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RADIOTRONICS

Volume 17 May 1952 No. 5

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RADIOTRONICS

Volume 17 **May 1952** **Number 5**

By the way—

Our cover illustration shows the manufacture of miniature valve button bases. The picture inset shows the base ready for the next operation.

The article appearing on the back page of this issue is reprinted from Ham News by courtesy of A.G.E. with acknowledgments to I.G.E.

In our April issue we inadvertently omitted crediting the P.G.A. Newsletter of the I.R.E. (U.S.A.) as the source of the article on "The Imitation of Natural Sounds".

Information published in Radiotronics concerning new R.C.A. releases is intended for information only, and present or future Australian availability is not implied.

In view of the many contradictory statements which have appeared in the technical press from time to time concerning the relative merits of A.M. and F.M., it is felt that readers will find the B.B.C. article in this issue of particular interest.

The pent-up demand for the new 4th edition of the Radiotron Designer's Handbook was such that a very considerable part of the first printing has now been reserved for orders which have come to hand since the original Radiotronics announcement.

There is every possibility that the first printing will be sold out before publication date, so readers are strongly advised to forward their orders immediately. Orders received too late may have to wait an indefinite time for a second printing.

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Circuit Laboratory Report **Number 13**

Vibrator-Operated 6V6-GT P.A. Amplifier

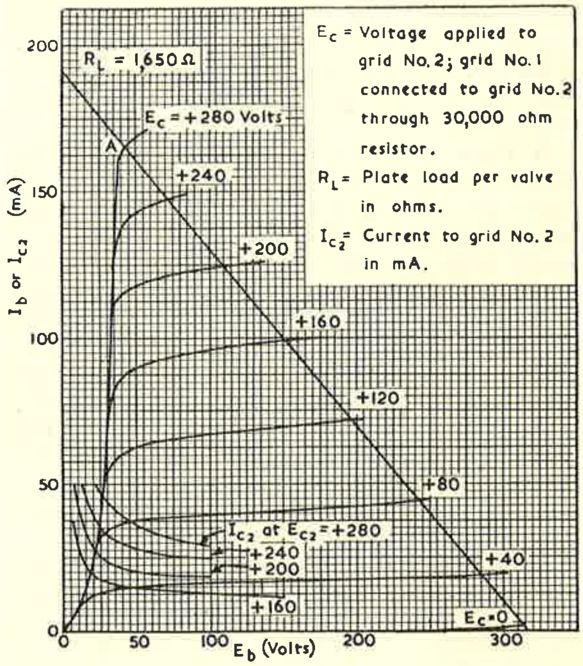
A method of operating type 807 valves in a triode-connected zero-biased class B output stage was described in Radiotronics 138, page 64. The method had two advantages, its large a-f power output of 120 watts and the absence of either a screen or a bias supply for the output valves. In conventional public-address amplifiers using class AB_1, AB_2 or class B output valves the stabilizing of the screen and bias supplies is usually the most difficult part of the design — unless it is possible to use separate supplies — and satisfactory stability is usually obtained only at the expense of a large current drain. For this reason, it was decided to investigate the use of such a circuit with the 6V6GT, which is the most widely used output valve in small public-address amplifiers.

The resulting amplifier has as its main virtue economy of operation, which makes it particularly suitable for vibrator-operated public-address work. The power output is similar to that obtained from the conventional method of use i.e. 15 watts in the primary of the output transformer for less than 5% total harmonic distortion, but the current drain of the whole amplifier is only 3.8 amps. at 12 volts with zero output, rising to 5.8 amps. at 20 watts output from the output valves. With the amplifier driven by typical speech input until some clipping of peaks occurs, which represents a peak power output of the order of 25 watts, the average current drain is slightly less than 4.5 amps. These figures can be compared with a continuous current drain of 6 to 7 amps. for an amplifier with similar output using type 6V6GT in conventional pentode class AB_1 operation.

Fig. 1 gives the plate characteristic of a typical 6V6GT operated under the conditions shown in the circuit (Fig. 2) of the A520 amplifier. From the characteristic it will be seen that the plate current under zero-signal conditions is very low (average about 1 mA) which is the reason for the economy of operation. Nevertheless, the increments of plate current for equal increments of driving voltage are sufficiently linear to indicate that distortion will be acceptable for all applications other than those requiring high fidelity reproduction.

In view of the very low zero-signal plate current it seemed possible that some 6V6GT valves might be completely cut-off, which would result in severe distortion particularly at low outputs. To test this, a large number of 6V6GT valves from different production batches and from different manufacturers was checked. The extreme values of plate current observed were 0.8 mA minimum and 1.8 mA maximum. Nevertheless, it would not be advisable to use a plate voltage appreciably less than 315 volts as this might lead to plate current cut-off in some valves. Nor is it permissible to use plate voltages higher than 315 as the maximum plate voltage rating for the 6V6GT would be exceeded.

Power output is very dependent upon the plate voltage available under full-load conditions, so that the regulation of the power supply is an important factor in determining the power output. For this reason, a vibrator power supply was built up using a commercial vibrator transformer which gave a voltage variation from 310 volts at 45 mA (the no-output high tension current of the whole amplifier) to 266 volts at 134 mA when the amplifier was delivering 20 watts into the output transformer primary. A power supply with better regulation than this would result in correspondingly higher power output.



6V6GT Plate Family with 30,000 ohm Resistor In No I Grid Circuit FIG. 1

The 0.02 μF buffer capacitors used across the secondary of the power transformer are of the correct size for the transformer used, but a different transformer might need different values of capacitance to obtain the correct vibrator waveform.

Driver stage: Examination of Fig. 1 shows that grid drive voltages as high as 280 volts peak (200 volts r.m.s.) per valve are needed to obtain full

Contributed by the Circuit Design Laboratory, Valve Works, Ashfield.

