

We need not follow the actual algebra here but the three requirements—(a) that L and C must tune to a certain frequency, (b) that the Q must be 15, and (c) that the effective resistance at resonance must have a predetermined value—all result in there being only one possible value for L and only one for C. In practice a transmitter will give an acceptable performance if there is some deviation from these values. Nevertheless, we should aim to be as close as possible to the ideal and not be content to use any handy coil and capacitor which happen to tune to the correct frequency.

Assuming the valve to be a typical tetrode the optimum values of L and C will be as given in Table 1. Table 2 shows the peak r.f. voltage which will be present at the anode when the transmitter is correctly loaded and operating on telegraphy (c.w.). When the transmitter is operated with a lighter load, such as when tuning up,

†The value of Q is given by $2\pi fL/(R_A+R_L)$, where f is the frequency in c/s and L the inductance in Henrys.

TABLE 1

Values of L and C to give Q of 15 in the circuit shown in Fig. 12(a).

$\frac{V_a}{I_a}$	C (μμF)		L (μH)	
	1·8 Mc/s	3·5 Mc/s	1·8 Mc/s	3·5 Mc/s
4	630	330	11	6
6	420	220	17	9
8	310	160	23	12
10	250	130	28	15

V_a = h.t. volts on p.a. anode. I_a = anode current in milliamperes.

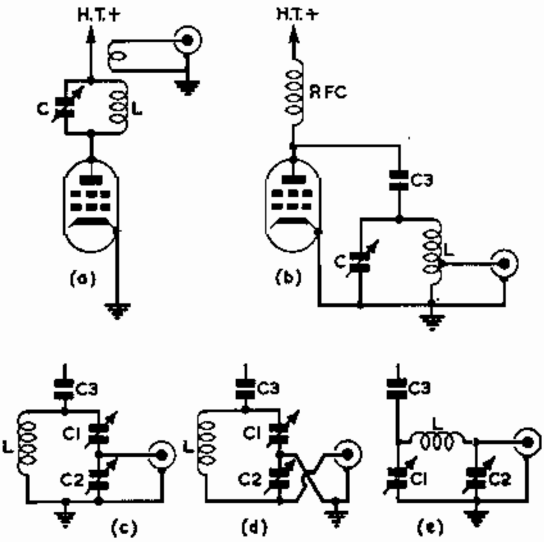


Fig. 12. Methods of feeding output to a co-axial cable. The pi-network circuit (e) is recommended because of its low harmonic output.

this voltage may be two or three times greater, and when using anode-modulated telephony it will be twice as high again. With the circuit shown in Fig. 12(a), this r.f voltage will be across the tuning capacitor C, so the spacing of the vanes must be sufficient to prevent any flashover. As a rough guide it is advisable to allow at least 0.02 in. per 500 volts. If the capacitor is connected direct from anode to earth it will also have the h.t. voltage across it and this should be added to the peak r.f. voltage.

As an example of tank circuit design, suppose we have a type 5763 miniature tetrode in a power amplifier which is to operate at frequencies within the 1.8 Mc/s band with an h.t. voltage of 300 and an anode current of 30 mA, *i.e.* with an input of 9 watts. The value of Va/Ia is 10 and, by reference to Table 1, we find the values of L and C to be 28 μH and 250 $\mu\mu$F respectively. From coil design tables, or from the formula given on page 33, we see that 28 μH can be obtained by approximately 50 turns of 22 s.w.g. enamelled wire close wound on a 1 in. diameter former. C could be a 500 $\mu\mu$F receiver type variable capacitor. These usually have specially shaped vanes, in which case the correct setting of 250 $\mu\mu$F would not be in the centre as might be expected but would be at about 120° rotation.

When tuning up the transmitter the loading would be adjusted to give the desired anode current at the dip, in the case of the example—30 mA; it could then be assumed that the valve had something like its correct anode load and that the Q was about 15.

Coupling the Transmitter to the Aerial Tuner

It is now a common practice among amateurs to terminate the aerial by what is known as an aerial tuner and to adjust this so that the aerial appears to the transmitter like a 72 ohm resistor. This simplifies the transmitter design because, whatever the actual characteristics of the aerial, the tank circuit will always be supplying power to the same load. The transmitter is usually connected to the aerial tuner by standard coaxial cable, such as that used for television aerial downleads, which is very efficient when terminated by a resistance of about 72 ohms.

One way of connecting the tank circuit to the output lead is to join the latter to a small coupling winding wound around the "cold" (or low r.f. potential) end of the tuned circuit as in Fig. 12(a). The tank circuit then becomes an r.f. transformer and the coupling can be regulated by varying the number of turns on the output winding or by adjusting its proximity to the main winding.

Several other possible arrangements are illustrated. In Fig. 12(b) the h.t. has been removed from the tuned circuit by the buffer capacitor C3 and an r.f. choke has been added to give a d.c. connection from the anode to the h.t. supply. Instead of using a coupling winding the output lead has been tapped into the coil.

A more elegant arrangement is to tap the output lead into the capacitance as in Fig. 12(c). If both C1 and C2 are variable we can use them not only to alter the tuning but also to adjust the effective tapping point. In order that the rotors of both capacitors can be earthed the connections may be modified to those shown in Fig. 12(d).

The circuit in Fig. 12(d) is extremely valuable. It is usually drawn as in Fig. 12(e) and, because of the resemblance of the network C1-L-C2 to the Greek letter π, is known as a pi-network tank circuit. Its great merit is that it is far more successful than most other circuits in suppressing harmonics. C1 is effectively from anode to earth and provides a fairly low impedance at harmonic frequencies; L is between the anode and the output socket and presents a high impedance; C2 provides a low impedance shunt right across the output socket. The suppression of the second harmonic is, in fact, four times better than with the circuit in Fig. 12(a). With the higher harmonics the improvement is greater

TABLE 2

Approximate peak r.f. voltages occurring in a tank circuit loaded to have Q of 15 and fed from tetrode p.a. valve.

Va/Ia	Peak r.f. volts at anode (across C1 in Fig. 12(e))			Peak r.f. volts across 72 ohm output (across C2 in Fig. 12(e))		
	150W	25W	10W	150W	25W	10W
4	630	260	160	120	50	30
6	780	320	200	120	50	30
8	900	360	230	120	50	30
10	1000	410	260	120	50	30

Voltages are for telegraphy (c.w.) and must be multiplied by 2 for anode-modulated telephony.

TABLE 3

Correct values for C1, C2 and L to give Q of 15 in a pi-network tank circuit feeding from a typical beam tetrode into a 72 ohm load.

Va/Ia	C1* ($\mu\mu$F)	C2* ($\mu\mu$F)	L* (μH)
4	140	730	4·3
6	100	640	6·1
8	75	560	7·8
10	61	510	9·5

*Values are for 7 Mc/s. Multiply by 4 for 1·8 Mc/s, 2 for 3·5 Mc/s, ½ for 14 Mc/s, ⅓ for 21 Mc/s, and ¼ for 28 Mc/s.

still and the suppression of the seventh harmonic, for example, is 49 times better. In the interests of reducing television interference, therefore, the use of the pi-network circuit is to be strongly recommended for 7, 14, 21 and 28 Mc/s—and for 3.5 Mc/s also if the input power exceeds 10 watts.

Assuming that the network is to feed from the anode of a tetrode into 72 ohms, and that the Q is to be 15, the correct values for C1, C2 and L will be approximately as given in Table 3. A typical pi-network tank circuit derived from this table is shown in Fig. 13.

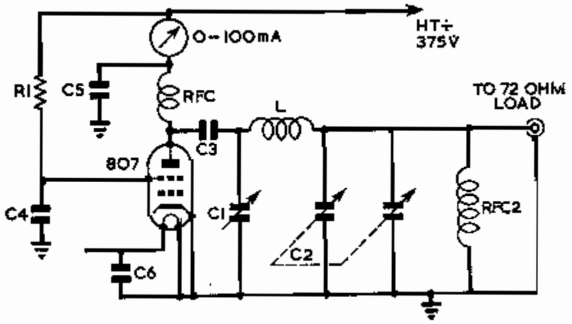


Fig. 13. A typical pi-network circuit for a 25 watt 14 Mc/s transmitter. Assuming the anode current to be 62.5 mA with the transmitter loaded, Va/Ia = 6, the correct values (Q = 15) for C1, C2 and L are 50 μμF, 320 μμF and 3.05 μH respectively. Practical component values are C1, 100 μμF variable; C2, 350 + 350 μμF receiver type; C3, 0.002 μF mica 500 V wkg.; C4, 5, 0.001 μF 500 V wkg.; C6, 0.001 μF 350 V wkg.; L, 13 turns 14 s.w.g. enam., 1 in. diam., 1¾ in. long, self-supporting; R1, 6800 ohms; RFC, 1mH. RFC2 2.5 mH is to prevent h.t. from reaching the aerial if C3 fails.

The adjustments of C1 and C2 will be to some extent interdependent but C1 can be considered as the tuning control and C2 as the loading control. The tuning procedure is first to set C2 to maximum capacitance (to give minimum loading) and then to tune C1 for the anode current dip. The meter reading should then be low, indicating insufficient loading. The value of C2 is therefore decreased a little and C1 retuned, the process being repeated until the anode current at the dip has been brought to the desired value.

Additional harmonic suppression can be achieved by the use of a further coil connected between C2 and RFC2; the circuit is then known as a pi-L network.

Harmonic Suppression

The mere use of a pi-network tank circuit alone does not guarantee that there will be negligible harmonic radiation in the television bands and it is still important to pay attention to a number of practical points. Among the most important are (a) enclosing the entire r.f. section of the transmitter in a metal box, ensuring that all parts of the box make good electrical contact to each other; (b) taking all earth connections associated with the p.a. stage by the shortest possible length of heavy gauge wire to one common point on the chassis close to the cathode pin; (c) using screened wire for all leads carrying h.t., g.b., or heater supplies; (d) fitting by-pass capacitors of 0.001 to 0.005 μF from all unearthed heater pins and from each side of the mains input to chassis; (e) avoiding excessive r.f. input to the grid of the p.a.

Provided that sufficient care is taken with the above points there should be no appreciable v.h.f. radiation from the transmitter itself or from the mains lead. There may, however, still be a large enough harmonic content in the output to cause troublesome radiation from the aerial and it may be necessary to connect a filter between the transmitter and the aerial tuner. If this filter is to give severe attenuation of frequencies above 40 Mc/s and yet have negligible effect on frequencies in any amateur band from 1.8 to 30 Mc/s it must be carefully designed. See also Chapter 2.

Spurious signals from a transmitter need not necessarily be caused by harmonics. They can also be due to parasitic oscillations occurring in one of the r.f. amplifiers or even in the oscillator. Sometimes they make themselves apparent by unstable or inefficient operation of the transmitter but sometimes are only noticeable as additional signals, usually rough in tone, picked up on a receiver.

Parasitic oscillations in the v.h.f. range can often be traced to poor screening or long wiring. Lengths of wire in the grid, anode, cathode and screen connections can act as tuned circuits which resonate at v.h.f. and, even though their Q may be low, the gain of a modern tetrode is so high that oscillation can easily result. Oscillations at v.h.f. are particularly liable when two or more valves are connected in parallel. It is then always advisable to include a parasitic stopper in the lead to each grid and to each anode. The stopper should be wired direct to the valveholder and can be made by winding 5-10 turns of about 20 s.w.g. wire around an insulated type 100 ohm ½ watt resistor, connecting the coil in parallel with the resistor. The optimum number of turns may have to be found by experiment.

If any stage has grid and anode chokes resonating at the same frequency, the feedback through the inter-electrode capacitance of the valve may occasionally give rise to spurious oscillation. The frequency will then usually be lower than the transmitter frequency. The remedy in such cases is to use a different type of choke in one position or to replace the grid choke by a resistor. Ferrite beads can also be used to prevent parasitics in r.f. and a.f. amplifiers.

KEYING THE TRANSMITTER

There are a number of ways in which the radio-frequency signal from a transmitter can be made to convey a message to a listener. We can, for example, transmit speech by using the output of a speech amplifier to control the amplitude of the r.f. signal as shown in Fig. 14. This is a form of amplitude modulation and is officially referred to as a type A3 emission.

Alternatively, we can interrupt the r.f. output by means of a telegraph key and send our messages in Morse code. The r.f. waveform would then be as in Fig. 15. Since the amplitude of the signal is being periodically switched between zero and maximum this is actually another form of amplitude modulation. The transmitting licence would call it a type A1 emission but the old-timer usually prefers the older, if somewhat paradoxical, description continuous-wave telegraphy and often abbreviates it to simply c.w. Normally it is this type of emission which will initially concern the newly licensed amateur.

There is one extremely important characteristic of amplitude modulation. If an r.f. signal of frequency *f* is modulated by a sine wave of, say, 1 kc/s what will

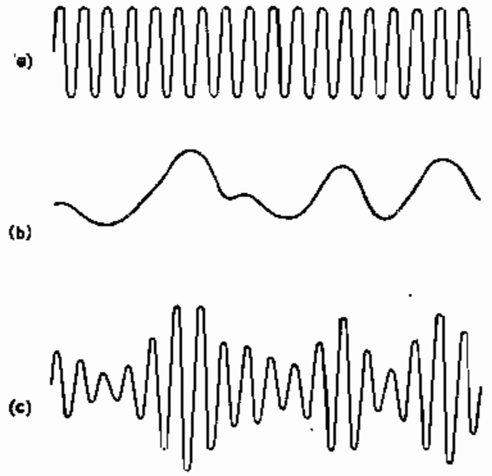


Fig. 14. Amplitude modulated telephony. (a) Unmodulated r.f. signal. (b) Typical speech waveform. (c) Speech modulated r.f. signal.

actually be emitted is a group of three frequencies. These will consist of the original carrier frequency f together with sideband frequencies of (f + 1 kc/s) and (f—1 kc/s). The complete signal will thus occupy a frequency band of 2 kc/s.

In a typical amateur speech transmission there may be modulation frequencies extending up to 5 kc/s, so that the total bandwidth is 10 kc/s.

In a c.w. transmission, over which no care has been taken, the envelope of the r.f. waveform might be as in

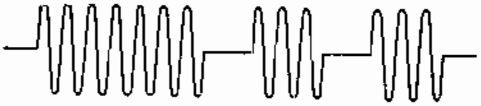


Fig. 15. Keyed r.f. signal.

Fig. 16(a). The modulation waveform would in effect consist of square waves and if analysed would be found to be composed of a large number of sine waves, the frequencies of which might extend to as high as 100 kc/s. The sidebands of such a transmission might therefore extend over an entire amateur band and be apparent to listeners as annoying clicks. To prevent this happening all the high frequency components of the modulating waveform must be severely attenuated. In practice this means that we should prevent any sudden changes in amplitude of the r.f. signal, and produce rounded dots and dashes such as in Fig. 16(b). With suitable shaping it is possible to reduce the frequency band covered by a c.w. signal to considerably less than 1 kc/s.

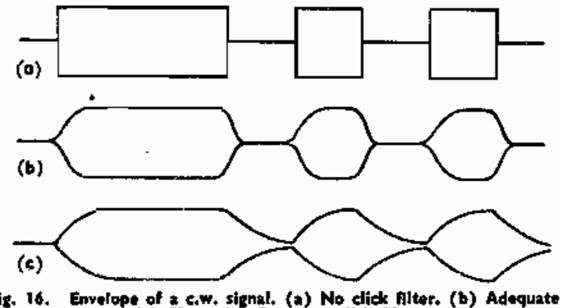


Fig. 16. Envelope of a c.w. signal. (a) No click filter. (b) Adequate click filter. (c) Excessive click filter.

H.T. Positive Keying

One method of producing a c.w. signal is to wire the key in series with the h.t. supply to the anode and screen of the final p.a. valve. Suitable shaping of the Morse characters can then be obtained by a click filter such as shown in Fig. 17. When the key contacts close the inductance of the iron-cored choke L prevents the anode current rising too suddenly. When the contacts are broken the capacitor C is initially in a discharged state and the anode current continues for a brief period, dying away as it charges C up to the h.t. voltage. When the key contacts close again they will short out the capacitor;

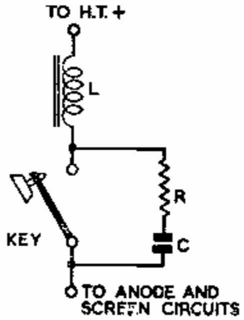


Fig. 17. Key click filter. Typical values for the components are: C, 0.005 to 0.5 μF; L, 1 to 5 H; R, 100 to 1000 ohms.

the resistor R is therefore included to prevent the discharge current being excessive.

The larger the values of L and C the more gradual will be the rise and fall of anode current and the narrower will be the frequency band occupied by the radiated signal. In our enthusiasm to restrict the sidebands, however, we must not go so far as to produce a signal like that shown in Fig. 16(c). The characters would then be indistinct and difficult to read. The optimum values of L and C are best found by experiment. In practice it is not very convenient to try a variety of different chokes. A useful dodge is to use one of about 5 Henrys and, if necessary, produce an effect similar to a reduction in inductance by shunting it with a resistor of 10,000 to 100 ohms.

When the key is open the contacts will have the full h.t. voltage across them and some care must therefore be exercised. Not only is there the danger of electric shock to the operator; there is the possibility that if the spacing of the contacts is inadequate, or if the click filter is inefficient, there will be sparking. Apart from damaging the contacts this would also produce high frequency components in the modulating wave-form.

Cathode Keying

An alternative method is to connect the key in the cathode circuit as in Fig. 18. When the key is open the cathode will rise to a high potential and the same

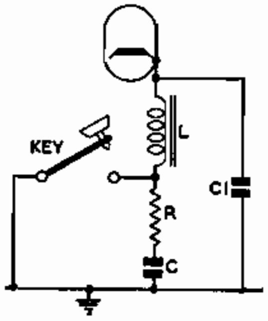


Fig. 18. Cathode keying. C, L and R are the click filter. C1 is for r.f. by-passing and should be about 0.005 μF.

precautions should be taken as for h.t. positive keying. The practice of cathode keying is usually not recommended by the valve manufacturer as it is liable to cause electrical breakdown between cathode and heater. Nevertheless many amateurs continue to use it, often claiming it gives better results than h.t. positive keying and without suffering a high valve mortality rate.

Screen Grid Keying

A rather better method is to key the screen grid supply only as in Fig. 19(a). The current broken by the key will then be much smaller and the voltage across the contacts when they are broken will often be less. When the key is depressed the screen voltage will rise gradually as C charges up through R1. When the key contacts are broken

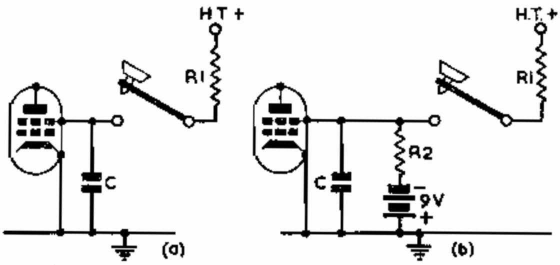


Fig. 19. Screen keying. (a) Simple circuit. (b) Modified to apply negative bias to the screen. The value of R1 will be governed by the h.t. voltage and the d.c. rating of the screen but might be 5000 to 50,000 ohms; C is the normal r.f. by-pass condenser and might be 0.001 to 0.01 μF; R2 might be about 100,000 ohms.

the voltage will fall gradually as C is discharged by screen current. No other click filtering is usually necessary.

Sometimes merely breaking the h.t. supply to the screen is not sufficient completely to kill the anode current. In such a case the resistor R2 and a battery (or small negative voltage supply) can be added as in Fig. 19(b) to bias the screen negatively when the key is up.

Blocked-grid Keying

Yet another way of interrupting the r.f. output is to arrange for the key to change the effective value of the grid bias voltage. A typical circuit is shown in Fig. 20.

When the key is up the grid receives the full bias voltage which must be large enough to prevent any r.f. output. When the key is depressed the resistors R2 and R3 form a voltage dividing network across the bias supply. A reduced voltage is then applied *via* R1 to the grid and the amplifier operates normally. Should it be desired to have no fixed grid bias at all with the key down, R3 can be shorted out. The key will then connect the bottom of the grid resistor R1 direct to earth.

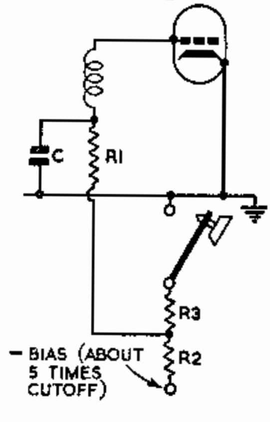


Fig. 20. Blocked-grid keying. R2 might be about 47,000 ohms. The value of R3 will depend on the fixed bias required with the key down. R1 is the normal grid resistor. C is the usual r.f. by-pass condenser.

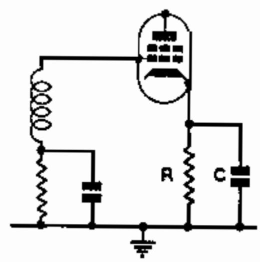


Fig. 21. Cathode bias. C is an r.f. by-pass condenser and a typical value would be 0.01 μF. Typical value for R, 470 ohms.

The capacitor C together with the resistance network prevents the bias voltage at the grid from changing abruptly when the key contacts make and break, and gives a click filtering action.

With a high-power amplifier, blocked-grid keying is not really practicable because of the very high bias voltage which is required.

If there is a buffer amplifier or frequency doubler preceding the final amplifier it is usually easier to key this instead of the final amplifier. Any of the keying systems described above can be used.

It must be remembered that none of the r.f. stages following the keyed valve will have any grid excitation when the key is up. They must therefore have protection against excessive anode current with no r.f. input. This protection can be given by some fixed grid bias or by a clamp valve, but for a lower power stage the cathode bias arrangement of Fig. 21 is often more convenient With this circuit any h.t. current through the valve produces a voltage drop across the cathode resistor R, thus making the cathode positive with respect to the grid and limiting the anode current to a safe value.

It is important that all the stages following the keyed valve should be stable with low grid excitation, otherwise momentary parasitic oscillations may occur just as the excitation is rising or falling and these will give rise to key clicks.

Oscillator Keying

Some c.w. operators like to use what are called "break-in" techniques. That is to say that they have the transmitter and receiver both switched on together but arrange for the receiver to be muted whenever the key is depressed. They can then listen during the pauses in their own transmission. It is usual to change the aerial from transmitter to receiver and vice versa automatically by means of an electronic switching circuit known as a T-R (transmit-receive) switch or coaxial relay.