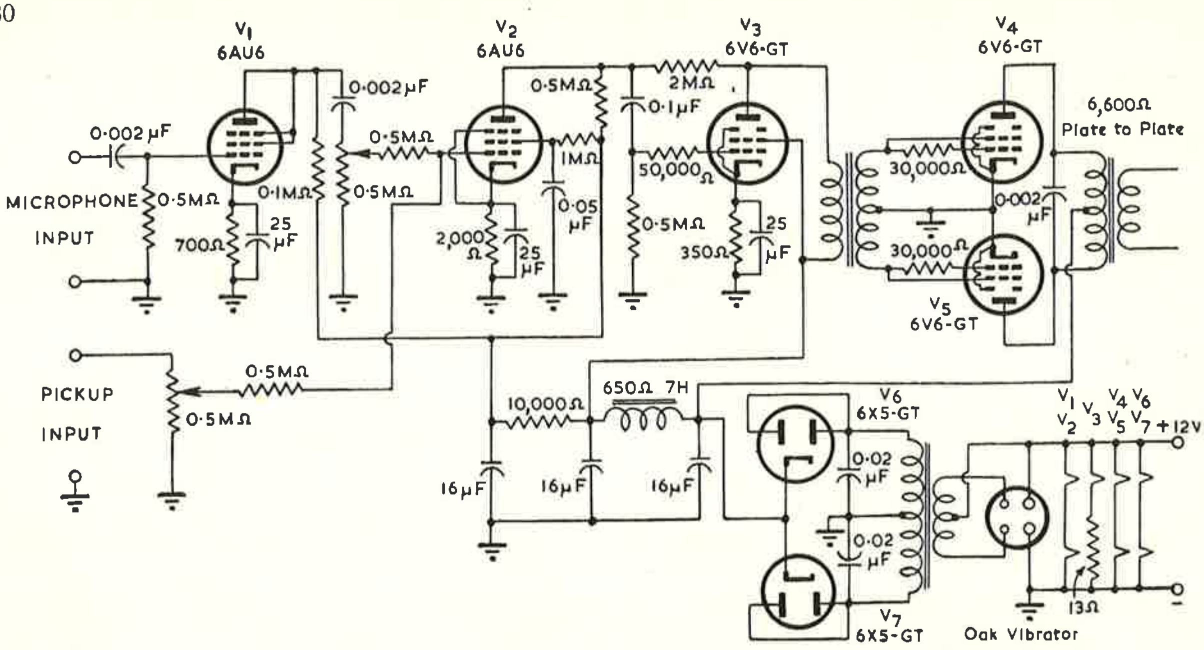


FIG. 2

RADIOTRON A520 BATTERY-OPERATED AMPLIFIER

output. However, under these conditions the r.m.s. screen current is only 8 mA, representing a screen grid driving power of 1.6 watts per valve. In addition, at 20 watts output 0.4 watt is supplied to each control grid circuit, of which 0.3 watt is dissipated in the 30,000 ohm resistor. Thus the required driving power is 4 watts plus the losses in the driver transformer.

A third 6V6GT provides this driving power economically and has the advantage that it safeguards the screen grids of the output valves against overdriving since, subject to the precautions mentioned below, it cannot deliver the power necessary to exceed the maximum permissible screen dissipation of 2 watts per valve plus the control-grid drive plus the transformer losses without excessive distortion. The plate current of the driver valve constitutes most of the B supply current of the amplifier at zero signal, i.e. 37 mA of the total of 45 mA. The plate and screen dissipations however are well within their maximum ratings and decrease when a signal is applied to the amplifier, due to the falling B supply voltage with increase of power output.

At the peak of each driving cycle the input impedance of each output 6V6GT is somewhat more than 6,000 ohms, so that a step-up ratio of 1 to 1.25, primary to half-secondary, is needed in the driver transformer. This ratio is not critical, however, and during the design of the amplifier, ratios between 1 to 1.15 and 1 to 1.5 were tried and did not seriously affect the output or distortion of the amplifier.

For the investigation of driver transformer ratios, power transformers were used, a transformer with 240 volt primary and 300 volt per side secondary giving the optimum ratio. Apart from having a low primary inductance this transformer operated satisfactorily and if the resulting poor bass response can be tolerated (in a particular case the loss experienced was 3 db at 350 c/s) there is no reason why such a transformer should not be used in the final amplifier.

However, if a driver transformer having a low secondary resistance, such as a power transformer, should be used as a driver it is desirable to use a resistor between the secondary centre tap and ground of such a size that will make the grid to ground resistance for each output valve not less than 1,500 ohms. The purpose of this resistor is to limit the screen dissipation of the output valves when the grid drive exceeds that required to reduce the instantaneous plate voltage to the diode line (point A in Fig. 1). Under these conditions, the screen current and screen dissipation increase sharply and *it is necessary to specify a minimum value for the total series screen resistance, in order to limit the maximum peak values of screen current, which if excessive are likely to cause screen primary emission.*

Driver transformer.

Ratio (primary to half secondary) — 1 to 1.25.
Primary:—3,000 turns 36 B & S enamel.
Primary inductance — 27.5 henrys with 35 mA d.c. flowing.
Primary resistance — 550 ohms.
Secondary — 7,500 turns 40 B & S enamel centre-tapped.
Secondary resistance — 3,950 ohms.
Core:—1″ square stack of 3″ × 2½″ silicon steel E and I laminations, MEA Pattern 29, butt jointed.

Negative feedback.

Several different methods of applying negative feedback were tried, but since most of the distortion at full output comes from the driver stage, the simple method used, i.e. 10 db of negative feedback across the driver stage alone, gave results as good as any other arrangement.

Frequency response.

The transformers used in the amplifier were designed to give a frequency response suitable for public-address work without being unduly expensive. Curve A in Fig. 3 shows the variation in power output with frequency, from the pick-up input to output transformer secondary and it will be seen that the linearity is adequate. For speech some bass cutting is desirable and the values of grid and plate circuit coupling capacitors for V1 have been chosen to provide this, as shown in Curve B.

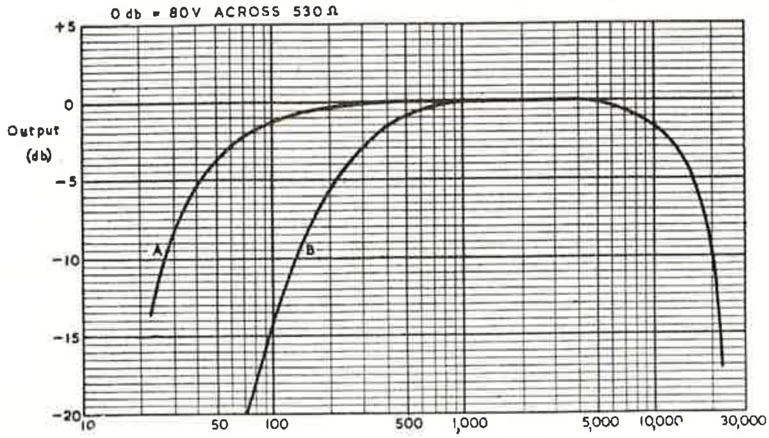


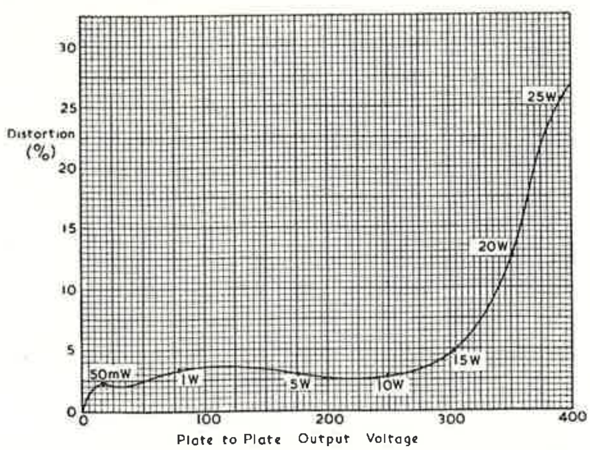
FIG. 3 FREQUENCY RESPONSE CURVE A – FROM PICKUP INPUT CURVE B – FROM MICROPHONE INPUT

Alternative inputs.

Provision is made for both pick-up and microphone inputs with separate volume controls, and the sensitivities from the respective input terminals are 0.25 volt r.m.s. and 7.7 millivolts r.m.s., for 15 watts output. To meet special requirements, additional sensitivity could be obtained by reducing the amount of feedback or by connecting the first 6AU6 as a pentode.

Power output.

Values of power output quoted throughout this description are those of power delivered by the output valves into the primary of the output transformer. The power available on the secondary of the transformer will be reduced by the losses in the transformer. This method is adopted firstly because it demonstrates the capabilities of the valves under the conditions used in the amplifier and secondly because allowance can be made for the efficiency of any particular output transformer that may be used in similar amplifiers. In the absence of more precise information it may be assumed that the loss due to a transformer of this type will range from 1 db for a good transformer to as much as 3 db for a poor one.



DISTORTION vs OUTPUT at 1,000 c/s FIG 4

Distortion.

Fig. 4 shows the relationship between distortion and output measured as described above with valves having characteristics approximately bogie for plate current, screen current and power output. In spite of the low plate current drawn by the output valves distortion does not rise appreciably at low levels, being only just above 2% at 50 mW output. At any output below 15 watts the distortion is less than 5%, whilst under overload conditions up to 25 watts output can be obtained with distortion still low enough for good intelligibility.

It will be noticed that although the load-line on Fig. 1 is for a 1,650 ohm load, representing 6,600 ohms plate-to-plate, the wattage figures marked on Fig. 4 corresponds with a 6,170 ohm plate-to-plate load. This represents the difference between the nominal and measured impedance of the transformer and secondary load used. The load impedance is not critical between the limits of 6,000 and 6,600 ohms in any case, although plate current under driven conditions increases as the plate-to-plate impedance decreases.

Voltage Analysis.

All voltages measured to chassis without signal input and with 20,000 ohm per voltmeter used on range indicated.

	Plate volts	Screen volts	Cathode volts
V1	65 (100)	—	1.3 (10)
V2	64 (100)	24 (100)	1.4 (10)
V3	260 (1000)	280 (1000)	14.5 (25)
V4	310 (1000)	—	—
V5	310 (1000)	—	—
V6	—	—	310 (1000)
V7	—	—	310 (1000)

RECEIVER NOISE FIGURES

The purpose of this article is to explain in simple language the terms "noise figure" and "signal-to-noise ratio". Admittedly this is not an easy job, but it will be attempted here because so few amateurs have a clear concept of just what noise actually is.

There are four general types of noise, and we are concerned primarily with only one type in this discussion. Static is one type of noise. It is produced primarily by lightning discharges. A second type of noise originates far from our planet Earth, and is called cosmic noise. Third, we have that well-known phenomenon, man-made noise, such as electric razors, which give off a noise similar to a hiss, and we have power leaks and ignition noise which sounds like a series of machine-gun shots. The three types of noise just mentioned are interesting, and they will help us to understand receiver noise problems, but they have absolutely nothing to do with so-called receiver or circuit noise. However, it is this fourth type of noise that we are interested in, because it is the only one we can do anything about.

This type of noise had better be called by another name, which is "thermal" noise. This name describes rather accurately the cause of this type of noise, because it is due to thermal agitation of electrons. That is, in every bit of matter, the electrons are moving back and forth, and this motion causes noise. The only way to stop this noise is to cool the electrons down to absolute zero, where they are just too cold to move. Thermal noise, in other words, depends upon the temperature (among other things), and the hotter the electrons, the greater the noise.