It is not intended to study all the details of this rather specialized subject here but it is worth noting that an essential requirement for break-in operation is that the master oscillator should be completely inaudible in the receiver when the key is up. It is difficult to achieve this state of affairs by screening and a more popular solution is to key the oscillator itself.

With an electron-coupled v.f.o. it is usually most satisfactory to key the screen. It is essential, however, that the oscillator frequency should be as immune as possible to changes in screen voltage. After the key contacts are closed it may take several milliseconds for the screen potential to rise from zero to its maximum value and, conversely, after the contacts have broken, it may take several milliseconds to fall. If these variations in screen voltage are accompanied by any appreciable changes in frequency the Morse characters will "chirp" and be difficult to read.

Voltage stabilizers will be of no help because it is in the transition from zero to the final voltage that the trouble occurs. Some apparent improvement can be made by reducing the time constant of the screen circuit, *i.e.*, by reducing the values of C and R1 in Fig. 19. The chirp will then occupy an extremely short period of time and be barely perceptible. Unfortunately, the resultant r.f. output will have very abrupt changes in both amplitude and frequency and these may result in particularly objectionable key clicks being emitted.

These difficulties can be overcome by a really well designed v.f.o. or by a special circuit which causes a succeeding stage to be keyed in such a way that it is switched on just after the oscillator and switched off just before, thus missing the clicks and chirps. The newcomer, however, is advised to be very cautious about keying a v.f.o. on the 14 Mc/s band or higher.

Cathode keying is not to be recommended for a v.f.o. because with some circuits slight variations in key contact resistance can produce noticeable fluctuations in the frequency.

When keying a crystal oscillator it is usually best to connect the key in the h.t. supply to that stage. The oscillator should be stable; otherwise chirps may be produced.

PHONE OPERATION

The commonest method of modulating a telephony transmitter is by simple amplitude modulation (A3). This, as we saw earlier in Fig. 14, uses the speech waveform to control the amplitude of the r.f. signal. A popular way of achieving this is to amplify the audio frequency voltage which appears across the microphone and to superimpose this amplified voltage on to the h.t. voltage of the r.f. power amplifier by means of a transformer as shown in Fig. 22. It is a useful characteristic of a class C amplifier that the output voltage is directly proportional to the h.t. voltage and the shape of the r.f. envelope is, therefore, a faithful replica of the a.f. waveform.

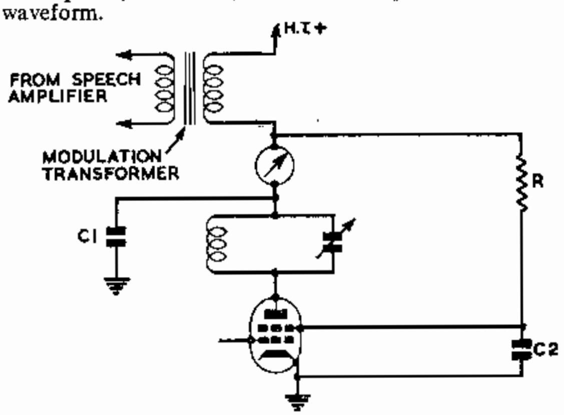


Fig. 22. Method of applying anode modulation to the p.a. valve. With a triode, R and C2 would be omitted. With a tetrode, the system is more correctly described as anode and screen modulation. The values of R, C1 and C2 can be the same as for an unmodulated stage except that C2 should not be greater than about 0.001μF.

When, as in Fig. 23(b), the modulated h.t. supply swings between zero and double its unmodulated level the modulation is said to be 100 per cent. If the modulating voltage is greater, as in Fig. 23(c), the anode of the r.f. valve will periodically be driven negative. The abrupt cuts in the r.f. output which this causes will produce modulation frequencies much higher than those present in the original speech waveform and these will cause "splatter" to be radiated perhaps as much as 50 kc/s either side of the signal. The aim, therefore, with an amplitude-modulated transmitter is to maintain the modulation percentage as high as possible without running the risk that it will exceed 100 per cent. For the most satisfactory results, it is advisable to have some form of modulation monitor. In its simplest form, this can be a meter which reads the peak amplitude of the a.f. voltage on the secondary of the modulation transformer. Alternatively, a simple oscilloscope can be used actually to look at the modulated r.f. output.

When amplitude modulation is applied to the p.a. the mean r.f. output power is increased, and in the case of anode modulation this extra power is supplied by the speech amplifier. For 100 per cent. modulation the speech amplifier must supply an a.f. power equal to about 50 per cent. of the total d.c. input power to the p.a. valve. Thus, in the example shown in Fig. 22, the total of the anode and screen currents might be 0.08 amps at 350 volts. The d.c. input power would then be 0.08 x 350 or 28 watts and thus the required a.f. power would be about 14 watts.

The Speech Amplifier

The speech amplifier shown in Fig. 24 is capable of giving up to 24 watts of a.f. output and is representative of what might be used.

Assuming that the microphone is of the crystal type, the a.f. voltage appearing across it will be of the order of 0.01 volt. V1a and V1b amplify this to give something of the order of 1 volt at the grid of V2a. V2a and V2b provide two equal output voltages of opposite phase and form what is known as a "phase splitter". The amplifier output of V2a appears across R12 and R14 in series and the portion of this voltage across R14 is applied to the grid of V2b. Thus, the output of V2b is in the opposite phase to that of V2a.

The output voltage from V2b appears across R13 and R14 in series and that part of this voltage across

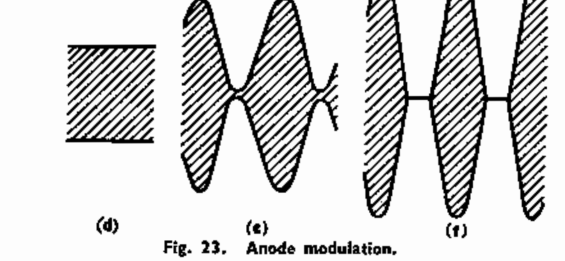


Fig. 23. Anode modulation.

(a) Unmodulated h.t. (b) H.t. with superimposed a.f. to give 100 per cent modulation. (c) H.t. with superimposed a.f. to give 150 per cent modulation. (d), (e), and (f) show the waveforms of the resultant r.f. outputs.

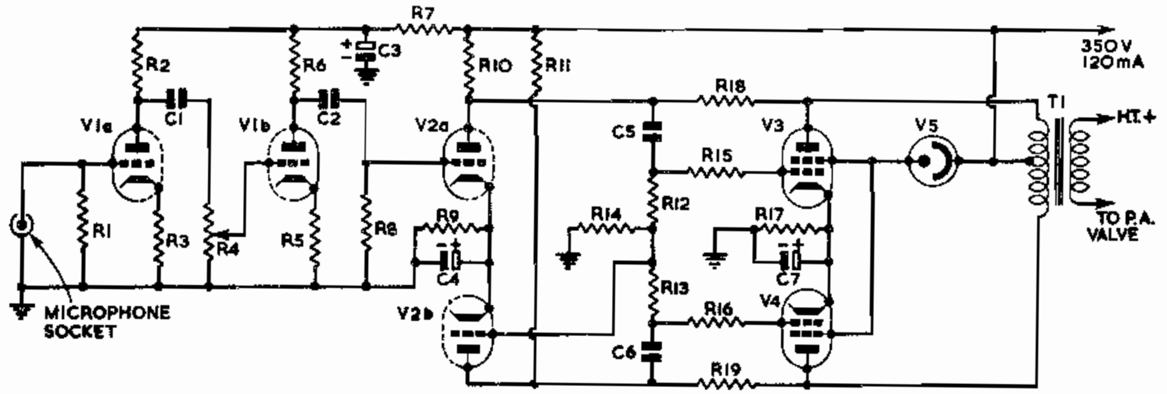


Fig. 24. Typical speech amplifier giving up to 24 watts output.

C1, 2, 5, 6, 0.02μF; C3, 8μF 450V wkg.; C4, 50μF 12V wkg.; C7, 25μF 50V wkg., R1, 18, 19, 2.2 Megohms; R2, 6, 10, 11, 100,000 ohms; R3, 5, 9, 1500 ohms; R4, 250,000 ohms volume control; R7, 47,000 ohms 2 watts; R8, 12, 13, 14, 220,000 ohms; R15, 16, 22,000 ohms; R17, 250 ohms 6 watts; T1, Modulation transformer (Woden UM1, etc.); V1a, b, V2a, b, 12AU7 or ECC82; V3, 4, 6L6, KT66 or EL37; V5, 90C1.

R14 opposes the voltage there from V2a, thus reducing the signal applied to the grid of V2b. The effect of this is to regulate the input voltage applied to V2b in such a way that the outputs from V2a and V2b are approximately equal.

The output valves are operated in class AB1. This means that the grid bias voltage is somewhat higher than for class A operation. With a single valve this would result in some distortion but with two valves in push-pull, the distortions tend to cancel out and the net effect is that greater power output can be obtained. With class AB1 operation, the screen current fluctuates fairly violently with variations in input. The screens are therefore fed *via* a voltage stabilizer tube V5 which gives a constant drop of 90 volts regardless of the current.

The resistors R18 and R19 introduce some negative feedback from the anodes of V3 and V4 to the anodes of V2a and V2b respectively. The effect of this negative feedback is to reduce the gain and the distortion in the output stage.

The Modulation Transformer

The load resistance which is imposed on the modulator by the p.a. valve is found by dividing the h.t. voltage of the latter by the h.t. current. In the case of our example, therefore, the load would be 350/0.080 or 4,375 ohms. Now the recommended anode-to-anode load for two 6L6s operating as shown is 9,000 ohms and therefore the windings on the modulation transformer must be such that when a resistance of 4,375 ohms is placed across the secondary the primary appears to have a resistance of 9,000 ohms. Making use of the fact that the turns ratio of a transformer is equal to the square root of the impedance ratio, this gives us a required turns ratio of $\sqrt{9000/4375}$:1 or approximately 1.4:1.

Commercial modulation transformers are available which have tapped primaries and secondaries. The novice would be advised to use one of these rather than attempt to modify some other transformer for the purpose.

Compressing the Frequency Band

It is a characteristic of speech waveforms that a large proportion of the power consists of frequencies below 200 c/s but that these frequencies do not add to the intelligibility of the speech. Many amateurs, therefore, attenuate the lower audio frequencies. They are then able to increase the a.f. gain and obtain more power at the useful frequencies for the same total power. Suppression of the bass frequencies can easily be achieved by choosing a suitably small value for one of the coupling capacitors. Thus, in Fig. 24, C1 could be reduced to 0.005 μF. This would reduce the voltage gain by about 2:1 at 100 c/s and by about 4:1 at 50 c/s.

It is also desirable to cut off all frequencies above 3000 or 4000 c/s so as to restrict the range of sidebands which is radiated. The outer sidebands will usually not be required by the person listening to the transmission because he will usually have the bandwidth of his receiver set to accept only 2 or 3 kc/s either side of the carrier, in order to reject any adjacent signals, in which case all the sidebands further than 3 kc/s away are doing is to interfere with someone else.

Suppression of the higher frequencies can be obtained by adding capacitors across either or both windings of the modulation transformer. The most suitable values will have to be found by experiment but will usually be between 0.001 and 0.01 μF.

Speech Clipping

Some amateurs include special circuits to clip the negative peaks within the modulator, and follow these with special filters to remove the high frequency components thus formed before the modulation reaches the p.a. valve. This allows the transmitter to work with what is effectively over 100 per cent. modulation without causing any splatter. Since these speech clipper circuits, as they are called, change the shape of the waveform they introduce some distortion. Nevertheless, it is possible to obtain a considerable increase in the effective modulation percentage before the distortion becomes apparent.

R.F. Feedback

In a telephony transmitter, some care must be taken to ensure that r.f. voltages do not enter the early stages of the speech amplifier. The valves in the speech amplifier might demodulate this r.f. and reproduce the original a.f. waveform, thus producing feedback which would cause distortion or howls. It is essential, therefore, to keep the early stage, or stages, fairly well screened from the rest of the transmitter and to use screened lead from the microphone to the grid of the first valve.

Grid Modulation Systems

There are a number of alternative methods which require less a.f. power than anode modulation.

It is possible, for example, to control the output of the final r.f. valve by varying the voltage on one of its grids. Thus the a.f. voltage might be superimposed on the fixed bias voltage applied to the control grid or the suppressor grid. Alternatively the a.f. voltage might be superimposed on the h.t. voltage to the screen grid.

Screen Modulation

When using a tetrode as the r.f. valve, very good results can usually be obtained by the latter method and a typical circuit is shown in Fig. 25. V4 is the final r.f. valve and V1, V2 and V3 comprise the modulator.

The value of R13 would be chosen so that the screen of V4 was at about half the maximum h.t. voltage recommended for c.w. operation. With 100 per cent modulation, the screen would then swing between the maximum voltage and zero. With most tetrodes the relationship between the screen current and screen voltage is usually far from linear so that the effective resistance of the screen depends on the voltage applied to it. This means that the effective load on the modulator varies throughout the audio frequency cycle and that, unless some care is taken, considerable distortion can result. It is therefore a common practice to use some negative feedback in the last stage of the modulator to make it more tolerant of deviations in the load resistance. In the circuit shown, this feedback is achieved by adding the resistor R11.

Because of the fact that the load resistance does not have a constant value, a little experimenting may be necessary in order to find the best turns ratio for the modulation tranformer. It is also difficult to predict exactly what a.f. power will be required, but as a rough approximation, this can be assumed to be one-quarter of the d.c. input power to the screen with the latter at its maximum voltage and the valve operating under c.w. conditions.

Where there is a clamp valve connected to the screen of the p.a. valve in order to protect the latter in the absence of any r.f. drive, the clamp valve can be used to modulate the screen voltage, but this system needs some careful adjustment. A recent development of this system is known as "series-gate modulation."

When using screen modulation (or grid or suppressor modulation), the p.a. stage is only working at maximum efficiency on the positive peaks of modulation. Its average efficiency is therefore less than with an anode modulated class C stage, which would be operating at maximum efficiency all the time.

The average efficiency can be improved by using a controlled carrier system. Such an arrangement would incorporate special circuits to reduce the h.t. current of the p.a. valve (and thus the strength of the carrier) during periods of low modulation intensity. But the fluctuations of carrier level which such systems produce can be a little disconcerting, and sometimes distinctly unpleasant, to the listener.

Other Methods of Amplitude Modulation

A number of other interesting forms of amplitude modulation have been devised. There is, for example, cathode modulation, in which the a.f. voltage is applied to the cathode of the p.a. valve. This system amounts to a combination of grid and anode modulation and has characteristics somewhere between the two. There are also some rather complex high efficiency grid modulation systems in which the r.f. valve is always operated at maximum efficiency, its d.c. power consumption increasing to supply the extra r.f. power when modulation is applied.

Yet another system, popular in broadcast transmitters but little used by amateurs, is to modulate a low power r.f. stage and then use the p.a. to amplify the modulated signal. When using this arrangement, it is essential that the output of the p.a. should be proportional to its r.f. input so that variations in magnitude of the r.f. input are faithfully reproduced in the output. This means that the p.a. stage cannot operate in class C and it is therefore usual in such circumstances to use what is known as a linear class B stage. This gives a lower efficiency than a class C stage.

It is important to remember that with any system which uses a low power modulator, all the r.f. power must be derived from the d.c. input power to that stage and that, since that stage cannot be 100 per cent efficient, the output power must be less than the d.c. input power. With anode modulation, on the other hand, a considerable proportion of the r.f. power is derived from the a.f. output of the speech amplifier and, under conditions of 100 per cent modulation, the r.f. output power can actually exceed the d.c. input power to the p.a. stage.

Thus, although often less efficient when the total input

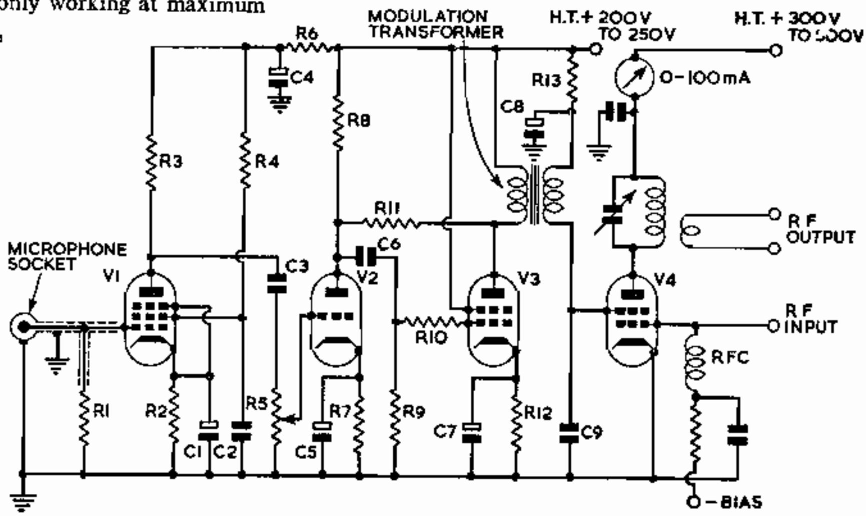


Fig. 25. Screen-modulated P.A. Stage

Typical values of the components are as follows:—
C1, C5, C7, 10μF 50V
C3, C6, 0.01μF 500V
C4, C8, 8μF 350V
C9, 0.001μF 500V
R1, 1 Megohm
R2, 1,000 ohms
R3, R9, 100,000 ohms
R4, 470,000 ohms
R5, 250,000 ohms volume control
R6, 10,000 ohms
R7, 1,500 ohms
R8, 150,000 ohms
R10, 22,000 ohms
R11, 330,000 ohms
R12, 270 ohms, 1 watt
R13, 5,000 to 50,000 ohms
V1, 6AM6, EF91, etc.
V2, One section of 12AU7, ECC82, etc.
V3, 6AQ5, EL90, 6V6, etc.
V4, 807

The optimum values for R13 and for the turns ratio of the modulation transformer are best found by experiment.

power to the whole transmitter is concerned, anode modulation does provide the greater possible r.f. output for a given input, as the latter is specified by the transmitting licence, i.e. for a given d.c. input power to the anode of the final r.f. stage. Anode modulation also has the advantage that it requires a minimum of initial adjustment for good results to be obtained. If economy of equipment is the most important consideration, however, there is much to be said for grid or screen modulation.

Single Sideband

We saw earlier in this chapter that amplitude modulation of a signal causes signals to be transmitted on sideband frequencies which are arrayed on either side of the carrier frequency. If we analyse the way in which the r.f. power is distributed we find that most of it is concentrated in the carrier signal and that only a fraction of it is accounted for by the sidebands.

Now since the carrier frequency is fixed and by itself carries no intelligence, we can suppress it at the transmitter and let it be reinserted from a local oscillator at the receiver. The amplitude of the sidebands can then be several times greater for the same total r.f. power and the effective signal strength at the receiver correspondingly greater. We can go even further. Since the two sets of sideband frequencies are equal in amplitude and symmetrical about the carrier, only one set is really necessary. We can, therefore, suppress one and double the power in the other, thus halving the bandwidth occupied by the signal. The output from a transmitter possessing all these refinements is said to be a single sideband (s.s.b.) suppressed carrier transmission. In spite of the fact that such a transmitter is quite complex to build and adjust, many amateurs are now becoming very enthusiastic about s.s.b. suppressed carrier operation because of the great advantage it gives in the effective signal strength at the receiver.

The usual technique in an s.s.b. transmitter is to produce the s.s.b. signal at a low power level and then to amplify it with a linear class B p.a. stage. The latter will have somewhat less efficiency than a class C amplifier, but the output will still be effectively far greater than could be obtained with a normal anode modulated class C stage using the same output valve and the same d.c. input power.

Frequency Modulation

Quite a different way of conveying intelligence is not to modulate the amplitude of the signal, but to modulate its frequency; an exaggerated representation of frequency modulation (f.m.) is shown in Fig. 26. It will be seen that when a modulating voltage is applied the carrier frequency is increased during one half-cycle of the modulating waveform and reduced during the other.

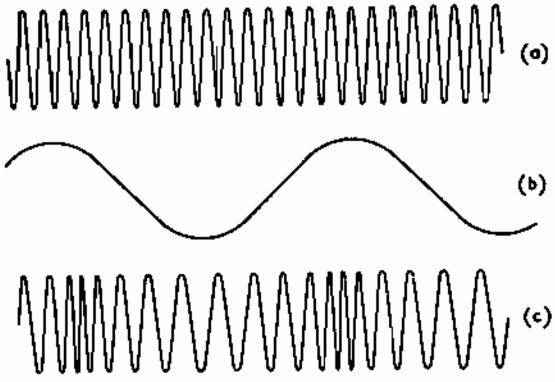


Fig. 26. Frequency Modulation. (a) Unmodulated r.f. signal. (b) A.f. waveform. (c) Modulated r.f. signals.

TYPICAL VALVES USED IN AMATEUR TRANSMITTERS

R.F. Amplifiers (Class C)

Valve	Max. H.T. volts	Max. D.C. input (watts)	Max. Freq. at Full Power (Mc/s)
6AG7	375	11.5 (A1)	10
5763, QV03-12	375	15 (A1)	175
6V6	350	16.5 (A1)	10
6AQ5	350	16.5 (A1)	54
6146, QV06-20	750	90 (A1)	60
	600	67 (A3)	60
6146B	750	120 (A1)	60
	600	84 (A3)	60
807	750	75 (A1)	60
	600	60 (A3)	60
TT21, TT22	1250	160 (A1, A3)	30
4-65A	3000	345 (A1)	30
	2500	270 (A3)	160
813	2250	500 (A1)	30
	2000	400 (A3)	30

Notes: Figures given for maximum power input apply to a single valve, and may be doubled if two valves are used in parallel or push-pull. Valves may be operated at higher frequencies than those shown provided the power ratings are reduced. There are also certain American colour television line output valves such as the 6HF5 which have become popular for use in linear amplifiers for s.s.b. operation. Typically a single 6HF5 can operate in Class C up to 115 watts input with an h.t. of 500 volts, or can give over 55 watts peak envelope power output in linear operation in Class AB1, up to 30 Mc/s.

Typical Efficiencies

Tripler Stage	20 – 25%
Doubler Stage	30 – 40%
Class A Amplifier	10 – 50%
Class AB Amplifier	50 – 60%
Class B Amplifier	55 – 70%
Class C Amplifier	65 – 80%

Modulators

	Class	H.T. volts	Power Output
6AQ5, 6V6 (single)	A	250	4.5
6L6, KT66 (single)	A	350	10.5
EL34 (single)	A	250	11
6AQ5, 6V6 (pair)	AB1	285	14
6L6 (pair)	AB1	360	26.5
6L6 (pair)	AB2	400	50
807 (pair)	AB2	500	75
807 (pair)	AB2	750	120
EL34 (pair)	AB2	800	100
KT88 (pair)	AB2	600	100
KT88 (pair)	AB2	750	150
TT21, TT22 (pair)	AB1	1250	230

Rectifiers

Valve	Filter	Max. Ratings (volts, A.C.)	Max. D.C. output (mA)
80, 5Y3, 5Y4	Condenser-input	350–0–350	125 mA
GZ30, 5Z4	Choke-input	500–0–500	125 mA
5Z3, 5U4G, GZ33, U54	—	500–0–500	250 mA
6X4, 6X5	Condenser-input	325–0–325	70 mA
	Choke-input	450–0–450	70 mA
5R4	Condenser-input	900–0–900	150 mA
	Choke-input	950–0–950	175 mA
866A (half-wave) (Mercury–Vapour)	—	3500	250 mA

The change in carrier frequency (the frequency deviation as it is usually called) is, in fact, made proportional to the instantaneous amplitude of the modulating signal. Thus the deviation is greatest on the peaks of the modulating waveform.

In Amateur Radio the frequency deviation must be restricted to less than 2½ kc/s so that the bandwith occupied by the signal is comparable with that of a normal amplitude-modulated transmission. Such a transmission is usually referred to as narrow-band f.m. or simply n.b.f.m.

The effectiveness of an n.b.f.m. transmission depends largely on the receiver. A receiver specially designed for f.m. reception will to a large extent suppress any interference from a.m. transmissions and any noise which may be picked up. Unfortunately, most communications receivers are specifically built for a.m. reception. They can be made to respond to an f.m. transmission by a suitable amount of detuning which translates changes in frequency to changes in amplitude due to the selectivity of the i.f. amplifier. However, the f.m. signal is not used to its full advantage and may find it very difficult to compete with a.m. signals of the same strength.

Frequency modulation is usually achieved by what is known as a reactance valve connected to the tuned circuit of the v.f.o. This valve supplies a current which is out of phase with the applied voltage and thus behaves as a reactance, usually a capacitance. The value of this out-of-phase current, and thus of the capacitance, depends on the gain of the valve and can be changed by varying the grid bias voltage. Thus if an a.f. voltage is applied to the grid of the reactance valve, the reactance will deviate about its mean value in sympathy with the a.f. waveform, and so will the oscillator frequency. It should be noted, however, that the reactance value offers great possibilities for unwanted frequency drifts and a special effort must be made to ensure that the mean value of the reactance is stable.

THE AERIAL

Whenever the intensity of the electric current passing through a wire changes, a very small amount of energy is radiated into space. When a radio-frequency current passes through the wire several million times a second the amplitude of the current may be alternating between its maximum positive value and its maximum negative value. The amount of energy radiated may then be quite considerable.

The radiated energy is said to consist of radio waves. It is not necessary to be able to visualize these waves but it is useful to remember that they travel outwards from the wire at 300,000,000 metres per second. Thus, with a radio signal whose frequency is 30,000,000 cycles per second (30 Mc/s) the distance occupied by one complete wave (i.e. from one positive peak to the next) is 10 metres. We therefore say that a 30 Mc/s signal has a wavelength (often abbreviated to λ) of 10 metres.

To radiate a strong signal we must persuade a large r.f. current to flow into the aerial wire, and in order to obtain some idea of how this may be done let us first consider the horizontal aerial shown in Fig. 27. If the switch S is suddenly closed, current will flow into the aerial to charge up the capacitance formed by the wire and the ground. Now it is normally assumed that the electric current flow through a wire is instantaneous but in reality it has a finite speed which is approximately equal to that of radio waves in space. Thus the current will not flow immediately into all the capacitance. If we consider the aerial to be made up of a series of small elements we can think of each element as starting to charge up in sequence. There will in effect be a "front" of current speeding along the wire at 300,000,000 metres per second. Behind this front, current will be flowing, while ahead of it there will be no current. With an infinitely long wire this current front would be continually moving on and at any instant in time the current from the battery would be charging up some new section of the wire. At point A there would consequently be a steady flow of current and, as far as the battery was concerned, it would be feeding into a resistance.

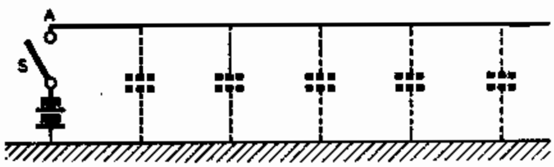


Fig. 27. A Horizontal Aerial.

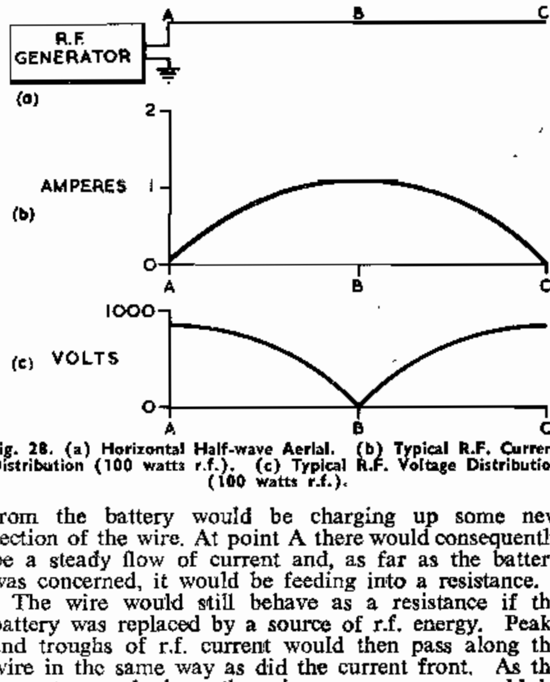


Fig. 28. (a) Horizontal Half-wave Aerial. (b) Typical R.F. Current Distribution (100 watts r.f.). (c) Typical R.F. Voltage Distribution (100 watts r.f.).

The wire would still behave as a resistance if the battery was replaced by a source of r.f. energy. Peaks and troughs of r.f. current would then pass along the wire in the same way as did the current front. As the current passed along the wire some energy would be lost due to the resistance of the wire but, with a reasonably thick wire, this energy would be far less than that radiated as radio waves, and we would have an efficient transmitting aerial.

The Half-Wave Aerial

A practical aerial cannot be infinitely long and its behaviour is not so simple. When the current reaches the end of the practical aerial it is reflected back.

A particularly important effect occurs when the aerial is exactly half a wavelength long as in Fig. 28(a). Suppose that a positive peak of current is moving from A to C. When it reaches C it will be reflected back again. The

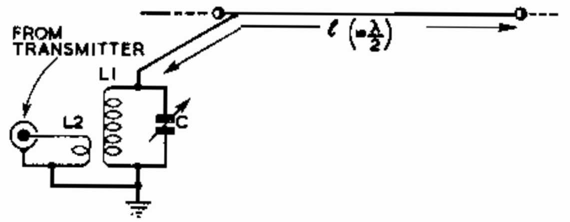


Fig. 29. Half-wave Aerial connected direct to Aerial Tuner. L ≃ 470/f ft, where f is the frequency in Megacycles.

reflected current will have the same amplitude and the opposite polarity and thus at C itself the net amplitude of the current will be zero. From B to C and back again is exactly half a wavelength. Thus by the time the reflected current peak, now negative, reaches B, it will meet the following negative peak which is on its outward journey from A to C. The two current peaks will therefore add together producing a very high peak of current at B.

When the reflected current peak reaches A it will be reflected back once more, this time as a positive peak. It will then have travelled exactly one wavelength since first leaving A and will therefore be reinforced by the next positive peak leaving the generator.

The same sort of thing also happens to the negative peaks. If we used an ammeter to measure the force of the alternating current at various points along the wire we would find it to be as shown in Fig. 28(b). At B each peak of current would be reinforced by a reflection from C and the amplitude of the alternating current there would be high. At C the incident current at any instant is always cancelled by its reflection and the net value of the current here is always zero. The net current at A would also be zero if the r.f. source were not connected at this point; in practice the ammeter would measure the current being supplied by the generator.

If we were to measure the r.f. voltages on the aerial we should find that each end of the aerial had a high voltage to earth and that the voltage fell as we approached the centre, at which point it would be zero. The voltages at the two ends would be equal in magnitude but opposite in phase.

The fact that the magnitudes of the r.f. currents and voltages vary along the length of the wire is often described by saying that there are standing waves present. We have the interesting condition that the ratio of voltage to current, that is to say the impedance of the aerial, is high at either end but low in the centre. This is in contrast to the infinitely long aerial where the amplitudes of the current and voltage were always in proportion, gradually diminishing along the length of the wire as energy became lost.

We have assumed so far that the capacitance to earth is essential for the operation of the aerial. There is, however, always capacitance between the individual points on the aerial and, although the operation is then not quite so easy to understand, the electrical characteristics of a half-wave aerial are in fact very similar with the wire perpendicular to the ground, or even without the earth being present at all.

If a half-wave aerial terminated at the transmitter, it could be connected in the manner shown in Fig. 29. At resonance the aerial would appear as though it were a resistance of a few thousand ohms to earth. Assuming that the transmitter has been designed to give its greatest power output when feeding into about 72 ohms† it would be necessary to interpose the r.f. transformer L1, L2, C. Then, although the aerial may be taking, for example, 0.1 ampere at 720 V, the input to L2 can be 1 ampere at 72 V so that the transmitter "thinks" it has a load of 72 ohms.

Now if the aerial is not exactly half a wavelength long the reflected current at A will not be exactly in phase with the applied voltage. This will give the effect of the aerial having some inductance or capacitance and will modify the tuning of L1C. But as long as C is used to tune the whole system to resonance the load applied to the transmitter will appear to be a pure resistance.

It must always be borne in mind that for maximum power output the transmitter must feed into a resistive load. Various combinations of reactance (either inductive or capacitive) and resistance can give an impedance of 72 ohms and any of these combinations will take 1 ampere at 72 V. The power taken, however, will only be 72 W if the voltage and current are exactly in phase, i.e., if the load is a pure resistance.

An aerial of the type shown might have its length chosen so that its natural resonance lay in the centre of an amateur band. The r.f. transformer, more commonly called an aerial tuner or aerial coupler, could then be used to tune the aerial to any frequency in the band, at the same time ensuring that the transmitter "saw" a resistance of about 72 ohms at each frequency.

Directivity

A half-wave aerial, or dipole as it is often called, which is well clear of the ground radiates quite well in all directions except those making an angle of less than about 30° to the wire. Thus a horizontal dipole lying north-south will radiate eastwards and westwards at all angles of elevation from horizontal to vertical. But northwards and southwards there will be little radiation at angles less than about 30° to the horizontal.

When the aerial is close to the ground, as must be the case in practice, the waves reflected by the earth interact with those radiated directly from the wire and modify the radiation pattern. This effect is most pronounced when the height of the aerial is λ/4 or lower and under these conditions all radiation at low angles to the earth tends to be suppressed and the high angle radiation is accentuated.

For almost all high frequency communication we use those waves which are reflected back to earth by the ionized layers in the atmosphere. When transmitting over a very long distance it is the low angle radiation which is used and consequently an aerial height of λ/2 or more is to be preferred. On the other hand, for communication over distances of only a few hundred miles we normally use the high angle radiation and a lower aerial usually gives better results.

If the dipole is mounted vertically there will be low angle radiation in all compass directions but little high angle radiation. Such an aerial has potential advantages for long distance communication but is not very often used because of the practical difficulties involved in constructing a vertical radiator half a wavelength long and clear of the ground.

If we are to obtain the best results from an aerial some care must be exercised in siting it, not only to ensure that it radiates in the required directions but also to ensure that it is as clear as possible from buildings and trees which might absorb some of the radiated energy. Consequently some method must often be devised whereby energy may be fed to an aerial which is remote from the transmitter. To understand how this can be done we must first give a little thought to the theory of transmission lines.

†Feeder cables generally have characteristic impedances between 50 and 100 ohms, 72 ohms being a popular value.

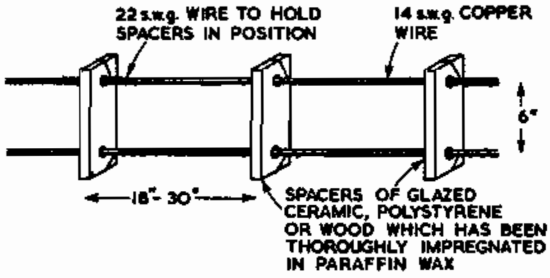


Fig. 30. Typical amateur-built Transmission Line.

Transmission Lines

A typical r.f. transmission line or feeder is shown in Fig. 30. If an infinite length of this feeder were coupled to an r.f. generator it would behave in a similar manner to the infinitely long aerial. With the dimensions given the feeder would appear to have a resistance of about 600 ohms and this value would be said to be its characteristic impedance. The current in the two wires at any instant would be equal in amplitude and opposite in polarity. Thus, because the feeder is symmetrical and the wires are close together, the net radiation from the feeder will be quite small.

Now suppose that we take a finite length of the feeder and connect a 600 ohm resistor across the far end. As far as the r.f. generator and the feeder are concerned it is just the same as if an infinite length of feeder had been joined on the end. This means that any length of the feeder, when terminated by a load having a resistance of 600 ohms, will present a resistance of that value to the generator. Moreover, nearly all the r.f. energy will be guided by the feeder to the load and not radiated en route.

If the feeder is not terminated by its characteristic impedance, reflections will take place at the end and standing waves will occur. An extreme case is that of a quarter-wave line terminated by a short circuit as in Fig. 31(a). We can think of this as rather like a half-

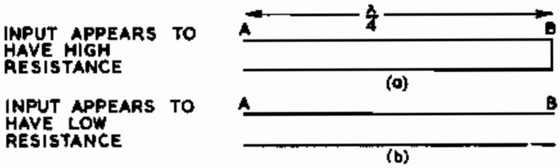


Fig. 31. Quarter-wave Line. (a) Short-circuited end. (b) Open-circuited end.

wave aerial doubled back on itself. Thus although the load resistance is very low the resistance at A will appear to be high. A converse effect occurs if the end B is open circuit as in Fig. 31(b). The apparent resistance at A is then very low.

The nearer the load resistance becomes to the characteristic impedance the nearer the input resistance becomes to it also. Mathematically the relationship is expressed $Z_i/Z_c=Z_cZ_L$, where Z_i is the impedance "seen" at the input to the feeder, Z_c the characteristic impedance and Z_L the load impedance. Thus with a 600 ohm feeder and a resistive load of 300 ohms the feeder input will appear to be a resistance of 1,200 ohms; with a 1,200 ohm load the input would appear to be 300 ohms. If any reactance is present in the load the input impedance will also contain some reactance.

The quarter-wave line acts in effect like a transformer. If the line is half a wavelength long we can think of it as being two of these transformers connected back to back. The net effect will consequently be as if there were no transformer at all and the input impedance will equal the load impedance. This condition will in fact hold for any even number of quarter-waves. With an odd number of quarter-waves the net effect is the same as if there were only one.

Commercial feeders are obtainable with characteristic impedances of about 70 to 300 ohms. There are also co-axial cables available which behave similarly and which usually have impedances around 50 to 100 ohms. The coaxial cables have one conductor completely surrounding the other; the outer one is usually earthed so that it forms a screen. The commercial products are perfectly satisfactory provided that the feeder is operated "flat," that is to say, provided that the ratio of maximum and minimum r.f. currents along the wires (the standing-wave ratio) is less than about 3:1. With higher standing-wave ratios there are liable to be appreciable losses at the high current points due to the resistance of the conductors and at the high voltage points due to leakage in the insulating material. In such cases the use of a home-made feeder such as shown in Fig. 30 is to be preferred.

Zeppelin ("Zepp") Aerials

An alternative method to the half-wave aerial is to use a tuned feeder as shown in Fig. 32(a). The feeder is approximately balanced with respect to earth and thus the voltages on the two wires at the top will be equal and opposite in phase. The effect of the aerial will be as if a resistance of several thousand ohms had been placed across the upper end of the feeder.

Thus, if the feeder has a characteristic impedance of about 600 ohms and is an odd number of quarter wavelengths long, it will act as a transformer and the lower ends of the feeder wires will appear to have a resistance of perhaps 50 to 100 ohms between them. If the feeder is a little short this resistance will appear to have a small inductance in series. Conversely, if the feeder is a little long it will have a fairly large capacitance in series. The bottom of the feeder is therefore connected in series with a coil and a capacitance, the latter being made variable so that it can be used to tune the whole system to resonance.

With the feeder an even number of quarter wavelengths long the bottom of the feeder will appear as a resistance of several thousand ohms. This will appear to have some associated capacitance if the feeder length is short and some inductance if the length is long. The most convenient type of aerial tuner would be as in Fig. 32(b).

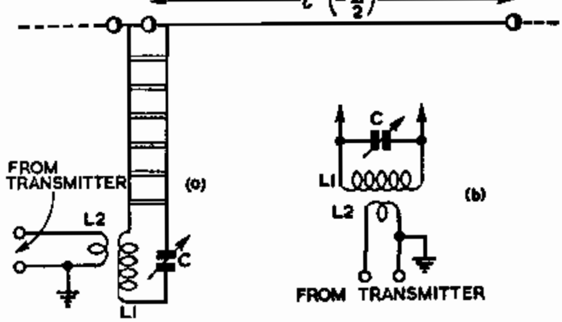


Fig. 32. Zeppelin Aerial. (a) Feeder an odd multiple of $\lambda/4$ long. (b) Suitable aerial tuner for a feeder which is an even multiple of $\lambda/4$ long. The length of the aerial $\simeq$ 490/f ft. where f is the frequency in Mc/s.

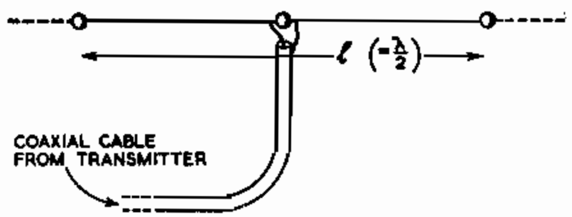


Fig. 33. Half-wave dipole fed by co-axial cable. The length $\simeq$ 470/f ft.

With a suitable aerial tuner it is possible to accommodate any length of feeder, but, in order that some easy assessment can be made of the aerial tuner requirements, it is preferable to make the length a whole number of quarter-waves. The tuner will also compensate for any errors in the length of the radiating section itself but it is advisable to keep this length as near the correct value as possible so that the feeder is balanced. With an unbalanced feeder the high current points in the two wires will not be opposite and there will be some radiation from them.

Centre-fed Aerials

There are often advantages in feeding an aerial at the centre. We have already seen that the impedance here is low and if, in fact, we break open the centre of a dipole the two ends thus formed appear to have a resistance of about 72 ohms between them. This means that we can take a 72 ohm coaxial cable direct from the aerial to the transmitter as shown in Fig. 33. Ideally a balanced feeder should be used but since the impedance is low the unbalance caused by using coaxial cable is usually negligible.

It should be noted that 72 ohms is the theoretical figure for a half-wave aerial of thin wire which is well clear of the ground. With a practical aerial the value will often be more like 50 ohms and some standing waves will occur. Nevertheless, provided that the aerial is not more than a few per cent off tune, the standing wave ratio will normally be less than 2:1. Any inductive or capacitive components appearing at the transmitter end of the coaxial cable, due to the latter not being an exact multiple of quarter-waves long or due to the aerial being slightly off resonance, will be fairly small and will be compensated for in the tank circuit tuning.

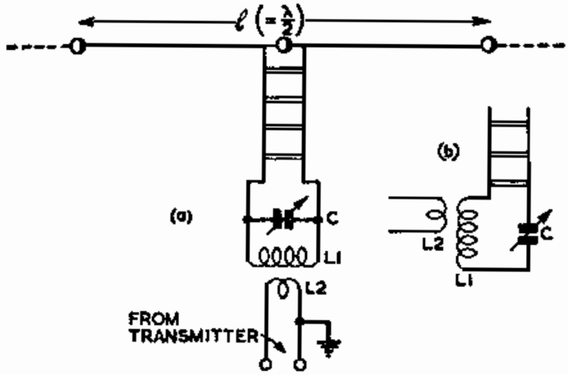


Fig. 34. Half-wave dipole fed by tuned line. (a) Feeder length an odd multiple of $\lambda/4$ long. (b) Suitable aerial tuner for feeder whose length is an even multiple of $\lambda/4$. The length $\simeq$ 470/f ft.

Fig. 34 shows the dipole centre-fed by a tuned line. Since the feed-point impedance of the aerial is low the impedance "seen" at the lower end of a given length of feeder will be the opposite to that with the end-fed version. Unlike the latter the whole aerial system is symmetrical and consequently the length of the radiating section is not particularly important since it can be compensated for by the aerial tuner without affecting the balance of the feeder.

The Folded Dipole

If a dipole is composed of two parallel wires joined together at their extremities the current will be divided between them. If we break open only one of these wires at the centre we find that the resistance there is not 72 ohms but more like 300 ohms. The reason for this is not difficult to understand. We know that the power in any circuit is given by I^2R, where I is the current and R the resistance. If, therefore, for the same aerial power we are only going to cause half the current to flow the resistance must be four times as large.

An aerial utilizing this fact, and usually known as a folded dipole, is shown in Fig. 35. Advantages of this

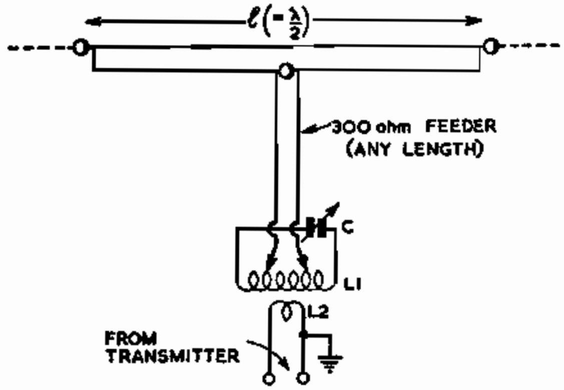


Fig. 35. Folded dipole. The length $\simeq$ 460/f where f is the frequency in Mc/s. The taps on L1 should be about 2/5 of the way in from either end.

type of aerial are that it is broadly tuned and that the standing wave ratio on the feeder is normally very low. The radiating portion of the aerial can be composed of two parallel wires spaced a few inches apart, or can be constructed from a length of the 300 ohm feeder itself.