What does this mean practically? For one thing, it means that your antenna generates noise, the resistors in the input circuit of your receiver generate noise, and the input tube generates noise, all due to the random motion of the electrons in the antenna wire, the resistor, etc. In fact, practically everything in the receiver generates noise, but generally only the noise in the first stage of the receiver means anything, since noise in subsequent stages is much less than the amplified noise from the first stage.

Thermal noise is random and appears at all frequencies. However, if a receiver is "sharp" there will be less noise in the output, because the receiver is looking at a smaller part of the radio spectrum than a broad receiver, and therefore it is amplifying less of the noise. Now that we have some of the fundamental ideas in mind, let's see what signal-to-noise ratio is.

Let us assume we have a receiver with an antenna connected to it. Present on this antenna will be all four types of noise (static, cosmic, man-made and thermal). Also present on the antenna is a certain signal that we want to receive. Let us assume further that the noise (all four types) on the antenna is a certain power, say one microwatt. Let us also assume that the signal has a strength of ten microwatts. The signal-to-noise ratio on the antenna is therefore 10:1. This is a comfortable margin, and you might think that the signal would be easy to receive. It would be, with a good receiver. However, remember that the receiver has its own internal noise. When this signal plus noise gets to the grid of the first tube, there may be enough additional noise added by the input circuit that the total noise power is now five microwatts. The signal is still ten microwatts, but now the signal-to-noise ratio is ten microwatts to five microwatts, or 2:1. You experts may realize that the example above represents a practically defunct receiver in an even worse location, but the figures do serve to illustrate the problem.

We have had a terrible loss in signal-to-noise ratio, and we barely got the signal into the receiver! Also, from this point on, the receiver cannot improve things. The first tube is going to amplify the signal and the noise by the same amount, and subsequent stages will do the same, so by having a poor front end on the receiver we have a poor signal-to-noise ratio to work with, and there is nothing we can do about it, except redesign the receiver. It is interesting to note that even if we had noise-free tubes (which we don't), there would still be noise generated by the input circuit (the antenna, lead-in, input impedance, etc.). We can minimize the noise generated in these elements only by careful design.

Let's go back to signal-to-noise ratio again, and assume that the noise on the antenna consists entirely of thermal noise due to the radiation resistance of the antenna. (This means that the antenna is in that perfect receiving location that everyone is looking for but never finding.) We have a certain signal-to-thermal-noise ratio on the antenna, and the ideal receiver would be one which did not change this signal-to-noise ratio. If the receiver adds no noise whatsoever, then the signal-to-noise ratio remains unchanged, and we have what is known as a perfect receiver. The better a receiver you have, the less the signal-to-noise ratio will be changed, and the worse the receiver, the more the signal-to-noise ratio will be changed. The amount that the receiver changes the signal-to-noise ratio can be expressed as a figure — in fact, this is called the "noise figure" of a receiver. In other words, the noise figure of a receiver is the measure of how much the signal-to-thermal-noise ratio is decreased due to the receiver itself.

(Continued on page 90)

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The B.B.C. Scheme for V-H-F Broadcasting

The purpose of this article is to outline briefly the technical reasons for the B.B.C. proposal to plan a v.h.f. (very high frequency) broadcasting service on the basis of a chain of f.m. (frequency modulated) stations of various powers giving substantially complete national coverage with three programmes.

The use of very high frequencies in the band 88 to 100 Mc/s (about 3 metres wavelength) was envisaged before the war as a possible method of increasing the number of channels available for sound broadcasting. The number of medium-wave and long-wave channels available to the B.B.C. has become insufficient, and their quality inadequate, for the satisfactory national distribution of three programmes. Fading, increasing interference from foreign stations, and the necessity of synchronised working are severely limiting the range of existing stations, mainly as a consequence of the unsatisfactory operation of the Copenhagen Wavelength Plan in Europe.

Although the available medium wave-band was slightly widened at the Atlantic City Conference by the inclusion of channels above 1,500 kc/s (below 200 metres), such channels are not very useful because their range is small, and because many existing receivers are not designed to tune to them. In the future the number of medium-wave channels available for British broadcasting is hardly likely to increase, and the situation may be expected to deteriorate further. It is therefore proposed to establish a broadcasting service within the v.h.f. band allocated for sound broadcasting in the European Region.

Propagation conditions on these very high frequencies differ very considerably from those on the medium and low frequencies. The signal strength decreases rapidly with distance from the transmitter; and receiver, hills casting partial shadows similar to optical shadows. Fading may occur at times owing to changes in the weather and to the close proximity of aircraft, the extent of the fading depending on the distance from the transmitter and on the location of the receiving site. The service area of a v.h.f. transmitter will therefore be to some extent 'patchy', owing to the existence of pockets of field strength lower than the average for the neighbourhood. It is thus not possible to give as precise an estimate for the range of a v.h.f. transmitting station as for that of a medium-wave transmitter. It is possible to predict average ranges over terrains of known general contour, but listeners living in notably unfavourable positions within, for example, a first-class service area may get only a satisfactory second-class service; conversely, listeners living outside a first-class service area, but in favourable geographical positions, may still get a first-class service.

A v.h.f. service suffers from some forms of electrical interference which do not much affect medium waves, and vice versa. Motor-car ignition systems, for instance, cause disturbances on v.h.f. which may result in interference to the programme if the received field strength is weak and the motor car fairly near. On the other hand, most natural and man-made disturbances which cause interference on long and medium wavebands do not affect reception on v.h.f. to the same extent.