The Quarter-wave Aerial

On Top Band half a wavelength works out to about 250ft. and becomes impracticable for the average amateur. For this reason a quarter-wave aerial as shown in Fig. 36 is usually employed. Such an aerial relies on the fact that the earth acts as a reflector and, in effect, produces an image quarter-wave underneath to complete the half wavelength.

At resonance the aerial would appear to the aerial tuner as a resistance of about 36 ohms if the radiator were vertical. In practice the aerial is usually bent into an inverted-L shape, the value being somewhat lower. L1 and C are chosen to resonate at the transmitting frequency but C will, in fact, be tuned to compensate for any errors in the aerial length.

It is very important that such an aerial should have an efficient earth connection. If care is not taken the latter may have a resistance greater than the feed-point resistance of the aerial; in such a case less than half the r.f. power would be radiated, the rest merely heating up the garden. A simple and efficient earth can often be obtained by connecting to a water pipe. Otherwise a connection can be made to several plates of copper or galvanized iron buried a foot or so beneath the surface, the soil being watered if necessary to keep it damp in dry weather.

Where space is severely restricted the length can be reduced below a quarter-wave. This will make the aerial appear as a resistance and capacitance in series, and a larger value of inductance may be required to restore resonance. Under these conditions the aerial resistance may be 10 ohms or less and very special care will be needed with the earth connection.

Multi-Band Operation

One advantage of the aerial in Fig. 32 is that it can be operated on harmonic frequencies. At twice the design frequency, for example, the top is effectively two half-wave sections joined together. The centre is no longer a high current point but a high voltage point. Nevertheless there are still high voltage points at the ends and the aerial can be fed just as for the fundamental frequency. All that will be required is a suitable modification to the aerial tuner, bearing in mind that the feeder length will now be a different multiple of quarter-waves. When a horizontal aerial is several half-waves long the low-angle radiation tends to be fairly evenly distributed in all compass directions.

The aerial in Fig. 34 can also be operated on harmonic frequencies. On the second harmonic each section will be a half-wave and the feed-point of the aerial will therefore have a high impedance. When operated on its second harmonic frequency the low-angle radiation tends to be concentrated in directions making angles of 45° to 135° to the aerial wire but on higher harmonics the low-angle radiation tends to be omnidirectional.

The simplest and most versatile multi-band aerial of all is a single wire about 132ft. long and terminated at the aerial tuner. This can be operated as a quarter-wave on 1.8 Mc/s, an end-fed half-wave on 3.5 Mc/s and as end-fed multiples of half-waves on, 7, 14, 21 and 28 Mc/s.

The Aerial Tuner

The aerial tuner should have a high Q when unloaded; the load of the aerial should reduce the Q to around 5 or 10. Under these conditions the r.f. power absorbed by the tuned circuit will only be a small proportion of that absorbed by the aerial. A low value of Q reduces the aerial tuner's capabilities for rejecting harmonics but if there has been adequate harmonic suppression elsewhere this should not be detrimental.

TABLE 4.

Approximate circuit values for the aerial tuners shown in Figs. 29 32, 34 and 35.

Band (Mc/s)	C ($\mu\mu$F)	L1 (μH)	L2 (turns)
1.8	30	60	2 — 4
3.5	2	32	60
7	120	16	1
14	15	8	1
21	10	5	3 — 6
28	8	4	2

L2 can have a slightly larger diameter than L1 and be slipped over the part of L1 having the lowest r.f. potential to earth.

The values of L and C given in Table 4 are only meant as a rough guide and some deviation from these will often be necessary. Some indication of the Q can be obtained by comparing the sharpness of the tuning with that of the p.a. tank circuit on the transmitter. If the aerial tuner efficiency is low it will be noticed that its coil becomes warmer than that in the tank circuit.

Before feeding a transmitter into the aerial tuner for the first time it is advisable to adjust first the tuning of the transmitter tank circuit with the transmitter feeding into a 72 ohm dummy load. This should have as little inductance as possible and might conveniently consist of a suitable series-parallel combination of one watt resistors. The dummy load should be capable of handling the r.f. power output although with carbon resistors it is often possible to overload them by as much as 10:1 provided that they are only dissipating power for short periods.

After adjusting the tank circuit the dummy load should be replaced by the aerial tuner. By means of the tuning capacitor, and by experimenting with the coupling coil and the taps on the main coil, the aerial tuner should then be adjusted until maximum power is absorbed by the aerial. The transmitter tuning can then be readjusted as a last refinement.

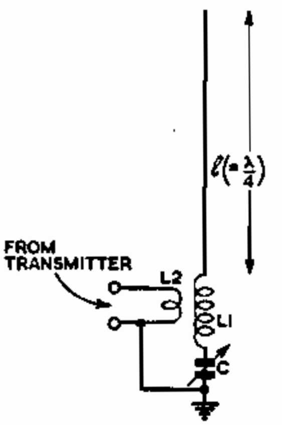


Fig. 36. Quarter-wave (or Marconi) aerial. The length $\simeq$ 230/f ft where f is the frequency in Mc/s.

Having found the optimum adjustments for any aerial on any waveband it is advisable to record the important details. This will then make it easier to change from one band to another or from one aerial to another. Many amateurs go even further and have several pre-adjusted aerial tuners in one box and use a rotary switch (with ceramic insulation) to select the one required.

Some indication of the power being fed to the aerial can be obtained from the p.a. anode current meter. This indication should not be relied on implicitly however, because the meter cannot differentiate between power absorbed by the aerial and that taken by the aerial tuner. When the aerial feeder presents a low impedance to the tuner it is better to check the current flowing into the feeder with an r.f. ammeter or a suitably rated flash-lamp bulb.

When the feeder presents a high impedance to the aerial tuner the current will be too small for easy measurement. It is then easier to use the voltage indication given by a small neon lamp held near the feeder.

With aerials fed against ground (that is where the earth forms part of the r.f. system as in Fig. 36), the best possible earth system or ground radials should be used; this is particularly true with the various vertical h.f. aerials which have become popular.

So far we have been mainly concerned with electrical details but there are a number of practical considerations which should be noted.

Due to various reasons the physical length of an aerial needed to produce resonance is usually a few per cent less than that which might be expected from simple theory. This discrepancy has been taken into account in the formulae which have been given here for aerial length. The physical length of a quarter-wave open line is also a few per cent less than might be expected; with commercial twin feeder the physical length is often 20 per cent less and with co-axial cable 30 per cent less.

Either wooden or metal poles are satisfactory for a horizontal aerial but a metal pole is not recommended for supporting a vertical aerial as it will couple to the radiator and distort the radiation pattern. Long guy wires are liable to interact with both horizontal and vertical aerials and should preferably be broken up electrically by inserting a compression type (egg-shaped) insulator about every $\lambda/10$. Trees and buildings can also have detrimental effects and the aerial should, therefore, be as much in the open as possible. The feeder should be kept at right angles to the aerial for as far as is practicable in order to minimize the intercoupling between them.

The quality of the insulators required will depend to some extent on their position. At the extremities of a half-wave aerial the voltages will be high and the insulators should be of glass or glazed ceramic and be several inches long. But in the centre of a half-wave aerial which is always used on its fundamental frequency the r.f. voltage will always be low and a poorer quality insulator will be acceptable. When high voltage points of the feeder, or of the aerial itself, come into the house, good insulation must be provided here. On the other hand, if the feeder has a low impedance as it enters the house less care will be necessary.

The rope used for halyards should be of good quality and preferably waterproofed by impregnating it in heavy oil or wax. Some allowance should always be made for shrinkage in wet weather. Better still is nylon cord.

For long-distance work, consult the great circle map (page 19) when planning an aerial.

Aerial Resonant Lengths

Table 5 indicates resonant lengths at selected frequencies in the amateur bands for wire aerials erected well clear of the ground and other large objects.

The second column shows the physical length of a half-wavelength converted from metres into feet. The next column shows a five per cent end correction, and the final column shows the correction deducted, i.e. 95 per cent of a physical half-wavelength which, for dipole type wire aerials, is approximately equal to an electrical half-wavelength.

The end column is thus the resonant length for any type of half-wave dipole clear of surrounding objects. Should the radiating section be bent a small additional length may be needed.

When using an aerial more than one half-wavelength long only one end correction need be deducted. For example a full-wave aerial for 14100 kc/s would be 2 × 34ft. 11in. less 1ft. 9in., i.e. 68ft. 1in.

The popular Zepp aerial does not require an end correction to be made. For example, a half-wave Zepp for 14000 kc/s would have the radiating top section 35ft. 2in. long, and not 33ft. 5in.

Under normal circumstances aerial lengths are not unduly critical and an aerial cut for about the centre of an amateur band will usually function satisfactorily over the entire band. However with low radiation resistance aerials (for example, where reflectors and directors are used) accuracy becomes increasingly important.

After erection the resonant frequency of an aerial should be checked, if possible, by means of a grid-dip oscillator.

TABLE 5

Frequency (kc/s)	½λ (ft. in.)	0.05 x ½λ (ft. in.)	0.95 x ½λ (ft. in.)
3500	140 7	7 0	133 7
3600	136 9	6 10	129 11
7000	70 3	3 6	66 9
7100	69 3	3 5	65 10
14000	35 2	1 9	33 5
14100	34 11	1 9	33 2
14200	34 8	1 9	32 11
21000	23 5	1 2	22 3
21200	23 3	1 2	22 1
21400	23 0	1 2	21 10
28000	17 7	– 10	16 9
28400	17 4	– 10	16 6
29000	17 0	– 10	16 2

FREQUENCY MEASUREMENT

When operating a transmitter it is important to have a fairly accurate idea of the frequency of the radiated signal. In particular we should always be quite sure that the signal does not lie outside the amateur band.

With a crystal controlled transmitter this presents no great difficulty because the frequency will be almost entirely dependent on the crystal.

The Absorption Wavemeter

Knowing the crystal frequency, however, is not in itself sufficient because there is the possibility that the final output from the transmitter may be on the wrong harmonic of that frequency. To ensure that this is not so, it is necessary to use an absorption wavemeter such as is shown in Fig. 37. This would be built as a compact portable unit and, to test the output frequency of any stage, would be held close to the relevant tuned circuit. With the wavemeter resonated to the circuit to which it is coupled some energy is absorbed from that circuit. If the wavemeter is held close enough the r.f. current induced into it will be sufficient to light the bulb. Thus, provided that the wavemeter has been previously calibrated, it is only a matter of tuning for a resonance indication on the bulb and reading off the frequency.

A convenient method of calibrating the wavemeter is to use a communications receiver. An aerial is connected to the receiver, the lead-in wire being loosely wound once or twice around the wavemeter coil on its way to the aerial socket. If a suitable station is then tuned in it will be found that at a certain setting of the wavemeter capacitor the strength of the received signal will fall. This will indicate that the wavemeter is absorbing some of the incoming signal and that it must therefore be tuned to the frequency of that station. By

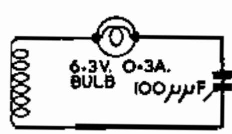


Fig. 37. Simple absorption wavemeter. This might have three plug-in coils, on 1 inch dia. formers, wound as follows: 90 turns 32 s.w.g. enam. (approx. 1.5-4.5 Mc/s); 32 turns 22 s.w.g. enam. (4-12 Mc/s); 7 turns 22 s.w.g. enam. (11-33 Mc/s).

repeating this operation with a selection of stations a number of calibration points can be obtained and it will therefore be possible to prepare a calibrated scale to fit under the knob of the variable capacitor.

A low power stage may not be capable of providing enough r.f. power to light the bulb. Under such circumstances resonance indication can be obtained from the anode current which will rise when the wavemeter absorbs energy.

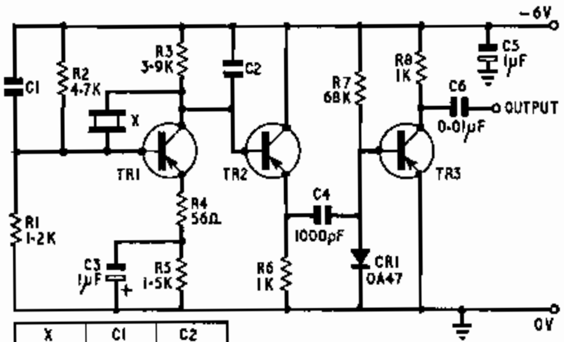
Transistorized Crystal Calibrator

When a variable frequency oscillator is used for transmission the absorption wavemeter is still invaluable for checking that circuits are tuned to the correct fundamental or harmonic frequencies but it is not capable of giving a sufficiently accurate reading to ensure that the transmitter is actually in the band, or to show the frequency other than very roughly. It is essential therefore to be able to check a v.f.o. type transmitter against a more accurate standard, and this will usually include a crystal controlled oscillator. The frequency meter may include a complete heterodyne unit with both stable variable oscillator and crystal reference, or alternatively a small crystal calibrator may be used to calibrate accurately the station receiver which is then used to check the transmitter.

It is unfortunate however that superhet receivers will generally respond to a very strong local signal at several spurious tuning points and it is not always obvious which of the responses are spurious. The use of a crystal calibrator, in the absence of a heterodyne frequency meter, still requires a really good absorption meter or some other unambiguous means of checking the output frequency.

The simple three transistor unit shown in Fig. 38—described originally by G3JGO—may be used with frequency standard crystals in the range 100 kc/s to 10 Mc/s to produce strong harmonics throughout a wide spectrum. The range over which harmonics of the crystal may be detected will be determined by the frequency of the crystal, the sensitivity of the detecting device, and the order of harmonic. For example, a 100 kc/s crystal should be audible at harmonics up to about 15 Mc/s, and a 500 kc/s crystal to beyond 30 Mc/s.

TR1 functions as a Colpitts oscillator, and the resistor R4 tends to prevent oscillation at spurious frequencies. TR2 is an emitter following buffer stage and reduces the loading on the crystal which would otherwise result from the TR3/CR1 "squaring" stage which produces an output rich in harmonics. The clipping diode CR1 prevents peak drive voltages from exceeding the base-emitter junction ratings of TR3.



X	C1	C2
100 kc/s	7000 pF	1500pF
250 kc/s	1000 pF	500 pF
500 kc/s	750 pF	110pF
10 Mc/s	100 pF	39pF

Fig. 38. The transistorized crystal calibrator. The valves of C1 and C2 for different crystal frequencies are shown alongside.

This design is tolerant of transistor types; for crystal frequencies up to about 2 Mc/s OC44, AF117 or similar transistors can be used; for TR1 and TR2 above this an OC170, OC171, AF115 or similar types would be needed. TR3 should always be suitable for use up to the highest frequencies involved, so that an OC171 or AF115, etc., would be a suitable choice.

Checking 100 kc/s Oscillators

The 100 kc/s harmonics can be checked against *standard frequency transmissions*, such as those radiated by stations MSF, WWV, etc., on exactly 2.5, 5, 10, 15, 20 and 25 Mc/s. In the UK there are fortunately also the accurate 200 kc/s BBC long-wave Light Programme transmissions. These are most convenient for checking a 100 kc/s standard, since the BBC station can be tuned on almost any receiver and the difference between these transmissions and the local oscillator heard as beats. Although the calibrator frequency will be determined primarily by the crystal frequency, this can if inaccurate often be "pulled" into zero beat with the BBC station by means of a trimmer across the crystal.

Heterodyne Frequency Meters

Many amateurs do not have a crystal calibrator built in as an integral part of their receivers but have what is usually called a heterodyne frequency meter as a separate instrument. This usually consists of an accurately calibrated v.f.o. complete with a crystal calibrator similar to that which has been described here. With some instruments the calibrated oscillator must be compared with the transmitter v.f.o. using a receiver. Others have facilities for accepting a small r.f. voltage from the transmitter, the comparison being effected by producing a beat note between the two frequencies within the instrument itself.

Many amateurs use an excellent American instrument of the latter type, the BC221, which was once readily obtainable on the surplus market. The newcomer, however, probably will not be lucky enough (or rich enough) to obtain one today.

A 1.8/3.5 Mc/s Phone/C.W. Transmitter

The transmitter described here—designed by G3JKA—represents one of the simplest practicable arrangements under present-day conditions for low power operation in the 1.8 Mc/s and 3.5 Mc/s bands. It is designed for an input power of 10 watts, telephony or c.w., and is free from television-interference troubles. Owing to its simplicity it can be recommended as an ideal beginner's transmitter, although unless fairly compact components are used, as in the original model, it may prove easier to construct the equipment on a somewhat larger chassis than is indicated in the diagrams. This will not affect performance, and a suitable size for the chassis can be determined by laying out the available components.

The circuit of the radio frequency section is given in Fig. 39. It consists of a Z77 Colpitts variable frequency oscillator operating in the 1.8 to 2 Mc/s range. This drives a second Z77 stage which is designed to operate either as an untuned buffer amplifier on 1.8 Mc/s or as a frequency doubler. The change-over is effected by switching in the inductance L2: in combination with the effective grid-to-earth capacitance of the power amplifier valve this introduces a wideband tuned circuit between the driver valve V2 and the p.a. stage. The capacitor C13 serves merely as a blocking capacitor to prevent the short-circuiting of the grid bias.

For the p.a. stage a TT11 valve (available very cheaply as government surplus) is used and a pi-network coupler transfers power from the anode to the aerial. The pi-network is tuned to either of the two bands by adjusting the tuning and loading capacitors C18 and C19. This

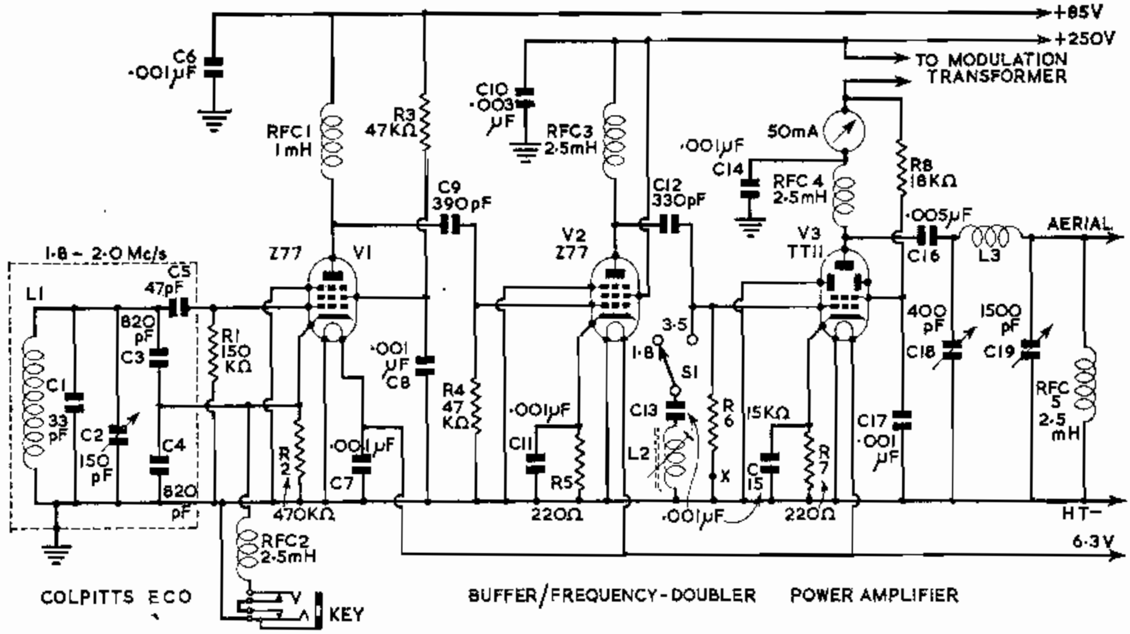


Fig. 39. Low-power transmitter for 1.8/3.5 Mc/s. C1 is a temperature-compensating capacitor, type N750K. C3, C4 and C5 should be silvered-mica capacitors. C19 can be a triple-gang receiving-type capacitor with the three 500 pF sections wired in parallel. L1 is 32 turns of 22 s.w.g. enamelled wire on a 1 in. diameter former. L2 is 60 turns of 36 s.w.g. enamelled wire pile wound on a ¾ in. diameter former with dust-iron core. L3 is 50 turns of 22 s.w.g. enamelled wire on a 1 in. diameter former. Valves types 6AM6, EF91 can be used for V1 and V2.

means that a compromise has to be made in choosing the values of L3, C18 and C19, but in practice the loss of efficiency is negligible.

For telegraphy operation the Morse key is inserted in the cathode lead of the oscillator valve V1, a high resistance R2 being added between cathode and earth to ensure that the heater-cathode voltage does not rise to a damaging value.

The power amplifier is anode-and-screen modulated by the modulator shown in Fig. 41. This consists of a straightforward four stage audio amplifier and is suitable for use with a crystal microphone; the high frequency response is purposely restricted to about 3000 c/s in order to reduce the bandwidth of the radiated signal. When operating on c.w. the modulator is switched off and the secondary of the modulation transformer is short-circuited to prevent the generation of voltage surges across the windings which may be caused by sudden changes of anode current in the p.a. valve during keying.

A suitable layout for the chassis is shown in Fig. 42 and the corresponding panel layout in Fig. 40.

In the power supply unit a conventional full-wave rectifier circuit is used, as shown in Fig. 43. The variable frequency oscillator valve is supplied from a stabilized h.t. line of 85 volts.

Pin connections for the TT11 are not always given in the data books: they are Pin 1 —; 2, heater; 3, suppressor grid; 4, grid; 5, screen grid; 6, —; 7, heater; 8, cathode.

Tuning the Transmitter

A 10 watt lamp should first be connected across the r.f. output connection to simulate aerial loading. With switch S2 (Fig. 41) in the c.w. position, the frequency range of the v.f.o. unit should be checked to verify that it covers the 1.8–2 Mc/s band, and its frequency stability and the quality of the keying checked in the receiver. With S1 in the 1.8 Mc/s position, the p.a. grid current (measured at the point X) should be found to remain constant at about 1–1.5 mA over the entire band. The tuning and loading capacitors C18 and C19 respectively should then be adjusted (for adjustment of a pi-network see page 47) and their settings noted for future convenience. On full load, the anode current to the output stage will be about 40 mA at 250 volts (i.e. 10 watts power input) and the 10 watt lamp should glow fairly brightly.