The receivers for these v.h.f. transmissions may take the form of adaptors added to existing medium-wave sets, or special sets for the new frequency band. The listener will therefore have to pay for an adaptor for his receiver, or buy a new set, in order to take advantage of this new service. To make this additional outlay worth while to the listener, it is proposed to radiate the present three programmes in the v.h.f. band, even in districts where adequate coverage on medium waves is available. It will thus be possible for the great majority of listeners ultimately to receive all three programmes with a straightforward v.h.f. receiver. The sound quality provided by the new service will be normally much better than that of the existing medium-wave service, since the audio-frequency bandwidth will not have to be limited by the carrier frequency separation. In addition there will in general be much less background noise. The close frequency-spacing of transmitters operating in the medium wave-band has made it necessary to restrict the bandwidth of receivers, in order to avoid interference from adjacent channels which might otherwise prejudice programme quality. Moreover, excessive sharing with continental stations is liable to create various forms of background interference at night.

The propagation peculiarities, the possibility of interference from motor cars when the signal is weak, together with improved programme quality and low background noise are common to all v.h.f. broadcasting systems. There is, however, a choice open in regard to the system of modulation to be used. Many new types of modulation have been proposed and tested during the past ten years, the main object being to minimise interference with the programme. Such improvement can be obtained only by taking certain technical precautions at the transmitting or receiving end, or both.

In a broadcasting system it is particularly important to keep the cost of the listener's receiver as low as possible. Bearing this in mind only three systems merit consideration. The first is a.m.

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(amplitude modulation), the conventional system used in the medium and long wave-bands; the second is a.m.l., i.e. amplitude modulation with a noise limiter incorporated in the receiver; the third is f.m. (frequency modulation). Pulse modulation systems have also been considered, but are not thought to offer sufficient advantages for broadcasting to merit further consideration.

COMPARISON OF A.M., A.M.L., AND F.M.

General.

The systems to be compared are therefore:

a.m. conventional amplitude modulation.

a.m.l. amplitude modulation with a noise limiter incorporated in a wideband receiver. The performance of this system depends on the receiver bandwidth; for the majority of the tests described in this article the bandwidth is the same as that of the f.m. receiver, namely ± 75 kc/s.

f.m. frequency modulation peak deviation ± 75 kc/s, pre-emphasis* time constant 50 micro-seconds.

In each of the three systems the quality of programme reproduction can be extremely high, being limited only by the audio-frequency stages of the receiver, including the loudspeaker. Programme quality, therefore, is not a point at issue, except possibly with a.m.l.

The criterion by which the different systems of modulation can be judged and compared is the extent to which all forms of noise and interference are suppressed. There are two main types of noise — receiver hiss, and impulsive interference such as that caused by motor cars and some domestic appliances.

Taking a.m. as the basis for comparison, f.m. results in a considerable reduction of both hiss and impulsive interference. On the same basis, a.m.l. gives a reduction of impulsive interference, but not of hiss. The magnitude of these noise-level reductions and the conditions in which they apply are discussed later.

The advantage of f.m. over both a.m. and a.m.l., in respect of noise suppression, can be used to obtain a larger service area, since a satisfactory service is possible at greater distances from the transmitter where the field strength is low. It may be mentioned in passing that it has also been suggested that this advantage can be exploited to permit a greater dynamic range of programme levels than is at present customary. The necessity of extending the service area is, however, paramount.

In order to realise the potential advantages of f.m. over the other systems of modulation, an efficient limiter must be incorporated in the receiver, for otherwise the advantage of f.m. will be lost in those parts of the service area where it is most needed, namely, where the field strength is low. Cheap types of receiver have been produced (for instance, in Germany) in which no limiter is incorporated, and the advantages of maximum coverage have therefore been lost. This may be justified, on the ground of cheapness, for those parts of the service area where the field strength is high, i.e. relatively close to the transmitter.

It is worthy of mention that, to achieve the full advantages of f.m., careful (but not necessarily costly) receiver design is necessary. It is, however, necessary to distinguish between difficulties associated with the reception of v.h.f. with any system of modulation, and those associated with a particular system of modulation. It is mainly on receiver design, handling difficulties, and cost, that the controversy over which system is superior has centred.

In the a.m.l. receiver special noise suppression circuits are incorporated. Some of these, although performing their primary purpose efficiently, introduce attendant disadvantages. In some instances, efficient noise suppression is accompanied by perceptible audio-frequency distortion. These 'half-measures' cannot be accepted for a new high-grade broadcasting service. However, the particular type of a.m.l. receiver used for the tests described in this article is the best available at the present time and gives very little perceptible deterioration of the sound quality.

A further word of explanation is necessary in connection with the use of pre-emphasis of the high-frequency components of the programme modulation, with corresponding de-emphasis in the receiver. Pre-emphasis has, in the past, been associated with f.m., but it could be applied also to an a.m. system. Pre-emphasis is of particular advantage in f.m. because of the 'triangular' noise spectrum of this system. It is, however, necessary to reduce the general level of modulation somewhat in order to avoid overmodulation at the higher frequencies, so that the advantage obtained is less than might at first be expected. The advantage to be obtained by applying pre-emphasis to a.m. is less than for f.m., and is in practice negligible. Unless otherwise stated, pre-emphasis and de-emphasis were used in the tests described with f.m. only.

LABORATORY TESTS ON NOISE SUPPRESSION.

Receiver hiss.

With 75-kc/s deviation and 50 micro-seconds pre-emphasis and de-emphasis, provided that the input level is sufficiently high to operate the limiter of an f.m. receiver, the level of receiver hiss with f.m. is 26 db lower than it is with a.m. or a.m.l.