Next the transmitter may be tuned in the 3.5 Mc/s band by setting S1 to the appropriate position and setting the v.f.o. to 1.83 Mc/s (corresponding to the mid-point of the 3.5 Mc/s band after frequency doubling).

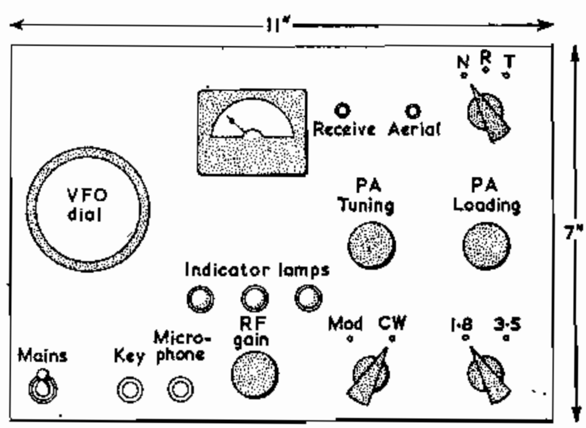


Fig. 40. Panel layout.

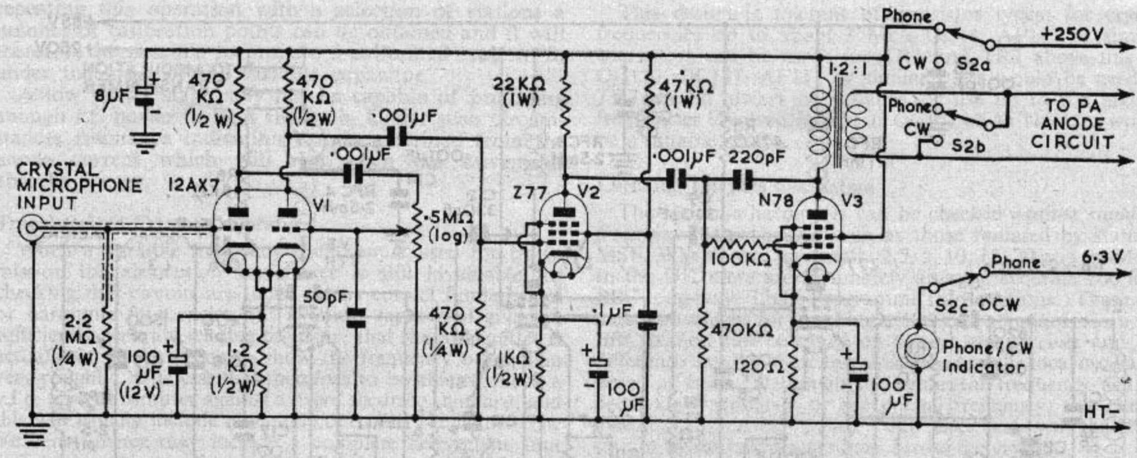


Fig. 41. Suitable modulator for the low power transmitter. V1 may be 12AX7 or ECC83, V2 6AM6 or EF91.

The core of L2 can then be adjusted to bring the p.a. grid current to about 1 mA—check that there is only slight variation over the entire range of 3.5–3.8 Mc/s. Finally, tune the pi-network for maximum output.

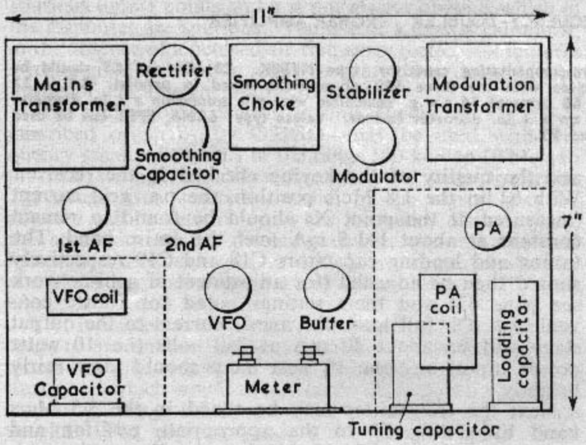


Fig. 42. Chassis layout.

Modulation is tested by switching S2 to the "phone" position. On modulation peaks, the increase of r.f. output power should be apparent by the brightening of the lamp. The amplitude and quality of the modulation should be carefully monitored before the transmitter is operated "on the air."

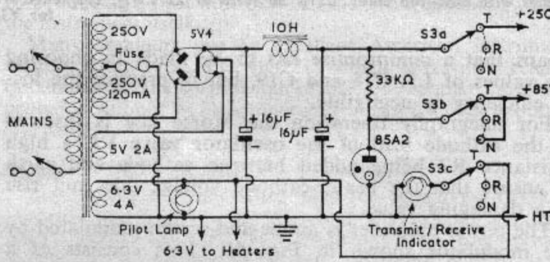


Fig. 43. Power supply. The switches S3a, S3b, S3c may be combined as a three-pole, three-way wafer-type giving TRANSMIT-RECEIVE-NET positions. One side of the heater should be connected to the cathode of the rectifier.

An example of a compact Collins transceiver in use as a complete amateur station.

CHAPTER FIVE

The Licence Examinations

UNLIKE radio and television receiving licences, amateur transmitting licences are not issued just on payment of the appropriate fee, but are granted only to those applicants who have proved their competence to control and operate a transmitter, and an awareness of their responsibilities to the users of other radio services. This is a reasonable precaution when one considers the havoc that even a low power transmitter could cause to radio and television reception, to world radio communications, or to important navigational services.

The danger of unskilled use of transmitters has been emphasised deliberately. Too often one hears expressed the erroneous belief that the conditions imposed by the P.M.G. have been devised to discourage the experimenter. Such is very far from the truth: the newcomer can be confident that his desire to obtain a licence will meet with courtesy, assistance and every encouragement from the authorities—provided that he does not expect "special concessions" in his particular case.

Detailed information on "How to become a radio amateur" can be obtained, free of charge, from the Radio Services Department, Radio Branch, General Post Office, Headquarters Building, St. Martins-le-Grand, London, E.C.1. For the benefit of those who have not yet obtained these details or who may be rather overawed at the official requirements, here are a few notes on the more important points.

(1) Applicants must be over 14 years of age and provide evidence of British nationality (a Birth Certificate, a valid Passport, or a Nationalisation Certificate is sufficient).

(2) Applicants must show that they have passed the Radio Amateurs' Examination, a three-hour written examination which covers the elementary theory of radio communication, knowledge of transmitting techniques, amateur operating procedure and licensing regulations.

(3) Applicants must have passed the Post Office Morse Test not more than twelve months before applying for a licence. This test involves the receiving and sending of plain language text at an average speed of 12 words per minute. This does not apply to the Amateur (Sound) Licence B (telephony only above 420 Mc/s) or the Amateur (Television) Licence.

(4) Before an Amateur (Sound) Licence A or B is issued the fee of £2 must be paid, and a renewal fee of £2 becomes due each year on the anniversary of the date of issue of the licence.

Since the Morse Test must be passed within the year before applying for the licence, it is usual to obtain a pass in the Radio Amateurs' Examination (R.A.E.) before attempting the Morse Test; otherwise there is always the possibility that the time limit will have expired before the written examination is passed, making it necessary to retake the code test.

Exemptions on the grounds of Service or civil qualifications are no longer granted from either of these examinations, and even if the applicant has previously held an amateur licence he must show that he has passed the R.A.E. (which was first held in 1946) and must retake the code test unless he has passed this within the last twelve months.

The Radio Amateurs' Examination

The City and Guilds of London Institute, Electrical and Telecommunications Branch, 76 Portland Place, London, W.1 (Telephone LANgham 3050), holds the Radio Amateurs' Examination No. 55 twice yearly in Spring and Autumn (usually May and December). This can be taken, by arrangement with the Local Education Authority, at centres throughout the country. Full details and a set of several specimen question papers may be obtained from the Institute at the above address, price 3/- including postage. The fee for the examination is 30/-, and a small fee, typically 5/-, may be payable to the local centre where the examination is taken. Applications to sit the examination usually have to be made at least three months in advance, so do not leave it too late.

There is a single paper, lasting three hours, divided into two parts. Part 1 contains only two questions both of which must be attempted; these two questions are drawn from items 1 and 2 of the syllabus. Part 2 comprises 8 questions, but only 6 should be attempted; these are based on subjects covered in items 3 to 10 of the syllabus. A pass mark *must* be obtained in *both* parts, and a failure in either part means failure of the examination.

SYLLABUS OF THE RADIO AMATEURS' EXAMINATION

1. **Licensing Conditions:** Conditions laid down by the Postmaster General for the Amateur (Sound) Licence, covering the purpose for which the transmitters may be used; types of signals permissible; types of emission; power; frequency control and measurements; avoidance of interference to other stations, particularly in bands key click filters and other means of preventing spurious emissions. shared with other services; qualifications of operators; log keeping and use of call signs.
2. **Transmitter Interference:** Frequency stability. Avoidance of harmonic radiation and of interference by shock excitation; use of Dangers of over modulation. Devices for reducing interference with nearby radio and television receivers.
3. **Elementary Electricity and Magnetism:** Elementary theory of electricity; conductors and insulators; units; Ohm's law; resistances in series and parallel. Power. Permanent magnets and electro-magnets and their use in radio work. Self and mutual inductance; types of inductors used in receiving and transmitting circuits. Capacitance; construction of various types of capacitors and their arrangement in series and/or parallel.
4. **Elementary Alternating Current Theory.** Alternating currents and voltages. Alternating current theory incorporating circuits with inductance, capacitance and resistance. Impedance, resonance, coupled circuits, acceptor and rejector circuits. The transformer.
5. **Thermionic Valves and Semiconductors.** Characteristics and essential constructional features of thermionic diodes, triodes and multi-electrode valves and of semiconductor diodes and transistors. Use of valves and semiconductor devices as oscillators, amplifiers, detectors and frequency changers. Power rectification. Power pack stabilization and smoothing.
6. **Radio Receivers:** Typical receivers; principles and operation of

t.r.f and superheterodyne receivers. C.W. reception. Interference caused by receivers.

7. **Low power transmitters:** Oscillatory circuits; use of quartz crystals to control oscillators. Frequency multipliers. Power amplifiers. Methods of keying transmitters. Methods of amplitude modulation and types of emission in current use.

8. **Propagation:** Wavelength, frequency, velocity. Nature and propagation of radio waves. Ionospheric and tropospheric conditions and their effect on propagation.

9. **Aerials:** Common types of receiving and transmitting aerials. Transmission lines. Directional systems. Aerial couplings to lines and transmitters. Matching.

10. **Measurements:** Measurement of frequency and simple frequency meters (including crystal controlled types). Use of verniers and other interpolation methods. Artificial aerials and their use for lining up transmitters. Measurement of anode current and voltage and power input to final stage. Use of cathode ray oscilloscope for the examination and measurement of waveform.

To give detailed guidance to prospective candidates, the RSGB publishes a comprehensive study guide *The Radio Amateurs' Examination Manual* (price, including postage, 5/6). Many typical questions and answers are given together with full details of licence conditions and regulations.

TYPICAL EXAMINATION PAPER

The question paper set by the City and Guilds of London Institute for a Radio Amateurs' Examination was as follows:

Eight questions in all are to be attempted, as under:

Both questions in Part 1 (which are compulsory) and six others from Part 2.

Part 1

Both questions must be attempted in this part.

1. Licence conditions. State the requirements in respect of the following:

(a) The use of call signs and notification of location;
(b) Non-interference;
(c) Re-transmission of recorded messages;
(d) Operators and access to apparatus;
(e) The kinds of messages which are prohibited.

(15 marks)

2. Explain how the following types of interference can be abated:

(a) At the transmitter:
(i) Harmonics;
(ii) Key clicks and thumps.
(b) At the receiver:
(i) Image response.

(15 marks)

Part 2

Six questions only to be attempted in this part.

3. Explain the meaning of:
(a) Self inductance;
(b) Mutual inductance.
Define the unit of inductance.

(10 marks)

4. An alternating current of 20 volts at a frequency of 1 Mc/s is applied to a circuit consisting of a capacitance of 100 picofarads in series with a non-inductive resistor of 10 ohms.
(a) What value of inductance in series is required to tune the circuit to resonance?
(b) At resonance, what is the current in the circuit?

(10 marks)

5. Explain with the aid of a diagram the action of any circuit commonly used for the detection of amplitude-modulated signals.

(10 marks)

6. Explain briefly why superheterodyne receivers are:
(a) more selective, and
(b) more sensitive than TRF receivers.
Explain what is meant by an image signal and give an example.

(10 marks)

7. Describe by means of a circuit diagram a method of applying amplitude modulation to the power amplifier stage of a transmitter.
Indicate by means of a sketch the modulation envelope of an amplitude-modulated wave
(i) Modulated with a sine wave to 50 per cent.
(ii) Modulated with a sine wave to 100 per cent.
(iii) Modulated with a sine wave over 100 per cent.

(10 marks)

8. State the relation between frequency and wavelength.
What are the frequencies corresponding to wavelengths of 500m and 10cm?
State the ranges of amateur frequencies which are more suitable for
(a) local transmissions;
(b) distant transmissions.

(10 marks)

9. Why are standing waves undesirable in a transmitter-aerial feeder system? How would you detect their presence and minimise them?

(10 marks)

10. Draw the circuit diagram of a heterodyne wave-meter and explain how the instrument may be used for the accurate checking of frequency.

(10 marks)

A SUMMARY OF LICENCE CONDITIONS

Full details of the conditions of the Amateur (Sound) Licences are supplied by the Post Office with the leaflet "How to become a radio amateur". The following is an informal summary of those points which are most likely to be needed for questions 1 and 2 of the Radio Amateurs' Examination, arranged according to their subject matter.

Location:—An amateur station may be used at the main address shown in the licence or any temporary premises (with call-sign suffix /A) or any temporary location (suffix /P) for separate periods none of which exceed four consecutive weeks, or in any alternative premises provided that notice in writing has been given at least seven days in advance to the GPO Telephone Manager (E/Radio) of the area concerned. The Telephone Manager must be notified when the station is no longer at the alternative premises.

Stations cannot be installed or used on the sea or within any estuary, dock, or harbour, or in any moving vehicle, vessel or aircraft (the special Amateur (Sound Mobile) Licence is required for all mobile operation in vehicles).

When not at the permanent address, particulars of the address or location in use must be sent at the beginning and end of each contact or at intervals of 15 minutes, whichever is the more frequent. The station, licence and log must be available for inspection at all reasonable times by duly authorized officers of the Post Office. The station must close down at any time on the demand of an officer of the Post Office.

Provision is made for revoking or varying the terms of the licence. A licence is not transferable and should be returned to the P.M.G. when it has expired or been revoked.

Messages:—Amateurs may send messages in plain language which are remarks about matters of a personal nature in which the Licensee, or the person with whom he is in contact, has been directly concerned, and use signals (i.e. procedure signals, etc.) which are not in secret code or cypher in relation to such messages. This does not include messages about business affairs. The use of the station for business, advertisement or propaganda purposes or (with the exception of the "disaster" message described below) for the sending of news or messages on behalf of, or for the benefit or information of, any social, political, religious or commercial organisations, or for anyone other than the Licensee or the person with whom he is in contact is not authorized. Messages which are grossly offensive or of an indecent or obscene character must not be sent. Note that it is an offence to send certain misleading messages.

Stations may be used during disaster relief operations—or exercises relating to such operations—to send messages on behalf of the British Red Cross Society, St. John Ambulance Brigade or the Police.

Messages must not be "broadcast" to amateur stations in general but only to amateur station(s) with whom contact has been established. The appropriate International Telecommunication regulations must be observed.

It is permitted to re-transmit recorded messages only when intended for reception by the original station concerned, and the call-sign of that station must not be included in the re-transmission.

The station may not be modulated by recordings other than special constant or gliding test tones. Entertainment-type gramophone or tape recordings may not be transmitted for any purpose. The station can be used to receive Standard Frequency Transmissions.

Operation:—Stations may be operated only by (1) the amateur himself; (2) a person holding another Amateur (Sound) Licence or a P.O. Amateur Radio Certificate, and such operation must be in the presence of and under the direct supervision of the Licensee.

An amateur must not allow unauthorised persons to operate his station or have access to the apparatus; he must ensure that any operator observes the conditions of the licence. Note that "speaking into the microphone" is regarded as operating the station.

Log:—(1) A record must be kept in a book (not loose-leaf) showing: (a) date; (b) time of commencement of calls; (c) call-signs of the stations from which messages addressed to the Licensee's station are received or to which messages are sent, times of making and ending contact, and the frequency or frequencies and class or classes of emission; (d) time of closing the stations; (e) the address of the temporary premises or alternative premises or particulars of the temporary location when the station is not used at the main address. Times must be in G.M.T. **and no gaps should be left between entries. All entries should be made at the time (i.e. the log should not be "written up" afterwards). (2) Should the station be operated by anyone other than the Licensee, the log must be signed by that person with his full name and call-sign, or number of his Amateur Radio Certificate.**

Call-sign:—The allotted call-sign must be used, except that where appropriate the correct country prefix (GM, GW, etc.) should be substituted and /A or /P used as already indicated. The call-sign may be sent by telephony or by telegraphy at not more than 12 w.p.m. at the beginning and at the end of each period of sending, and whenever the frequency is changed. If the period of use exceeds 15 minutes, the call-sign must be repeated at the commencement of each 15-minute period. On telephony the call-sign may be confirmed by the use of well-known words having the same initial letters as the letters of the call-sign but the words used must not be of a facetious or objectionable character.

Equipment:—A satisfactory method of frequency stabilization must be used in the transmitter; frequency measuring equipment capable of verifying that the transmitter is within an authorized amateur band

must be provided. The station equipment must be so designed, constructed, maintained and used as not to cause: (a) any avoidable interference with other amateur stations; or (b) any avoidable interference with other "wireless telegraphy" (this includes any service using radio waves: television, radio broadcasting, radio communications, radio navigation, etc.)

On telegraphy precautions must be taken to eliminate the risk of key clicks. At all times, every precaution must be taken to avoid over-modulation, and to keep the transmissions as narrow as possible having regard to the type of emission used. In particular, the radiation of harmonics and other spurious emissions must be suppressed to such a level that they do not cause interference. Tests must be carried out from time to time to ensure that these conditions are fulfilled and details of the tests entered in the log. "Spark" transmitters are specifically forbidden.

A receiver must be available for the frequencies and types of emission in current use at the station.

Aerials and masts must not exceed 50 ft. above ground level within half a mile of the boundary of any aerodrome. Aerials crossing power cables, etc., must be guarded to the satisfaction of the owner of the cables concerned. Note that aerials should be sited as far as possible from any existing television or other receiving aerials in the vicinity, particularly with indoor aerials. In some circumstances it might not be possible to use an indoor aerial.

For Radio Teleprinter (RTTY) operation only the International Telegraph Code No. 2 (5-unit start stop) at speeds of 45.5 or 50 bauds may be used.

Frequencies and Powers:—These and the types of emission are given below.

FREQUENCIES AVAILABLE TO U.K. AMATEURS

Foot-note No.	Frequency Bands (In Mc/s) (See A below)	Classes of Emission (see B)	Power: Maximum D.c. Input Power (see C and D)	Power: Radio Frequency Output Peak Envelope Power for A3A and A3J emissions only (see D)
1 and 5	1·8– 2		10 watts	$26\frac{2}{3}$ watts
2	3·5– 3·8			
	7 – 7·10 14 –14·35 21 –21·45 28 –29·7		150 watts	400 watts
1 and 3	70·1–70·7	A1, A2, A3, A3A, A3H, A3J, F1, F2 and F3	50 watts	$133\frac{1}{3}$ watts
1, 4 & 6	144– 145			
6	145– 146			
1 1 1 1 1 1	427– 450 1215– 1325 2300– 2450 3400– 3475 5650– 5850 10000–10500		150 watts	400 watts
	21000–22000			
1 1 1	2350– 2400 5700– 5800 10050–10450	P1D, P2D, P2E, P3D and P3E	25 watts mean power and 2·5 kilowatts peak power	—
	21150–21850			

A. Except as provided in Footnote 6 below, artificial satellites may not be used by stations in the Amateur Service.

1. This band is allocated to stations in the amateur service on a secondary basis on condition that they shall not cause interference to other services.
2. This band is shared by other services.
3. This band is available to amateurs *until further notice* provided that (i) only the frequency 70·375 Mc/s ± 25 kc/s shall be used for the purposes mentioned in Clause 1 (1) (c) of this Licence; (ii) frequencies between 70·1–70·3 Mc/s inclusive and 70·5–70·7 Mc/s inclusive shall not be used on the North West side of the Line Firth of Lorne to the Moray Firth; and (iii) use by the Licensee of *any* frequency in the band shall cease immediately on the demand of a Government official.
4. The following spot aeronautical frequencies must be avoided *whenever* the band is used: 144·0, 144·09, 144·18, 144·27, 144·36, 144·45, 144·54, 144·63, 144·72, 144·81 and 144·9 Mc/s.
5. The type of transmission known as Radio Teleprinter (RTTY) may not be used in this band.
6. In the band 144–146 Mc/s artificial satellites may be used by stations in the amateur service.

B. The symbols used to designate the classes of emission have the meanings assigned to them in the Telecommunication Convention. They are:

Amplitude Modulation
A1. Telegraphy by on-off keying, without the use of a modulating audio frequency.
A2. Telegraphy by on-off keying of an amplitude-modulating audio frequency or frequencies, or by on-off keying of the modulated emission.
A3. Telephony, double sideband.
A3A. Telephony, single sideband, reduced carrier.
A3H. Telephony, single sideband, full carrier.
A3J. Telephony, single sideband, suppressed carrier.

Frequency (or phase) Modulation
F1. Telegraphy by frequency shift keying without the use of a modulating audio frequency, one of the two frequencies being emitted at any instant.
F2. Telegraphy by on-off keying of a frequency-modulating audio frequency or on-off keying of a frequency modulated emission.
F3. Telephony.