This is a result which can be justified theoretically, and it has also been checked by measurements. For the latter the receiver was terminated in an ear simulating network of the performance specified by

*** Pre-emphasis is a method of getting relatively greater modulation at the higher audio-frequencies so as to offset the effect of noise, which in an f.m. system increases with frequency. The degree of pre-emphasis is expressed as the time constant of the electrical circuit giving the desired frequency characteristic.**

the International Telephone Consultative Committee (CCIF) followed by an r.m.s. meter. Corresponding subjective tests have also been carried out and show close agreement with objective measurements.

This result can be expressed in another way — in terms of the field strength necessary to provide a service in which the background receiver hiss is classed as 'perceptible' but not by any means disturbing. With a simple dipole working into a well designed receiver with a low noise factor, it was found that the required field strength on a.m. or a.m.l. is 1,000 μV/m, whereas using f.m. the corresponding figure is 50 μV/m.

It may be asked whether, in view of the fact that the present B.B.C. proposal is to provide at least a second-class service with an ambient field strength at 30 feet above ground level of 250 μV/m, the advantage of f.m. in suppressing receiver hiss can be usefully exploited.

First, it should be remembered that owing to the propagation conditions applying on these very high frequencies, considerable deviations of field strength may occur between points a relatively short distance apart, particularly if the country is hilly or built-up. Secondly, it is desirable that listeners should be able to receive these v.h.f. transmissions so far as possible without the need to erect an outdoor aerial, which may be expensive. Many listeners have been impressed by the fact that relatively simple aerials will give satisfactory reception of f.m. transmissions. The field strength indoors may be considerably less than the ambient value, particularly in difficult conditions — in a ground floor or basement flat or inside a steel framed building (where, incidentally, v.h.f. reception will often give satisfactory results when medium-wave reception is unsatisfactory).

Thirdly, it should be remembered that a wide audio-frequency band (which at least some listeners will demand) increases the level of receiver hiss. Critical listeners are aware of receiver hiss if the signal/noise ratio is less than about 60 db. Fourthly, the field strengths quoted above for satisfactory reception of f.m. and a.m. transmissions apply to a well-designed receiver. It is possible that some receivers having a relatively high noise factor will be manufactured; for instance, a relatively inefficient input radio-frequency amplifying stage, or none at all, may be used.

Taking all these factors into account, therefore, the suppression of receiver hiss is considered to be a desirable and important feature of a high-grade v.h.f. broadcasting service.

Impulsive noise.

It is more difficult to be as precise about the relative performance of f.m., a.m.l., and a.m. in combating impulsive interference. To obtain optimum suppression, careful attention to the time constants of the circuits preceding the discriminator is necessary. Receivers which otherwise give a similar performance may behave very differently in the presence of impulsive interference. Furthermore, the degree of suppression of impulsive noise due to the use of f.m. depends upon the ratio of peak interference to peak carrier.

This effect is illustrated in Fig. 1, which applies to repeated uniform impulses, typical of, but more regular than the impulses caused by motor car ignition systems. When the peak noise to carrier ratio is less than unity the improvement of f.m. over a.m. is 25 db. At ratios exceeding unity, i.e. at signal levels below the 'improvement threshold', the advantage of f.m. over a.m. falls rapidly to a minimum and thereafter increases (f.m. always showing a substantial improvement over a.m.). The part of the curve below the improvement threshold is particularly important in the f.m. service under consideration, because it is in this range that car ignition interference begins to be annoying.

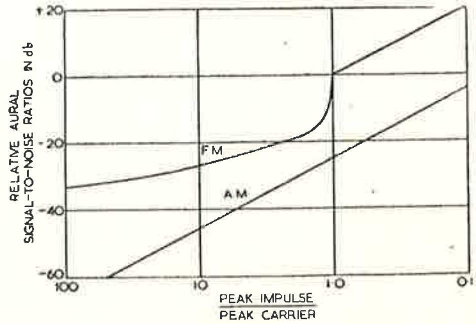

Fig. 1. Impulsive interference: theoretical comparison of f.m. and a.m.

Experimental confirmation of this effect has been obtained. A typical result is shown in Fig. 2, which includes also the corresponding results for two typical a.m.l. receivers. The curves are for interference consisting of repeated uniform impulses and correspond, therefore, closely to the conditions assumed for the calculation illustrated in Fig. 1. For these measurements the receiver was terminated in a CCIF ear simulating network followed by an r.m.s. meter; results obtained in this way show agreement with subjective assessments of the annoyance caused by interference. The performance of a.m.l. lies in general between that of f.m. and a.m.; it may approximate, however, to that of f.m. over a limited range of the ratio of peak noise to carrier.

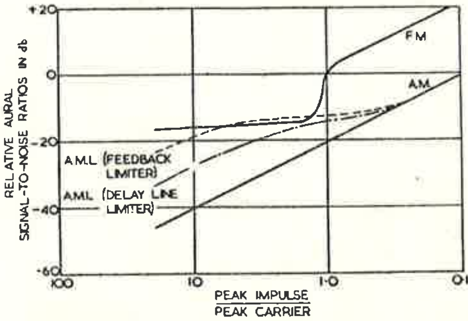

Fig. 2. Impulsive interference: experimental comparison of f.m., a.m., and a.m.l. receivers.

In practice the most important source of impulsive interference is the ignition system of motor cars. The waveform here is far from the regularly repeated pulses on which the theory previously mentioned is based and to which quoted measurements apply. Subjective tests carried out using actual motor cars indicate that in practice the curves corresponding to Fig. 2 are considerably 'smoothed out'; nevertheless, f.m. does show a marked improvement over both a.m. and a.m.l.

FIELD TESTS ON WROTHAM TRANSMISSIONS.

During the laboratory experiments outlined above, field tests were carried out with low-power transmissions on a.m. and f.m. simultaneously from Alexandra Palace. The results of the experiments, data from which were limited by the short range of the transmitters, were so promising that it was decided to carry out full-scale tests with high-power transmissions. After due survey, a site at Wrotham, Kent, was chosen. On this site two transmitters were installed with a carrier power of approximately 20 kW; one of these transmitters was frequency modulated on 91.4 Mc/s and the other amplitude modulated on 93.8 Mc/s. The outputs were fed simultaneously into a slot aerial array* with a gain of 8 db. The effective power of the horizontally polarised radiation from this aerial, the centre of which is 1,100 feet above sea level, is approximately 150 kW.

* **G. D. Monteath, 'An Aerial for V.H.F. Broadcasting', B.B.C. Quarterly, Vol. 6, No. 2. Summer, 1951.**

A comprehensive series of field-strength measurements was made on these transmissions in order to check theoretical computations. The results are shown in the field-strength contour map (Fig. 3), which applies to both the f.m. and the a.m. transmissions.

In July, 1950, the two transmitters began a series of modulated test transmissions on a regular time schedule. A listening survey was started, with the assistance of listeners provided mainly with specially designed v.h.f. sets capable of receiving a.m., a.m.l., and f.m. These specially designed sets were made to a specification believed to be typical of a reasonably, but not abnormally good receiver. The team taking part in these tests consisted of both technical and non-technical listeners, living in parts of the country within the projected service area of the Wrotham transmitter. Each listener was asked to answer a standard questionnaire, designed to give in condensed form his opinion of the three possible settings of the receiver. A copy of the questionnaire will be found at the end of this article. The completed questionnaires were analysed, and served as an excellent check on the results obtained by technical observers, both under laboratory conditions and in the field. Further listening tests with a mobile laboratory were made in the area covered by the 0.1-mV/m contour.

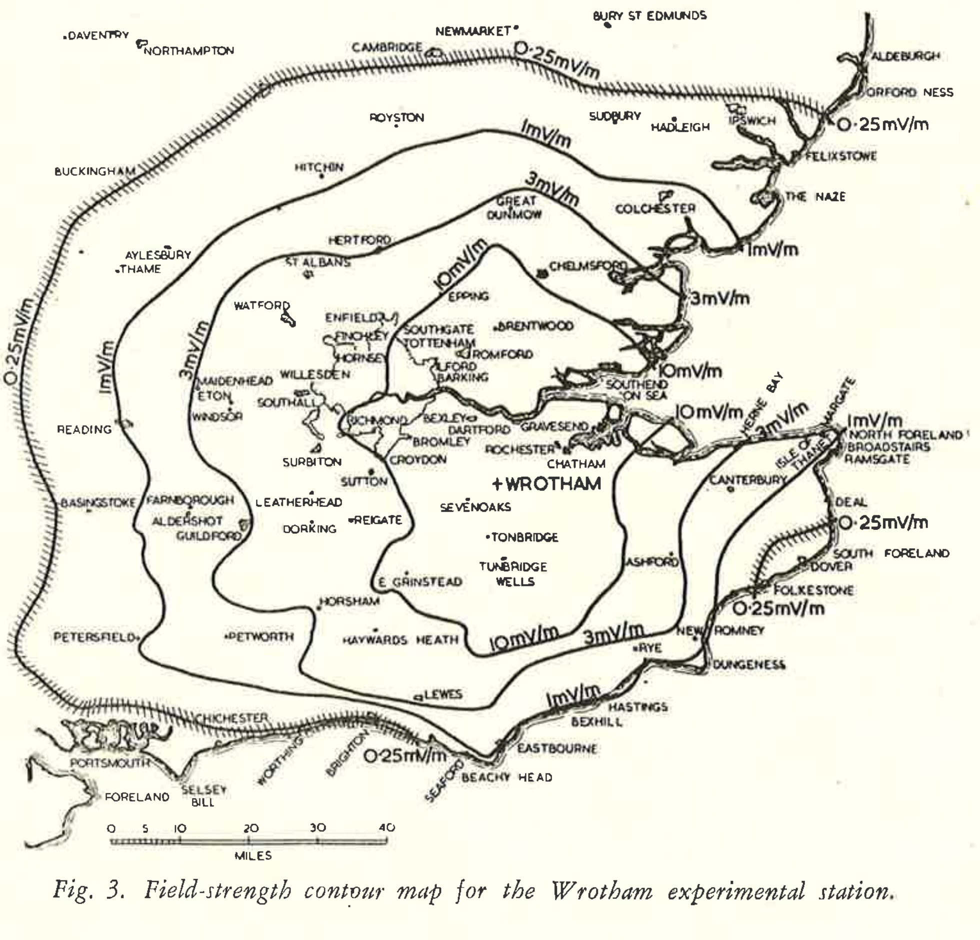

Fig. 3. Field-strength contour map for the Wrotham experimental station.

RESULTS OF TESTS.

With f.m. transmission, the first- and second-class service areas were as defined below, the limits being set mainly by the level of impulsive interference from motor cars. Owing to the wide range of interference levels from different types of cars, and the varied reception conditions, it is extremely difficult to specify a minimum 'standard' of reception for the service area.

To allow for difficult, but by no means extreme, conditions it has been assumed that the listener's receiving aerial is within 30-60 ft. from a busy road, on which traffic may be continuous. Two types of service area were defined.

(a) First-Class Service Area: Impulsive interference from 50 per cent. of cars is imperceptible; of the remainder, occasional cars may give rise to interference graded as 'slightly disturbing'. In view of the difficult reception conditions assumed, this is considered a reasonable standard to adopt.

(b) Second-Class Service Area: The average level of impulsive interference from at least 50 per cent. of cars is never graded as worse than 'perceptible'; occasional cars may give rise to interference graded as 'disturbing'.