Pulse Modulation
P1D. Telegraphy by on-off keying of a pulsed carrier without the use of a modulating audio frequency.
P2D. Telegraphy by on-off keying of a modulating audio frequency or frequencies or by on-off keying of a modulated pulsed carrier—the audio frequency or frequencies modulating the amplitude of the pulses.
P2E. Telegraphy by on-off keying of a modulating audio frequency or frequencies or by on-off keying of a modulated pulsed carrier—the audio frequency or frequencies modulating the width (or duration) of the pulses.
P3D. Telephony, amplitude modulated pulses.
P3E. Telephony, width (or duration) modulated pulses.

C. D.c. input power is the total direct current power input to (i) the anode circuit of the valve(s) or (ii) any other device energizing the aerial.

D. As an alternative, for A3A and A3J single sideband types of emission, the power shall be determined by the peak envelope power (p.e.p.) under linear operation. The radio frequency output peak envelope power under linear operation shall be limited to 2·667 times the d.c. input power appropriate to the frequency band concerned. This column gives the maximum power determined by this method which may be used.

Preparing for the Technical Examination

It is difficult to suggest just how long it should take to prepare for the R.A.E. So much depends upon the radio knowledge already possessed. Obviously, a complete beginner who does not know how to read theoretical diagrams or who does not have at least a vague idea of how valves and simple receivers work will need longer to reach the necessary standard than someone who has been interested in radio for some time but who has only just become keen on amateur transmission. But whatever the state of your present knowledge, it can soon be improved beyond measure by a little careful study and by taking note of what is read.

Many candidates (but by no means all) study for the exam at a local Technical College or Evening Institute, or attend the special lectures often held by local radio clubs—so check to see if there is a suitable course in your locality. Many others follow Correspondence Courses or are entirely self-taught.

Just as most of us forget the finer details of a novel as soon as we have reached the end, so it is possible to read hundreds of pages of excellent technical books without assimilating more than a tiny fraction of the information contained in them. Haphazard reading is often worse than none at all: the mind becomes confused with half-forgotten and never fully understood technicalities. The answer lies in choosing one or two books which will help you most, and then reading slowly through them, jotting down in a study notebook each new idea, and all the useful *simple* circuits. After you have copied a circuit, close your book, and then try to reproduce it from memory, explaining to yourself what is the purpose of each component.

In this way you will soon learn a tremendous amount about the relatively few *basic* circuits around which almost all amateur apparatus is designed. Start with "straight" receivers, noting the radio frequency and audio frequency amplifiers, detectors, regenerative circuits and power supplies. Once you know these elements you will be surprised how often the same basic circuits appear time and time again even in the most complex superhets and multi-stage transmitters. Never try to commit to memory a complex design as a whole but learn to split it up into its various "stages".

Although the full syllabus for the examination appears at first sight rather formidable, it is possible—where necessary—to compress the amount of preparatory work a little by "intelligent anticipation" of likely questions. This is not just a matter of hopefully guessing at what the test paper will contain. But when the aims and purposes of the examination are considered, it soon becomes clear what type of question is almost certain to occur in some form or other. As one of the main objects of holding the examination is to ensure that amateur operators will not cause interruption to other radio services, it follows that emphasis will always be placed on the causes of broadcast and television interference, harmonic radiation, the suppression of key clicks and parasitic oscillation, overmodulation, the keeping of log books and similar problems. Particular attention should therefore be given to items 1 and 2 of the syllabus.

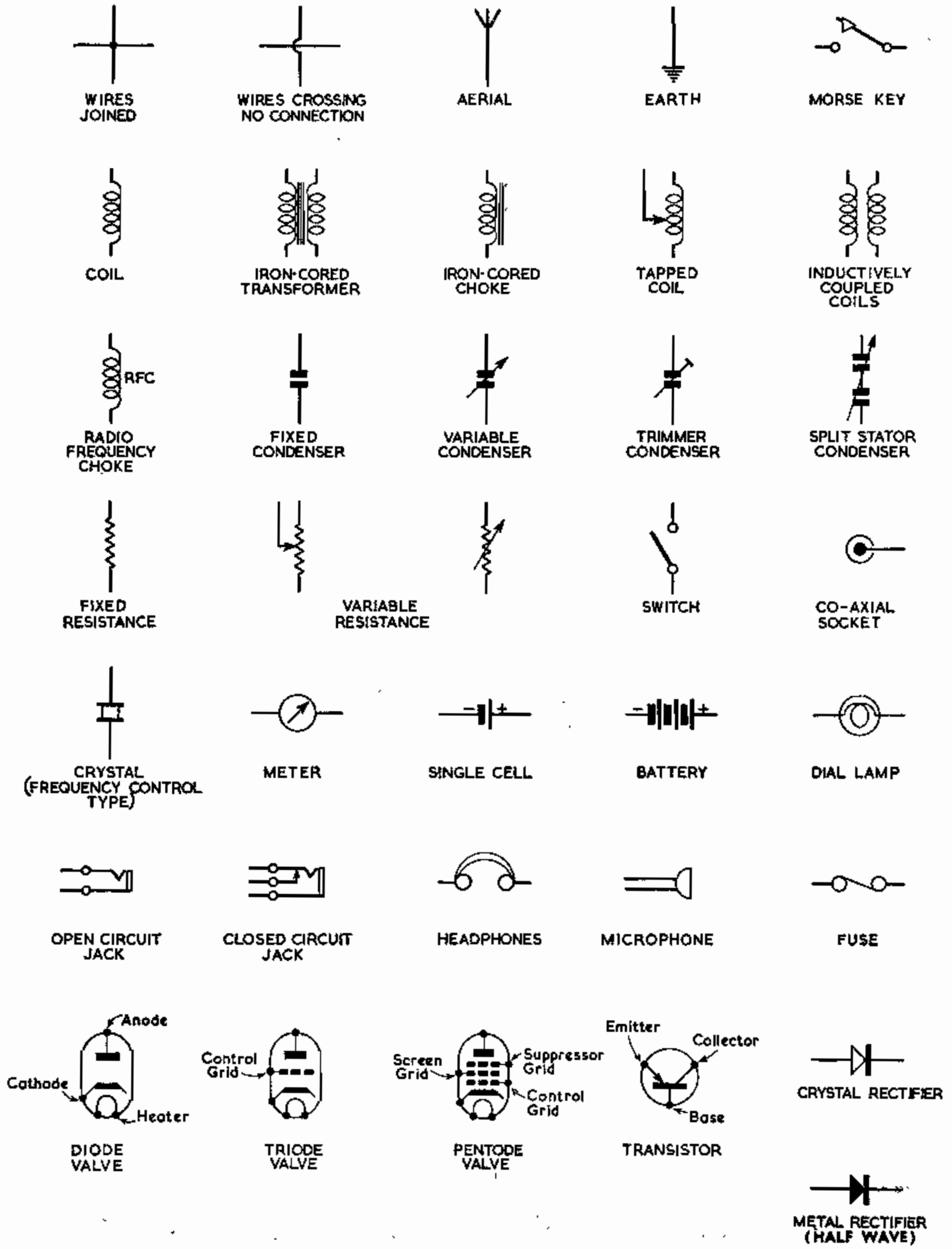
Another tip to candidates is to make sure that their knowledge of simple radio mathematics is sound. The questions set require only comparatively elementary

Technical Abbreviations and Symbols

The following list includes technical abbreviations and symbols commonly found in amateur radio journals.

A	ampere (unit of current)
A1, A2, etc.	types of emission, see page 73
a.c.	alternating current
a.f.	audio-frequency
a.f.c.	automatic frequency control
a.g.c.	automatic gain control
a.m.	amplitude modulation
ant.	antenna (aerial)
a.t.u.	aerial tuning unit
a.v.c.	automatic volume control
b.a.	buffer amplifier
BCI	interference to broadcast reception
b.f.o.	beat frequency oscillator
C	condenser or capacitance
c.f.	cathode follower
c.o.	crystal oscillator
coax.	coaxial cable
Cp	counterpoise
c.r.o.	cathode-ray oscilloscope
c.r.t.	cathode-ray tube
c/s (or c.p.s.)	cycles per second
c.t.	centre tap
c.w.	continuous wave emission (A1) often used to denote telegraphy
dB (or db)	decibel
d.c.	direct current
d.c.c.	double cotton covered (insulation of wire)
d.p.d.t.	double pole double throw (switch)
d.p.s.t.	double pole single throw (switch)
d.s.b.	double sideband emission with suppressed carrier
e.c.o.	electron-coupled oscillator
e.h.t.	extra high tension
e.m.f.	electromotive force
enam.	enamelled (insulation of wire)
e.r.p.	effected radiated power
F	farad (unit of capacity)
f	frequency
f.d.	frequency doubler
f.m.	frequency modulation
f.s.d.	full scale deflection (of meter)
gc	conversion conductance
Gc/s	gigacycles per second (Mc/s x 1000)
gm	mutual conductance
g.b.	grid bias
H	henry (unit of inductance)
h.f.	high frequency (10-100 metres, 3-30 Mc/s)
h.p.	high pass (filter)
I	symbol for current
Ia	anode current (of a valve)
Ig	grid current (of a valve)
Ig2	screen-grid current (of a valve)
Ih	heater current (of a valve)
i.f.	intermediate frequency
i.f.t.	intermediate-frequency transformer
k	kilo (1000 times)
kc/s	kilocycles per second (c/s x 1000)
kV	kilovolts (volts x 1000)
kW	kilowatts (watts x 1000)
kΩ	kilohms (ohms x 1000)
l.p.	low pass (filter)
l.t.	low tension
l.u.f. (or l.u.h.f.)	lowest usable (high) frequency
m.c.w.	modulated continuous wave emission
mic.	microphone
mix.	mixer valve
m.o.	master oscillator
m.u.f.	maximum usable frequency
mult.	(frequency) multiplier
MΩ	megohms (ohms x 1,000,000)
Mc/s	megacycles per second (c/s x 1,000,000)
mA	milliampere (ampere ÷ 1,000)
mA/V	milliamperes per volt
mH	millihenry (henry ÷ 1,000)
mV	millivolt (volt ÷ 1,000)
n.f.m. or n.b.f.m.	narrow band frequency modulation
o.d.	outside diameter
osc.	oscillator
o.w.f.	optimum working frequency
p.a.	power amplifier
p.d.	potential difference (or power doubler)
p.m.	permanent magnet
p.p.	push-pull
p-p	peak-to-peak
pri.	primary winding (of transformer)
p.v.c.	polyvinyl chloride covered
R	resistor or resistance
r.c.c.	resistance-capacitance coupling
rect.	rectifier
r.f.	radio frequency
r.f.c.	radio frequency choke
r.m.s.	root mean square
RT	radio-telephony
RTTY	radioteletype
s.c.c.	single cotton covered (insulation)
sec.	secondary winding (of transformer)
s.g.	screen-grid
s.p.d.t.	single pole double throw (switch)
s.p.s.t.	single pole single throw (switch)
s.s.b. (or s s.s.c.)	single side band, suppressed carrier, emission
s.w.g.	standard wire gauge
T-R	transmit-receive
t.p.i.	turns per inch
t.r.f.	tuned radio-frequency (usually indicating "straight" receiver
TVI	interference to television reception
u.h.f.	ultra high frequency (300 - 3000 Mc/s)
V	volt (unit of potential difference)
v.f.o.	variable frequency oscillator
v.h.f.	very high frequency (30 - 300 Mc/s)
VOX	Voice-operated switching device
v.r.	voltage regulator
W	watt (unit of power)
w/t	wireless-telegraphy
w.w.	wire-wound (resistor)
Z	symbol for impedance
λ	(lambda) wavelength
μ	(mu) micro- (prefix meaning 1/1,000,000th)
μA	microampere (ampere ÷ 1,000,000)
μμF (or pF)	micro-microfarad (picofarad) (μF ÷ 1,000,000)
μH	microhenry (henry ÷ 1,000,000)
μF	microfarad (farad ÷ 1,000,000)
μV	microvolt (volt ÷ 1,000,000)
Ω	(omega) ohms

Radio Circuit Symbols



knowledge of how to use a few basic formulæ; yet year after year the examiners report that the mathematical questions—which are almost certainly the most straightforward ones on the paper—are the most poorly answered. So make sure by a careful revision of any of the many textbooks on elementary radio theory that you are familiar with the formulæ governing resonant frequency, the value of condensers, resistors and inductors in series and parallel, Ohm's Law and the calculation of power, and that you are not unduly put off by such symbols as π and the square root sign.

Passing the Examination

From the examiners' reports it can be seen that many of the candidates who fail do so from a failure to train themselves in examination technique. The older candidates, who may not have taken a written examination for many years, often find that they seem to have lost the knack of putting their knowledge on to paper. Fortunately, examination technique can soon be learned or regained. The main points to remember are:

(1) Always read the question paper, and particularly the introductory remarks, through very carefully—at least two or three times—until you are sure that you know exactly what the examiner requires. Many candidates read the paper too hurriedly and fail to grasp the real point of the questions. There is, for instance, no point in wasting time in drawing a full circuit diagram if the examiner has asked for a block diagram.

(2) Attempt to answer the exact number of questions asked for; neither more nor less. Allot yourself a certain time for each question and try to keep reasonably closely to your provisional schedule. This point is of the utmost importance; it is far better to obtain six out of ten marks in each of eight questions, than to obtain nine out of ten marks for four questions and then find there is no time left to attempt the remainder. If at the end you are pressed for time, jot down even the briefest summary of relevant points rather than submit a paper with less than the required number of questions attempted.

(3) There is no need to keep to the order in which the questions are set, provided you clearly indicate the number of the question you are answering. It may be far better to gain confidence by tackling what you consider to be the easy questions first rather than ploughing doggedly through the paper. But remember point (2) and do not spend too long on your favourite subjects.

(4) Before you begin your answer, note down in your answer book a short list of the main points of the answer as they come to mind, a word or a phrase representing a paragraph. You can then select these points in a logical order. Afterwards draw a line through your original notes to show the examiner that they are not part of your answer.

(5) Pay reasonable heed to the neatness and style of your answers. The examiners are only human and cannot be expected to decipher illegible handwriting. As you complete each question, read carefully through what you have just written, correcting spelling and grammar. Carefully check all drawings—it is all too easy to make an elementary mistake when in a hurry. Do not use Amateur Radio operating abbreviations though of course you may use recognised technical abbreviations and symbols.

(6) Remember that while it is an examination and cannot be considered too lightly, there is no reason to be over-awed by the occasion. It is not a professional examination, and every allowance will be made on that score. All that is required is for you to show that you possess sufficient knowledge about radio and amateur practice to be trusted to make proper use of a transmitting licence. There are never any "trick" questions, and you are not competing against others taking the exam.

The Morse Test

Morse Tests can be taken throughout the year at the G.P.O. Headquarters in London; at any of the Post Office Coast Stations (located at Highbridge, Somerset; Whitley Bay, Northumberland; near Mablethorpe, Lincs.; near Penzance, Cornwall; near Ventnor, Isle of Wight; Broadstairs, Kent; Connel, Argyll; near Stranraer, Wigtownshire; near Almwch, Anglesey; Stonehaven, Kincardineshire; Wick, Caithness; Ilfracombe, Devon); or at any of the Radio Surveyor's Offices (located at Belfast; Cardiff; Falmouth; Glasgow; Hull; Edinburgh; Liverpool; Newcastle-on-Tyne; Southampton). Tests are also held, provided there are sufficient applicants, in March and September of each year, at the Head Post Offices in Birmingham, Cambridge, Derby, Leeds and Manchester.

In the Test, 36 words (average length five letters per word) must be sent and 36 words received in two periods of three minutes each. Up to four errors are permitted in the copy received and up to four corrections may be made while sending; there must be no uncorrected errors in sending. Ten groups of five figures must be sent, and ten groups copied, in two periods of 1½ minutes each; a maximum of two receiving errors are permitted in this section, and up to two corrections made while sending.

The fee for the Post Office Morse test is 10/-.

Learning the Morse Code

Newcomers who really wish to learn Morse operating are few and far between. The majority view it as a necessary evil that has to be surmounted before an "A" licence can be obtained. Yet once achieved, mastery of the code opens up a new world to the short wave enthusiast and proves a source of endless satisfaction. So much so that many amateurs spend most of their time using the Morse key rather than a microphone. But it is a fascination that comes only with experience and eludes the printed page.

It was proved during the 1939-45 war that reasonably competent operators could be trained in a matter of a few months from all sections of the community, young or old, men or women. Admittedly a few exceptional individuals become proficient in a fraction of the time required by the far greater number who find the early stages rather difficult. And yet many who appear to make only slow headway at first often in the long run become the best operators. The real key to Morse is perseverance and a refusal to be discouraged.

The first requirement then is the determination to devote regular time to practice; and this should preferably consist of frequent short periods rather than occasional long sessions. It is far better in the early stages to practice for 15, 30 or 45 minutes daily than to devote a whole evening to it once a week.

A booklet, *The Morse Code for the Radio Amateur* (price 1/9), available from the RSGB, provides full information on how to learn the code and bring your speed up to that required for the GPO test.

A Morse code practice tape, recorded at 3¾ in./sec., is available from the RSGB, price 17/6, post paid. The speed of sending on the 450 ft. tape is approximately 14 w.p.m. The exercises are not intended to teach the code but by running the tape at 1⅞ in./sec., useful practice at 7 w.p.m. is available for beginners. A separate beginners' Morse Code course on a 900 ft. tape is also available.

Morse practice long-playing gramophone records are also available through the Society.

CHAPTER SIX

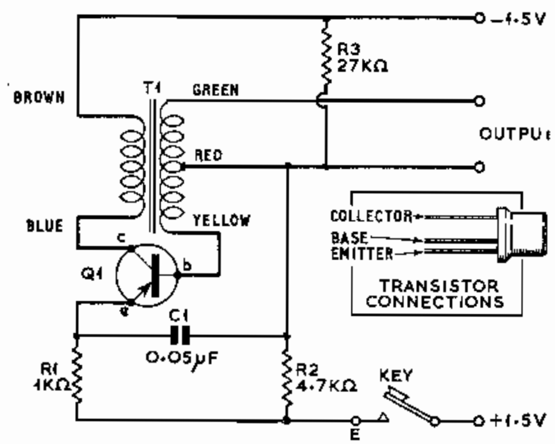
Operating an Amateur Station

NEWCOMERS are often puzzled by the codes and abbreviations used by radio amateurs. These codes are necessary in order to enable international communication to take place with operators who may speak little or no English, and also to save time in conveying information. When using Morse telegraphy, for example, it would take far too long to spell out every word in full, but, by condensing routine phrases into code groups and by abbreviating certain commonly used words, it is possible to transmit and receive information almost as quickly as when operating on telephony.

The Value of Codes

The advantage of using codes was realized by commercial operators in the early days of telegraphic communication with the result that a number of international codes—such as the Q-code—have been established for many years. Amateur operators use these codes but alter them slightly in order to meet their particular needs: in addition, they have adopted many informal abbreviations until today they possess a form of international Morse language—often called "radioese" —which covers all the routine needs of amateur communication. Thus it is possible for an Englishman to enjoy radio contacts in quick succession with, for example, a German, a Spaniard, a Japanese, and a Czech: each understanding the other perfectly.

Fortunately, most of these abbreviations and codes are very easy to learn: in many cases "once seen, never forgotten." The Q code will be found on page 78 and amateur abbreviations on page 79.



A transistor Morse practice oscillator which works from a 1.5 volt dry cell and provides sufficient output to feed two pairs of headphones. Almost any type of audio transistor should prove satisfactory. T1 is a small transistor driver transformer (Osmor Radio). The components can conveniently be assembled on a piece of 1/16 in. paxolin, 2¼ by 2¼ inches with the wiring on the reverse side, but almost any form of construction can be used without affecting results.

THE MORSE CODE AND SOUND EQUIVALENTS

A	di-dah	**S**	di-di-dit
B	dah-di-di-dit	**T**	dah
C	dah-di-dah-dit	**U**	di-di-dah
D	dah-di-dit	**V**	di-di-di-dah
E	dit	**W**	di-dah-dah
F	di-di-dah-dit	**X**	dah-di-di-dah
G	dah-dah-dit	**Y**	dah-di-dah-dah
H	di-di-di-dit	**Z**	dah-dah-di-dit
I	di-dit	**1**	di-dah-dah-dah-dah
J	di-dah-dah-dah	**2**	di-di-dah-dah-dah
K	dah-di-dah	**3**	di-di-di-dah-dah
L	di-dah-di-dit	**4**	di-di-di-di-dah
M	dah-dah	**5**	di-di-di-di-dit
N	dah-dit	**6**	dah-di-di-di-dit
O	dah-dah-dah	**7**	dah-dah-di-di-dit
P	di-dah-dah-dit	**8**	dah-dah-dah-di-dit
Q	dah-dah-di-dah	**9**	dah-dah-dah-dah-dit
R	di-dah-dit	**0**	dah-dah-dah-dah-dah

(0 is sometimes sent as one long dah)

Punctuation

Frequently employed in Amateur Radio

Question Mark	di-di-dah-dah-di-dit
Full Stop	di-dah-di-dah-di-dah
Comma*	dah-dah-di-di-dah-dah

**Often used to indicate exclamation mark.*

Procedure Signals

Stroke	dah-di-di-dah-dit
Break sign (=)	dah-di-di-di-dah
End of Message (+ or $\overline{AR}$)	di-dah-di-dah-dit
End of Work ($\overline{VA}$)	di-di-di-dah-di-dah
Wait ($\overline{AS}$)	di-dah-di-di-dit
Preliminary call ($\overline{CT}$)	dah-di-dah-di-dah
Error	di-di-di-di-di-di-di-dit
Invitation to transmit (K)	dah-di-dah

Note also the procedure signal used by many amateur stations inviting a named station only to transmit $\overline{KN}$ dah-di-dah-dah-dit

★ ★ ★

One dah should be equal to three di's (dit's).

The space between parts of the same letter should be equal to one di (dit).

The space between two letters should be equal to three di's (dit's).

The space between two words should be equal to from five to seven di's (dit's).

A Typical Telegraphy Contact

The following imaginary c.w. contact is shown in full to give newcomers an idea of the general form of amateur operating procedure: operators, however, should guard against allowing their contacts to become too rigidly set in the "rubber-stamp" mould.

CQ CQ CQ CQ DE G3ZZZ G3ZZZ + K

G3ZZZ G3ZZZ DE GM2XXX GM2XXX + K

GM2XXX DE G3ZZZ = GM OM ES MNI TKS FER CALL = UR SIGS RST 579X = QTH LONDON = NAME HR IS JOHN NW PSE HW? + GM2XXX DE G3ZZZ K

G3ZZZ DE GM2XXX = R FB ES GM JOHN = TKS FER RPRT ES GLD TO MEET U = UR RST 558C = QTH EDINBURGH ES NAME MAC = WX COLD ES DULL = RIG IS VFO/FD/PA WID 75 WATTS INPT ES ZEPP ANT = RX IS DOUBLE SUPER = OK? + G3ZZZ DE GM2XXX K

GM2XXX DE G3ZZZ = R OK MAC ES TKS FER ALL = SRI ABT CHIRP HR NEW VFO = RIG IS VFO/PA WID 15 WATTS ES 132 FT LONG WIRE = HR CNDX POOR FER DX = QSL VIA RSGB = NW QRU? + GM2XXX DE G3ZZZ K

G3ZZZ DE GM2XXX = MOST OK JOHN BUT NW VY HVY QRM ON FREQ = OK UR RIG ES WL SURE QSLL = NW 73 ES HPE CUAGN SN = GM JOHN ES GUD DX + G3ZZZ DE GM2XXX VA

GM2XXX DE G3ZZZ = R FB MAC ES MNI TKS FER QSO = 73 ES BCNU GB + GM2XXX DE G3ZZZ VA

READABILITY

R1 Unreadable.
R2 Barely readable, occasional words distinguishable.
R3 Readable with considerable difficulty.
R4 Readable with practically no difficulty.
R5 Perfectly readable.

SIGNAL STRENGTH

S1 Faint, signals barely perceptible.
S2 Very weak signals.
S3 Weak signals.
S4 Fair signals.
S5 Fairly good signals.
S6 Good signals.
S7 Moderately strong signals.
S8 Strong signals.
S9 Extremely strong signals.

TONE

T1 Extremely rough hissing note.
T2 Very rough a.c. note, no trace of musicality.
T3 Rough, low-pitched a.c. note, slightly musical.
T4 Rather rough a.c. note, moderately musical.
T5 Musically modulated note.
T6 Modulated note, slight trace of whistle.
T7 Near d.c. note, smooth ripple.
T8 Good d.c. note, just a trace of ripple.
T9 Purest d.c. note.

If the note appears to be crystal-controlled add X after the appropriate number. Where there is chirp add C, drift add D, clicks add K.

For amateur c.w. operation, the RST code, devised originally by W2BSR, is now universally adopted. R denotes readability, S indicates signal strength, and T the tone of the note. On telephony, a similar code but omitting the tone report is generally adopted.

THE INTERNATIONAL Q CODE

The following Q signals taken from the official list are widely used in the Amateur Service.

QRG Will you tell me my exact frequency? Your exact frequency is............kc/s.
QRH Does my frequency vary? Your frequency varies.
QRI What is the tone of my transmission? The tone of your transmission is ....(amateur T1 — T9).
QRK What is the readability of my signals? The readability of your signals is............(amateur R1 — R5).
QRL Are you busy? I am busy. Please do not interfere.
QRM Are you being interfered with? I am being interfered with.
QRN Are you troubled by static? I am troubled by static.
QRO Shall I increase power? Increase power.
QRP Shall I decrease power? Decrease power.
QRQ Shall I send faster? Send faster.
QRS Shall I send more slowly? Send more slowly.
QRT Shall I stop sending? Stop sending.
QRU Have you anything for me? I have nothing for you.
QRV Are you ready? I am ready.
QRX When will you call me again? I will call you again at............hours.
QRZ Who is calling me? You are being called by............(on kc/s).
QSA What is the strength of my signals? The strength of your signals is............(amateur S1 — S9).
QSB Are my signals fading? Your signals are fading.
QSD Is my keying defective? Your keying is defective.
QSL Can you give me acknowledgment of receipt? I give you acknowledgment of receipt.
QSO Can you communicate with............direct or by relay? I can communicate with............direct (or by relay through............).
QSP Will you relay to? I will relay to............
QSV Shall I send a series of VVVs? Send a series of VVVs.
QSY Shall I change to another frequency? Change to transmission on another frequency (or on............kc/s).
QSZ Shall I send each word more than once? Send each word twice.
QTH What is your location? My location is............
QTR What is the correct time? The correct time is............hours.

Punctuation signals are seldom used, sections of a transmission being split up by means of the break (double hyphen =) sign.

Unless asked to do so, or given a readability report less than R4, words should be sent once only. Exceptions are the RST report, location and name, which are generally sent twice.

A common, but most annoying, fault is the sending of long strings of CQ calls without interspersing the station's call-sign. A good rule is to send *four* (or, at the most, five) CQs followed by the station call-sign *twice*, *e.g.*, CQ CQ CQ CQ DE G3ZZZ G3ZZZ CQ CQ CQ CQ DE G3ZZZ G3ZZZ etc.

Amateurs often use Q-signals as nouns rather than in question and answer form. Examples are:

QRG	... Frequency	QRT	... Close down
QRI	... Bad note	QRX	... Stand by
QRK	... Signal strength	QSB	... Fading
QRM	... Interference from other stations	QSD	... Bad sending
		QSL	... Verification card
QRN	... Interference from atmospherics or local electrical apparatus	QSO	... Radio contact
		QSP	... Relay message
		QSY	... Change of frequency
QRO	... High power	QTH	... Location (sometimes the older code group QRA is still used)
QRP	... Low power		

Telephony Operation

Whereas a poor or inconsiderate c.w. operator is a nuisance only to his fellow enthusiasts, bad telephony operation discredits Amateur Radio generally. The man-in-the-street judges our hobby by the quality of our telephony transmissions, the subjects discussed, and the procedure used

When using telephony, operators should talk normally and avoid the excessive use of amateur abbreviations and jargon other than signal reporting codes or, when it becomes necessary, to make themselves understood by foreign amateurs.

Contests and Band Planning

Although Amateur Radio is primarily a scientific pursuit the hobby possesses a strong competitive side which is well catered for by a number of contests mostly of an annual nature. These events provide opportunities to test not only equipment but also the skill and ability of those who compete.

The types of contest vary widely, from international events extending over several weekends to concentrated three-hour hidden transmitter hunts in which physical endurance is almost as necessary as radio equipment. Almost all operating interests are catered for: DX (c.w. and telephony); Top Band; low power; portable; single operator and club and group events; v.h.f. and u.h.f.; and lightweight portable work.

In addition to contests, there are many other ways in which the radio amateur is able to show his prowess. Certificates and awards for various feats of operating ability and skill are issued by societies and Amateur Radio magazines all over the world.

In order to make the best possible use of the frequencies available to radio amateurs, the Radio Society of Great Britain suggested some years ago that a voluntary Band Plan should be adopted by all users of the 3.5, 7, 14, 21 and 28 Mc/s bands.

The primary purpose of the Plan is to protect those who use c.w. telegraphy.

The Band Plan, which has been adopted by the European section of the International Amateur Radio Union, is as follows:—

Frequency Band	Use
3500 — 3600 kc/s	Telegraphy only
3600 — 3800 kc/s	Telegraphy and Telephony
7000 — 7040 kc/s	Telegraphy only
7040 — 7100 kc/s	Telegraphy and Telephony
14000 — 14100 kc/s	Telegraphy only
14100 — 14350 kc/s	Telegraphy and Telephony
21000 — 21150 kc/s	Telegraphy only
21150 — 21450 kc/s	Telegraphy and Telephony
28000 — 28200 kc/s	Telegraphy only
28200 — 29700 kc/s	Telegraphy and Telephony

RTTY operation is recommended to take place around 14090 kc/s.

Zoning plans have also been adopted for 144 and 430 Mc/s (that for 144 Mc/s is given on page 11).

Amateur Abbreviations

AA	All after . . . (used after a question mark to request a repetition)
AB	All before . . . (see AA)
BK	Signal used to interrupt a transmission in progress
BN	All between . . . and . . . (see AA)
C	Yes
CFM	Confirm (or I confirm)
CL	I am closing my station
CQ	General call to all stations
DE	Used to separate the call-sign of the station called from that of the calling station
ER	Here
K	Invitation to transmit
N	No
NIL	I have nothing to send to you
NW	Now
OK	We agree (or It is correct)
R	Received
RPT	Repeat (or I repeat)
TFC	Traffic
W	Word(s)
WA	Word after (see AA)
WB	Word before

Informal Amateur Abbreviations

ABT	about
ADR	address
AGN	again
ANI	any
ANT	antenna (aerial)
BA	buffer amplifier
BC	broadcast
BCI	broadcast interference
BCL	broadcast listener
BCNU	be seeing you
BD	bad
BFO	beat frequency oscillator
BK	break-in
BLV	believe
BUG	semi-automatic key
CANS	headphones
CC	crystal-controlled
CK	check
CLD	called
CNT	cannot
CO	crystal oscillator
CONDX	conditions
CPSE	counterpoise
CRD	card
CUD	could
CUAGN	see you again
CUL	see you later
CW	continuous wave
DF	direction finding
DR	dear
DX	long distance
DXCC	DX Century Club
ECO	electron-coupled oscillator
ELBUG	electronic key
ENUF	enough
ES	and
FB	fine business
FOC	First Class Operators' Club
FCC	Federal Communications Commission
FD	frequency doubler
FM	frequency modulation
FER	for
FONE	telephone
FREQ	frequency
GA	go ahead, or good afternoon
GB	goodbye
GD	good day
GE	good evening
GG	going
GLD	glad
GM	good morning
GN	good night
GND	ground (earth)
GUD	good
HAM	amateur transmitter
HI	laughter
HPE	hope
HR	here or hear
HRD	heard
HV	have
HVY	heavy
HW	how
IARU	International Amateur Radio Union
II	repetition signal
INPT	input
LID	poor operator
LSN	listen
MNI	many
MO	master oscillator
MOD	modulation
MSG	message
MTR	meter (or metres)
NBFM	narrow band frequency modulation
ND	nothing doing
NR	number
OB	old boy
OC	old chap
OM	old man
OP	operator
OT	old timer
PA	power amplifier
PP	push-pull
PSE	please
PWR	power
RAC	rectified (raw) A.C.
RAOTA	Radio Amateur Old Timers' Association
RCC	Rag Chewers' Club
RCVR	receiver
RPRT	report
RX	receiver
SA	say
SED	said
SIG	signal
SKED	schedule
SN	soon
SRI	sorry
SSB	single sideband
STN	station
SUM	some
SW	short-wave
SWL	short-wave listener
TFC	traffic
TKS	thanks
TMW	tomorrow
TNX	thanks
TRI	try
TV	television
TVI	television interference
TX	transmitter
U	you
UR	your
VFO	variable frequency oscillator
VY	very
W	watts
WAC	Worked all Continents
WID	with
WKD	worked
WKG	working
WL	will or well
WUD	would
WX	weather
XMTR	transmitter
XYL	wife
XTAL	crystal
YF	wife
YL	young lady
73	best regards
88	love and kisses

Amateur Radio Prefixes

AC3	Sikkim
AC4	Tibet
AC5	Bhutan
AP	Pakistan
BV	Formosa
BY	China
C9	Manchuria
CE	Chile
CE7Z-CE9	Antarctica
CE0A	Easter Island
CE0Z	Juan Fernandez Is.
CM	Cuba (telegraphy)
CN2	Tangier
CN8	Morocco
CO	Cuba (telephony)
CP	Bolivia
CR4	Cape Verde Is.
CR5	Portuguese Guinea, Principe and Sao Thome
CR6	Angola
CR7	Mozambique
CR8	Portuguese Timor
CR9	Macau
CS	Portugal (experimental)
CT1	Portugal
CT2	Azores
CT3	Madeira
CX	Uruguay
DI	Germany (special)
DJ	Germany
DL	Germany
DL2	Germany (U.K. assigned)
DL4	Germany (U.S. assigned)
DL8	Germany (Saarland)
DM	Germany (East Zone)
DU	Philippines
EA	Spain
EA6	Balearic Is.
EA8	Canary Is.
EA9	Spanish Morocco, Rio de Oro, Ifni
EA0	Spanish Guinea
EI	Eire
EL	Liberia
EP	Persia (Iran)
EQ	Persia (Iran)
ET2	Eritrea
ET3	Ethiopia
F	France
FB	Glorieuses Is., Comono Is., New Amsterdam and St. Paul Is., Kerguelen Is., Tromelin Is.
FC	Corsica
FG	Guadeloupe
FH8	Comoros Isle
FK	New Caledonia
FL	French Somaliland
FM	Martinique
FO	French Oceania (e.g. Tahiti), Clipperton Is.
FP	St. Pierre and Miquelon Is.
FR	Reunion Island
FS7	St. Martin
FU	New Hebrides
FW	Wallis and Futuna Is.
FY	French Guiana
G	England
GB	United Kingdom (Exhibitions and Special Purposes)
GC	Channel Islands
GD	Isle of Man
GI	Northern Ireland
GM	Scotland
GW	Wales
HAHG	Hungary
HB1	Switzerland (portable)
HB9	Switzerland
HC	Ecuador
HH	Galapagos Is.
HC8	Liechtenstein
HE	Haiti
HI	Dominica
HK	Colombia
HK0	San Andres, Providencia
HL, HM	Korea
HP	Panama
HR	Honduras
HS	Siam
HV	Vatican City
HZ	Saudi Arabia
I	Italy
IS	Sardinia
IT	Sicily
JA, JH	Japan
JA0	Bonin and Volcano Is.
JT	Mongolia
JW	Jan Mayen
JX	Svalbard
JY	Jordan
K, KN	U.S.A. (for Districts see under "W")
KA	Japan (Amer. assigned)
KA0	Bonin and Volcano Is.
KB6	Baker, Howland and Amer. Phoenix Is.
KC4	Navassa Is.
KC4	Antarctica
KC6	Caroline and Palua Is.
KG4	Guantanamo Bay
KG6	Mariana Islands, Marcus Is., Guam.
KH6	Hawaiian Islands, Kure Is.
KJ6	Johnston Island
KL7	Alaska
KM6	Midway Islands
KP4	Puerto Rico
KP6	Palmyra Group, Jarvis Island
KR6	Ryukyu Islands (e.g., Okinawa)
KR8	Okinawa (Japanese Nationals)
KS4	Swan Islands, Roncador Cay and Serrana Bank
KS6	American Samoa
KV4	Virgin Islands
KW6	Wake Island
KX6	Marshall Islands
KZ5	Panama Canal Zone
LA	Norway
LB	Norway (Special)
LH	Bouvet Is.
LU	Argentina
LX	Luxembourg
LZ	Bulgaria
M1	San Marino
MP4	Kuwait, Qatar, Trucial Oman
MP4B	Bahrein Island
MP4T	Muscat
OA	Peru
OD	Lebanon
OE	Austria
OH	Finland
OH0	Aland Is.
OK	Czechoslovakia
ON	Belgium
OX	Greenland
OY	Faeroes
OZ	Denmark
PA	Holland
PI	Holland (Special)
PJ	Dutch West Indies
PJ2M	St. Maarten
PK	Indonesia
PX	Andorra
PY	Brazil
PY0	Fernando de Noronha, Trindade and Vaz Is.
PZ	Dutch Guiana
SL	Sweden (Special)
SM	Sweden
SP	Poland
ST	Sudan
SU	Egypt
SV	Greece and Crete
SV5	Dodecanese Islands
TA	Turkey
TF	Iceland
TG	Guatemala
TI	Costa Rica
TI9	Cocos Is.
TJ	Cameroons
TL8	Central African Republic
TN8	Congo Republic (formerly French Congo)
TR8	Gabon Republic
TT8	Tchad Republic
TU2	Ivory Coast
TY	Dahomey Republic
TZ	Mali Republic
UA, UV, UW, RA 1, 3, 4, 5, 6	European Russian S.F.S.R
UA2	Kaliningradsk
UA9, 0, UW9	Asiatic R.S.F.S.R.
UB5, UT5, UY5	Ukraine
UC2	White Russia
UD6	Azerbaijan
UF6	Georgia
UG6	Armenia
UH8	Turkoman
UI8	Uzbek
UJ8	Tadzhiz
UL7	Kazakh
UM8	Kirghiz
UN1	Finno-Karelia
UO5	Moldavia
UP2	Lithuania
UQ2	Latvia
UR2	Estonia
VE, VO	Canada
VE1	Maritime Provinces
VE2	Province of Quebec
VE3	Province of Ontario
VE4	Province of Manitoba
VE5	Province of Saskatchewan
VE6	Province of Alberta
VE7	Province of British Columbia
VE8A-L	Yukon Territories
VE8M-Z	N.W. Territories
VO2	Newfoundland
VO6	Labrador
VK0	Heard Is., Macquarie Is., Cocos Is.
VK1-8	Australia
VK1	Canberra
VK2	New South Wales
VK3	Victoria
VK4	Queensland
VK5	South Australia
VK6	Western Australia
VK7	Tasmania
VK8	Northern Territories
VK9	New Guinea, Norfolk Is., Papua, Nauru, Cocos-Keeling and Admiralty Islands
VO	See under VE
VP1	British Honduras
VP2	Leeward Is., Windward Is.
VP2A	Antigua and Barbuda
VP2D	Dominica
VP2G	Grenada
VP2H	Anguilla
VP2K	St. Kitts and Nevis
VP2L	St. Lucia
VP2M	Montserrat
VP2S	St. Vincent
VP2V	Brit. Virgin Isles
VP3	British Guiana
VP5	Turks and Caicos Islands
VP6	Barbados
VP7	Bahamas
VP8	Falkland Is., S. Georgia, S. Orkneys, Shetland Is., Sandwich Is., Grahamland
VP9	Bermudas
VQ1	Zanzibar
VQ7	Aldabra Is.
VQ8	Mauritius
VQ8B	St. Brandon Is.
VQ8C	Chagos
VQ8R	Rodriques
VQ9	Seychelles
VR1	Gilbert and Ellice Is., Brit. Phoenix Is.
VR2	Fiji
VR3	Fanning Is. (Christmas Is.)
VR4	Solomon Is.
VR5	Tonga (Friendly) Is.
VR6	Pitcairn Is.
VS5	Brunei
VS6	Hong Kong
VS9	Aden, Socotra Is.
VS9K	Kamaran
VS9M	Maldive Is.
VS9O	Sultanate of Oman
VU2	India
VU5	Andaman Is., Laccadive Is.
W, WA, WN, WV,	United States of America (see also KH6, KL7)

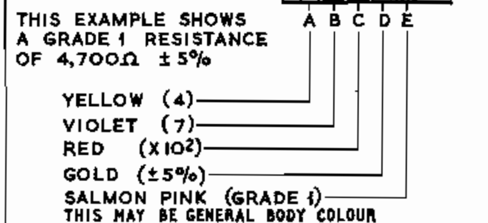
K, KN	
W1	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
W2	New Jersey, New York
W3	Delaware, Maryland, Pennsylvania (including District of Columbia)
W4	Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia
W5	Arkansas, Louisiana, Mississippi, New Mexico, Oklahoma, Texas
W6	California
W7	Arizona, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming
W8	Michigan, Ohio, West Virginia
W9	Illinois, Indiana, Wisconsin
W0	Colorado, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
XE, XF	Mexico
XE4	Revilla Gigedo
XT2	Upper Volta
XW8	Laos
XZ	Burma
YA	Afghanistan
YI	Iraq
YJ	New Hebrides
YK	Syria
YN	Nicaragua
YO	Roumania
YS	Salvador
YU	Yugoslavia
YV	Venezuela
YV0	Aves Is.
ZA	Albania
ZB2	Gibraltar
ZC3	Christmas Island
ZD3	Gambia
ZD5	Swaziland
ZD7	St. Helena
ZD8	Ascension Island
ZD9	Tristan da Cunha, Gough Is.
ZE	Rhodesia
ZF1	Cayman Isles
ZK1	Cook Island
ZK2	Niue
ZL	New Zealand, Chatham Is., Kermadec Is.
ZL1	Auckland District
ZL2	Wellington District
ZL3	Canterbury District
ZL4	Otago District
ZL5	New Zealand Antarctica
ZM6	Western Samoa
ZM7	Tokelau Is.
ZP	Paraguay
ZS	Rep. of South Africa, Prince Edward and Marion Is.
ZS1	Cape District
ZS2	Cape Province (excluding ZS1)
ZS4	Orange Free State
ZS5	Natal (including Zululand)
ZS6	Transvaal
ZS3	South West Africa
ZS8	Basutoland
ZS9	Bechuanaland
3A2	Monaco
3V8	Tunisia
3W8	Cambodia, Viet Nam
4M	Venezuela
4S7	Ceylon
4U1ITU	ITU, Geneva
4W	Yemen
4X4	Israel
5A	Libya
5B4	Republic of Cyprus
5H3	Tanganyika
5N2	Nigeria
5R8	Malagasy Republic
5T5	Mauritania
5U7	Niger Republic
5V	Togo
5W1	British Samoa
5X5	Uganda
5Z4	Kenya
6O	Somali Republic
6W8	Senegal Republic
6Y	Jamaica
7G1	Guinea Republic
7Q	Malawi
7X2	Algeria
8F4	Indonesia
8J1	Antarctica (also OR4, VK0 ZL5, VP8)
8Z4	Iraqui/Saudi Arabia Neutral Zone
8Z5	Kuwait/Saudi Arabia Neutral Zone
9A1	San Marino
9G2	Ghana
9H1	Malta
9K2	Kuwait
9J2	Zambia
9L1	Sierra Leone
9M6, 9M8	East Malaysia
9M2, 9M4	West Malaysia
9N	Nepal
9Q5	Congo Republic
9U5	Burundi
9V1	Singapore
9X5	Rwanda
9Y4	Trinidad

COLOUR CODE FOR RESISTORS AND CAPACITORS

Colour	Value in ohms or pF for Cols. A, B & C				Band D. (Tolerance rating)			Capacitors Band E. Temp. Coefficient per 10^6 per °C.
	Band A First Figure	Band B Second Figure	Band C (Multiplier) Resistors (ohms)	Band C (Multiplier) Capacitors (pF)	Resistors	Ceramic Capacitors Up to 10pF	Ceramic Capacitors Over 10pF	
Black	—	0	1	1	—	2pF	±20%	0
Brown	1	1	10	10	±1%	0·1pF	± 1%	−30
Red	2	2	100	100	±2%	—	± 2%	−80
Orange	3	3	1,000	1,000	—	—	±2·5%	−150
Yellow	4	4	10,000	10,000	—	—	—	−220
Green	5	5	100,000	—	—	0·5pF	± 5%	−330
Blue	6	6	1,000,000	—	—	—	—	−470
Violet	7	7	10,000,000	—	—	—	—	−750
Grey	8	8	100,000,000	0·01µF	—	0·25pF	—	+30
White	9	9	1,000,000,000	0·1µF	—	1pF	±10%	+100
Silver	—	—	0·01	—	±10%	—	—	—
Gold	—	—	0·1	—	± 5%	—	—	—
Salmon Pink	—	—	—	—	—	—	—	—

Standard tolerances for resistors are as follows: wire-wound type: 1%, 2%, 5%, 10%; composition type, grade 1: 1%, 2%, 5%; grade 2: 5%, 10%, 20% (20% is indicated by a fourth (D band) colour). Grade I high-stability composition resistors are distinguished by a salmon-pink fifth ring or body colour. (Reference: B.S. 1852: 1952 B.S.I.)

FIG. 1
COLOURED BAND MARKING PREFERRED



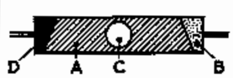


FIG. 2
BODY, TIP AND SPOT MARKING

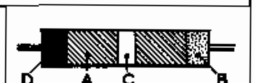
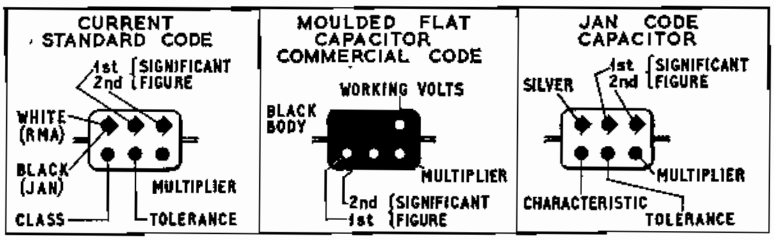


FIG. 3
BODY, TIP AND CENTRAL BAND MARK'G



(Left) American RMA, JAN and Commercial markings for moulded mica capacitors

CHAPTER SEVEN

The RSGB and the Radio Amateur

H.R.H. The Prince Philip, Duke of Edinburgh, K.G.—the Society's Patron—broadcasting a message over an Amateur Radio Station at Yellowknife, North West Territory.

THE Radio Society of Great Britain (RSGB) is the National Society of radio amateurs in the United Kingdom. Over 8000 of its more than 14,500 members hold amateur transmitting licences; the remaining 6000 or so members either hope to do so later or are interested primarily in the receiving side of Amateur Radio. Over 1000 members live overseas.

H.R.H. The Prince Philip, Duke of Edinburgh, K.G., is the Society's Patron.

The Society acts as the spokesman for the radio amateur in the United Kingdom and is one of the Founder Members of the International Amateur Radio Union, the world-wide association of the various National Societies.

The Society was founded (as the London Wireless Club) more than fifty years ago (1913) but soon attracted members throughout the country; the name of Radio Society of Great Britain was formally adopted in 1922. For many years its activities have been devoted almost entirely to the many aspects of Amateur Radio—that is, the transmission and reception of short-wave and ultra-short-wave radio signals as a hobby.

The Society helps Amateur Radio in many ways. Of particular importance is the provision of information on technical matters and on the various activities and events of concern to amateurs. Since 1925 it has published a monthly journal—the *RSGB Bulletin*—the oldest and largest magazine devoted to Amateur Radio in this country. All members receive this magazine by post, without payment other than their annual membership subscriptions to the Society.

The Society is administered by a Council elected by the Corporate membership. The Council includes members from all parts of the country. A full-time, staffed Headquarters is maintained in London. There are also 17 elected Regional Representatives who, with the help of Area Representatives, arrange local meetings and other activities.

More than 250 local societies and clubs are in affiliation with the Society.

The Society is proud of its half-century role in the development of Amateur Radio and of the many eminent scientists who have been connected with it—including Marconi, Lodge and Fleming. It was the organised radio amateurs who originally demonstrated that wavelengths below 100 metres could provide world-wide communication on low power. But the Society looks to the future, rather than the past, and concentrates its efforts on the effective organisation of amateur activity, to provide the greatest opportunities for useful experimental work, and to encourage general interest in and enjoyment of the hobby of Amateur Radio.

WHY YOU SHOULD JOIN

All those who are actively engaged in any form of Radio Research Experimentation or Communication are eligible for election as Corporate Members. This includes anyone who builds or operates amateur radio equipment. You do not have to be engaged professionally in radio—but equally this would not debar you from joining. Many members do in fact work in the electronics field—often as the result of their interest in Amateur Radio—but for very many others radio is purely a spare-time hobby. If you are under 21 years of age, a genuine interest in experimental radio makes you eligible for Associate Membership. Associates have many of the privileges of full membership but do not vote in the annual Council election or on matters affecting the management of the Society. Licensed amateurs cannot be Associates.

The following are just a few of the many reasons why, if you are really interested in Amateur Radio, you should join the RSGB immediately.

You will receive every month a copy of the *RSGB Bulletin*, recognised as providing a complete and accurate survey of every phase of Amateur Radio activity. Containing at least 64 pages each month, the *Bulletin* is noted internationally for the high standard of its technical and constructional articles, written by Britain's leading radio amateurs, and the wide scope of its news coverage. The needs of newcomers are not overlooked in the selection of technical articles. A sample back issue will be gladly sent for 2/6 post free.

You will be able to use the world's largest and most comprehensive free QSL Bureau operated by the Society. Use of this efficient Bureau will save the active amateur and listener a great deal of trouble and expense. QSL cards are sent and received from the Bureau in batches. This eliminates the need for stamping, addressing and posting of individual cards. The Bureau distributes the cards via other National Societies' bureaux to amateurs throughout the world. Full details of how the QSL Bureau operates are sent to every member on election.

You will receive a certificate of membership and a lapel badge which identifies you as part of the Amateur Radio movement. Members who do not hold amateur transmitting licences are given special identification numbers for use in connection with the QSL Bureau, beginning BRS (British Receiving Station), ORS (Overseas Receiving Station), or A. (Associate), followed by a number.

You will be encouraged to contribute, according to your interests, to the advancement of Amateur Radio. Many members serve as local representatives or on local or national committees, or pass on to other members through the *Bulletin* or by lectures the results of their experiments and observations. The members in fact *are* the Society.

The Society helps organize many special scientific studies and tests, and has set up a Radio Amateur Emergency Network in collaboration with the British Red Cross Society, the St. John Ambulance Brigade and the Police.

The Society maintains special committees dealing with such matters as television interference, licences and questions concerned with the Town and Country Planning Act, which are often able to help with related problems.

The Society is recognised as the representative of the Amateur Radio movement in all negotiations with the Post Office on matters affecting the issue of amateur transmitting licences.

The Society has been established for over half a century. It has a long record of sound and efficient administration, through an elected Council, aided by a full-time Secretariat.

HOW TO JOIN THE RSGB

Joining the RSGB is simple, but there are of course certain formalities to be observed. As explained earlier, anyone with an active and genuine interest in Amateur Radio is warmly welcome to apply for membership.

All applicants, for both Corporate and Associate membership, should be proposed by a Corporate Member of the Society to whom they are personally known. The member simply completes the proposal on the Application Form, and you will find that he will be glad to do this.

The Society however fully recognizes that many newcomers to Amateur Radio—who are most welcome as members—may not know or be in touch with other members. In such cases a brief reference in writing should be submitted from a suitable person who can vouch for your interest in Amateur Radio.

In order to apply for Associate membership, you must be under 21 years of age and not be a holder of an amateur transmitting licence. Associates must apply for transfer to Corporate membership on reaching 21 years of age or, if under this age, immediately they obtain a transmitting licence.

An application form for Corporate membership is included on page 88. If you wish to apply for Associate membership you should ask the Society for the appropriate application form.

All applications are placed before the Council at its monthly meetings, generally held during the second or third week of the month.

The current annual subscription rates are: Corporate Members £2 10s.; Associates £1 5s. There is no entry fee. The first year's subscription should be sent with the application form. After having been a Corporate Member for five consecutive years, subject to the approval of Council, a member can commute all future annual subscriptions by a payment of a fee determined by the Council.

All correspondence should be sent to the Radio Society of Great Britain, 28 Little Russell Street, London, W.C.1. The telephone numbers are HOLborn 7373 and 2444.

WHAT THE SOCIETY DOES

Some of the important activities of the Society have already been described, but there are many other ways in which the Society helps radio amateurs and all those interested in Amateur Radio. A few of these are outlined below.

Publications

The main publishing activity of the Society is in producing the monthly *RSGB Bulletin*. But the Society also produces many books and other publications to help the amateur. Because the Society is anxious to disseminate sound technical information as widely as possible, many of these publications are issued at prices well below what a commercial publishing organization would have to charge. A notable example is the *RSGB Amateur Radio Handbook*, a large up-to-date book of over 500 pages covering principles, design and construction of all types of amateur equipment. Some publications of the Society are specially written for newcomers to help them obtain transmitting licences; these include this booklet, *A Guide to Amateur Radio*, and also *The Radio Amateurs' Examination Manual* and *The Morse Code for Radio Amateurs*. The Society also provides facilities for obtaining a selection of the many Amateur Radio publications issued in the United States where there are over a quarter-million radio amateurs.

Technical guidance and a large number of practical hints and circuits will be found in *Technical Topics for the Radio Amateur*.

Meetings

Official Society meetings are held throughout the British Isles. Local meetings are held by RSGB Groups and by affiliated societies. Mobile rallies and specialised conventions are also held regularly. A full list of Forthcoming Events appears monthly in the *RSGB Bulletin*. A list of affiliated societies and clubs is given in the *RSGB Amateur Radio Call Book*.

Frequencies

The Society maintains close liaison with the GPO on all matters affecting licence facilities and the frequencies assigned to Amateur Radio, and regularly sends official representatives to the important World Radio Conferences of the International Telecommunication Union and other conferences where decisions vital to the future of Amateur Radio are taken.

Contests and Field Days

Many interesting Tests, Contests and Field Days—some of which are open to listeners as well as transmitting members—are held each year. Trophies or Certificates are awarded to leading entrants.

Achievement Certificates

A number of Certificates representing graded degrees of achievement in Amateur Radio operating (receiving as well as transmitting) are issued by the Society. These include the DX Listeners' Century Award, the Worked the British Commonwealth Award, Four Metres and Down Certificates and the Commonwealth DX Certificate. The Rules governing all awards are available from RSGB Headquarters.

GB2RS SCHEDULE

RSGB News Bulletins are transmitted on Sundays in accordance with the following schedule:

Frequency	Time	Location of Station
3600 kc/s	9.30 a.m.	South-East England
	10 a.m.	Severn Area
	10.15 a.m.	Belfast
	10.30 a.m.	North Midlands
	11 a.m.	North-West England
	11.30 a.m.	South-West Scotland
	12 noon	North-East Scotland
145.10 Mc/s	9.30 a.m.	Beaming north from London
	10.00 a.m.	Beaming west from London
145.8 Mc/s	10.15 a.m.	Beaming south from Belfast
145.30 Mc/s	10.30 a.m.	Beaming north west from Sutton Coldfield
	11.00 a.m.	Beaming south west from Sutton Coldfield
145.50 Mc/s	11.30 a.m.	Beaming north from Leeds
	12 noon	Beaming east from Leeds

Slow Morse Transmissions

The Society sponsors the transmission by amateurs throughout the country of Morse practice lessons intended for beginners. Details appear periodically in the *RSGB Bulletin*.

News Bulletin Service

Every Sunday morning special news bulletins for radio amateurs are transmitted, under the call-sign GB2RS, from stations throughout the British Isles, in the 3.6 and 144 Mc/s bands on a.m. phone.

Beacon Stations

By arrangement with the BBC the Society operates a beacon station on 144.5 Mc/s under the call-sign GB3VHF from Wrotham, Kent, with the aerial beaming north-west. A number of other beacon stations on h.f., v.h.f. and u.h.f. bands are operated by or in conjunction with the RSGB and details are published regularly in the *RSGB Bulletin*.

* * *

In brief, the Society supports and encourages all activities "For the Advancement of Amateur Radio". It welcomes within its ranks all those who share this view.

THE ROLE OF THE AMATEUR

No introduction to Amateur Radio and the RSGB can be considered complete without at least a few very brief notes on how this remarkable international hobby has developed through the years; and on how it has already contributed a vast amount of original work to the practice of radio communication and to the self-training of countless thousands of radio operators and engineers. This work, it should not be forgotten, has been financed entirely by the amateurs themselves, without any form of government subsidy, and arises solely from the very real interest to be found in such work as a hobby.

How Amateur Radio began

Although, from the very earliest days, amateur experimenters followed in the wake of Hertz, Loomis, Lodge, Marconi and Popov in developing telegraphy without wires, Amateur Radio may be said to have been officially recognized in the UK in 1904, when the first " Wireless Telegraphy Act " made necessary the registration of all radio receiving and transmitting apparatus, but made specific provision for the use of such equipment for experimental purposes.

By 1914 some 1000 amateur experimental permits with three-letter call-signs (MXA, etc.) had been issued in Britain. Meanwhile, in 1912, after a period of growing congestion of the radio frequencies, the first specifically Amateur Radio licences were issued in the United States allowing unrestricted operation on " 200 metres and down "—wavelengths then believed by most professional communications engineers to be valueless for other than short-distance working.

British enthusiasts soon felt the need for some organization to cater specifically for their interests and 1913 saw the formation of the Wireless Society of London with members throughout the country. It was this Society which in 1922 changed its name to the Radio Society of Great Britain.

Almost all of these early amateur stations used spark transmitters and crystal receivers but even before 1914 primitive attempts were being made at 'phone as well as telegraphy operation, and some of the larger stations were already covering distances to be measured in tens of miles.

On the outbreak of war in 1914, all British experimental stations were closed down and there was a total ban on amateur receiving as well as transmitting. Indeed it was only after a tremendous struggle that the first British amateur licences to use the present style of call-signs (apart from the lack of an international prefix) were issued late in 1920. At first many of these stations used wavelengths of 1000 metres and later 440 metres, but these permits, like the American ones, made provision for operation below 200 metres. Soon spark transmitters were replaced by valves, and a good deal of operation was on phone.

The Dawn of International DX

The early 'twenties saw the famous series of Trans-Atlantic and Trans-Ocean Tests in which the RSGB co-operated closely with the American and Commonwealth societies and which culminated in the opening of the short-waves (below 200 metres) for long-distance, low-power, two-way working. The first American amateur stations were heard in Britain in November 1921 and next year amateur stations in London (operated by the RSGB) and Manchester were heard in the United States. Two years later, in November 1923, the first amateur two-way trans-Atlantic contact took place on about 110 metres between France and America—and within a few days British amateurs reduced wavelength and began to work across the Atlantic.

With the valves and components then available it was no simple matter to achieve operation on wavelengths of 100 metres and below. But by the following Autumn, two-way contacts between Britain and New Zealand on about 80 metres represented almost the longest span possible on the globe.

Soon operation around 40 and 20 metres was producing long-distance contacts at all times of the day and night, and there began a flood of commercial stations opening up to exploit these discoveries which had stemmed directly from Amateur Radio. By 1928 the Atlantic was spanned on 10 metres, and even 5 metres was being used by the amateurs before the end of the 'twenties.

But the continuing necessity for an effective organization to look after the interests of the amateurs was again strikingly shown in the mid-twenties when an attempt was made by the authorities—alarmed at the ease with which the amateurs were working one another throughout the world—to introduce a ban on international working by British amateurs. Fortunately this ban was soon circumscribed—though its effect was to remain for many years in the banning of the signal " CQ " by British stations until 1946.

Amateurs and Broadcasting

Meanwhile British amateurs had played a decisive role in the institution of regular broadcasting in the UK. Although much interest had been aroused by some experimental broadcasts made by the Marconi Company in 1920, the British government hesitated, and forbade further broadcasts. This led in December 1921 to the presentation by the Wireless Society of London of a strongly worded petition urging regular transmissions. This petition was almost certainly the decisive factor which led to the agreement that broadcasts should be started from Writtle (2MT) and that a British Broadcasting Company should be formed. As one journal put it: " Regular broadcasting in this country was initiated not only at the request of, but through the insistence of the experimental amateur "—though one of the first results of broadcasting was that the British amateur soon lost the use of 440 metres (1000 metres had already been lost to aircraft communication). Later, a British amateur, the late Mr Gerald Marcuse, 2NM, was to be instrumental in starting British broadcasting on h.f. to the Commonwealth.

The year 1925 saw the formation of the amateur's international organization (IARU) which forms a link between the various national societies which exist in almost all countries of the world, and the start of the *T and R Bulletin* (now RSGB BULLETIN) as the journal of the " Transmit and Relay " Section of the RSGB—the section which soon afterwards guided the main body to concentrating almost exclusively on Amateur Radio activities.

During the 'thirties membership of the RSGB increased from about 1000 to almost 4000 by 1939, and a full-time secretariat was set up. In 1933 the first edition of *A Guide to Amateur Radio* was published, to be followed in 1938 by the first edition of the *RSGB Amateur Radio Handbook*.

Once again, on the approach of war, amateur licences were withdrawn in Britain (August 31, 1939) and remained in suspension until January 1946. But throughout the war years the spirit of Amateur Radio was kept very much alive by the many amateurs who used their radio operating and technical skills on behalf of their country, and indeed by the end of the war membership of the RSGB had more than doubled to some 9000 members!

And so this time, thanks to the high regard in which Amateur Radio was now held and the effective organization kept in existence by the RSGB, activities were resumed within three months of the end of the war, with licences noticeably more liberal than the pre-war experimental permits. Soon there were more amateurs than ever before, not only in the UK but throughout the world.

But Amateur Radio again faced an extremely difficult period in the late 'forties and 'fifties when, with the spread of television, it seemed for a time that many amateur activities might be seriously curtailed by the formidable problem of operating stations alongside domestic television receivers without causing interference. Active measures by the amateurs, encouraged by the RSGB and American society ARRL, succeeded to a remarkable extent in overcoming this problem.

Amateurs Today

Today the number of licences in the UK stands at an all-time high of over 12,000, and Amateur Radio enjoys facilities which should ensure its future growth. But the enormous growth of other forms of radio communication in the h.f. and v.h.f. spectrums—in many cases using techniques which have come from the amateurs—means that the demand for radio frequency allocations grows constantly more pressing—and this underlines the necessity for radio amateurs to maintain strong national and international organizations to keep careful watch on the position: the RSGB is recognized throughout the world as one of the leading organizations among those which have striven effectively over many years to improve or retain the vital operating privileges.

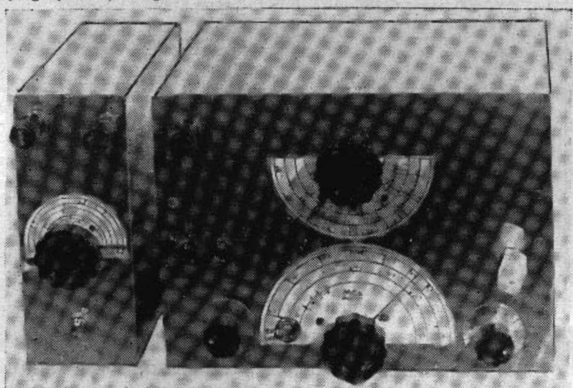
Amateurs continue to play a significant role in the development of practical h.f. and v.h.f. radio communication, and in such allied fields as radio astronomy and the scientific study of radio propagation. Equally important is that many of the scientists, engineers and technicians in this sphere owe their initial interest to the hobby; while those amateurs without professional connection with electronics form a most useful body, within the community, of knowledgeable opinion on radio communications.

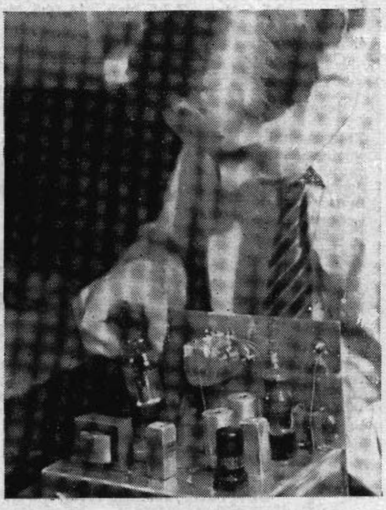
One example of the current work of the amateurs in keeping in the forefront of communications technology is illustrated by the fact that since December 1961 a series of successful communications satellites—called Oscars from " orbital satellites carrying amateur radio "—have been orbited. Although the launchings have been made by the American services (an indication of the regard in which Amateur Radio is held there) the actual satellites have been designed, constructed and used operationally by amateur enthusiasts.

One sometimes hears it suggested that as Amateur Radio is now a relatively " ancient " hobby, already well past its first half-century of exciting years, there can be little scope left for fresh experimental work. Nothing could be farther from the truth. Today, perhaps more than at any other time for many years, we stand at the brink of breath-taking new developments in radio communications. Particularly is this true in the tremendous number of new applications of transistors and other semiconductor devices; in improved methods of modulation; and in the microwave regions. Already it is possible to build a complete phone two-way station for world-wide operation in less space than is occupied by the average domestic broadcast receiver. Tomorrow . . . who knows?

This simple superhet receiver with an external r.f. pre-amplifier was built by a 15-year-old schoolboy and now forms part of the exhibits at the Science Museum Amateur Radio Station GB2SM.

(Right) Completing the receiver.





Radio Society of Great Britain

(Incorporated 1926)

Patron: H.R.H. THE PRINCE PHILIP, DUKE OF EDINBURGH, K.G.

Application for Corporate Membership

Radio Society of Great Britain
28 Little Russell Street
London, W.C.1

I hereby apply for election as a Corporate Member of the Society and enclose a remittance for £2. 10s. 0d. being the amount of my first annual subscription.

I, the undersigned, agree that in the event of my election to Membership of the Radio Society of Great Britain, I will be governed by the Memorandum and Articles of Association of the Society and the rules and regulations thereof as they now are or as they may hereafter be altered; and that I will advance the objects of the Society as far as may be in my power; providing that whenever I shall signify in writing to the Society addressed to the Secretary that I am desirous of withdrawing from the Society I shall at the end of one year thereafter after the payment of any arrears which may be due by me at that period be free from my undertaking to contribute to the assets of the Society in accordance with Clause 8 of the Memorandum of Association of the Society.

Date.. *Signed*..

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Surname (BLOCK LETTERS)..

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Address for all correspondence (BLOCK LETTERS)...

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Nationality.. Age (if under 21)......................................

Current Call-sign (if any)...

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Proposer's Name (BLOCK LETTERS).. ....

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Signed ....

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