The results obtained from the listening tests may be roughly summarised as follows:

(i) Within a range of approximately thirty miles from the transmitter no general preference is expressed for either system; reception conditions were excellent with a.m., a.m.l., and f.m. Where any preference was stated it was for f.m., because of the absence of receiver hiss. Listeners were impressed by the comparatively simple, and therefore inexpensive, aerial systems which gave satisfactory reception with f.m. This means that it will be possible for a very large proportion of listeners to any one station to use an indoor aerial for f.m., which would not be practicable for a.m. This constitutes a very marked saving in cost to listeners, which can be set against any difference in the cost of the receiver itself.

(ii) Beyond a range of thirty miles the majority of listeners expressed a distinct preference for f.m.

(iii) Many listeners did not notice any marked difference between a.m.l. and a.m. An improvement in favour of a.m.l. was, however, noticeable in areas subject to heavy impulsive interference.

(iv) Fading at times was reported on a.m., a.m.l., and f.m. at distances in excess of forty miles, and this has been taken into account in assessing the service areas; in some cases the fading was associated with the presence of aircraft.

Table I shows the approximate field strengths which represent the lower limit of a first- or second-class service area, and the corresponding ranges. It is obvious that the coverage provided by the f.m. transmissions is greatly superior to that provided by a.m.l. or a.m.

PLANNING OF F.M. BROADCAST SERVICE FOR THE UNITED KINGDOM.

From the foregoing laboratory experiments and listening tests on the Wrotham transmissions, it has been estimated that the use of f.m. ensures a first-class service within the area of the 1-mV/m contour, and a second-class service up to the limit of the 0.25 mV/m contour, assuming average conditions of reception. In conditions better than average, that is in areas comparatively remote from a busy highway, lower values of field strength would be sufficient.

In view of the close accord between the predicted and measured field-strength contours of the Wrotham transmissions, it was decided to draw up a preliminary scheme for an f.m. broadcasting system to cover the major part of the United Kingdom, on the basis of three programmes (Home, Light, Third)

TABLE I

System	*First-Class Service Area*		*Second-Class Service Area*	
	Field-strength (mV/m)	*Approx. Range Miles*	*Field-strength (mV/m)*	*Approx. Range (Miles)*
f.m.	1	45	0·25	60
a.m.l	3	35	1	50
a.m	10	25	3	35

TABLE II

	Population (1931 Cenus)	*Population Receiving*	
		First-Class Service (substantially interference-free)	*Second-Class Service (or better) (motor car interference tolerable)*
England	37,359,000	33,285,000 (89·0%)	36,724,000 (98·3%)
Wales	2,593,000	2,078,000 (80·0%)	2,438,000 (94·0%)
Scotland	4,843,000	3,883,000 (80·2%)	4,014,000 (82·9%)
N. Ireland	1,280,000	943,000 (73·7%)	1,064,000 (83·2%)
	46,075,000	40,189,000 (87·2%)	44,240,000 (96·0%)

for each service area. For certain areas this entailed some considerable overlapping because of the need to provide regional programmes appropriate to the areas concerned. A population survey based on this plan is set forth in Table II.

It should be noted that if a.m. were to be chosen for the v.h.f. scheme, the number of broadcasting stations required would be approximately three to four times as many as those required if f.m. were chosen, for the same grade of service. This would involve heavy capital expenditure on technical equipment, buildings, and the necessary high-grade lines. Moreover, there would be difficulty in obtaining agreement to the erection of such a large number of high masts. In addition, the running costs would be very seriously increased.

COMMON CHANNEL INTERFERENCE.

In planning a national v.h.f. broadcasting service within the frequency band available, common channel working may be necessary, whichever system of modulation is used, since it may not be possible to assign a separate frequency to each transmitter. Moreover, channel sharing by agreement will no doubt be necessary with stations in western Europe. Common channel stations would be spaced geographically as far apart as possible so that interference would occur only when the tropospheric conditions favoured long-distance transmission; this will be for a comparatively small proportion of the total time. Long-distance field-strength measurements of transmissions from extending over a period of some two years, have provided valuable, though as yet incomplete, information on the values of field strength likely to be encountered under extreme tropospheric conditions.

In v.h.f. broadcasting it is not practicable to achieve as close synchronisation between two stations nominally operating on the same frequency as is possible on medium frequencies, and the frequency difference under conditions of interference may give rise to an audible beat note. If, however, the frequency spacing between nominally common-channel stations is made greater than the maximum audible frequency, i.e. greater than about 12 kc/s, the beat note is not heard, and interference occurs only when one or both signals are modulated; with f.m., it then takes the form of a rasping noise. Laboratory experiments have been carried out to compare the impressions of a number of listeners regarding the amount of interference which occurs with common-channel f.m. stations having carrier-frequency differences both within and above the audible range and also to ascertain the ratio of wanted to unwanted signals required to provide protection against interference in these two conditions.

As a result of these experiments it was found that the level of interference does not depend significantly upon whether the programmes used to modulate the wanted and unwanted stations are the same or not. Moreover, there is no change in the degree of interference if the frequency difference between the two carriers is increased from a low audio frequency to about 5 kc/s. There is, however, a reduction of interference by about 6 db if the frequency spacing is increased to 15 kc/s.

The allocation of frequencies to the various transmitters forming part of the provisional national scheme will be so planned that interference will not occur for any listener within the service area for more than 5 per cent. of the time on the worst days in the year, i.e. when propagation conditions are conducive to long-distance transmission. Some slight relaxation of the ratio of the wanted to interfering field strength that would otherwise have been necessary to avoid interference in any circumstances may therefore be permitted. The conception of 'tolerable interferences' has accordingly been introduced, which refers to the grade of interference that would be tolerated by all but the most discriminating listeners.

Table III shows the required ratio, expressed in decibels, of the wanted to the interfering carrier for various degrees of suppression of common-channel interference using f.m.

TABLE III

Beat frequency between wanted and unwanted carriers	*No perceptible interference*	*Just perceptible interference*	*Tolerable interference*
Frequencies up to 5 kc/s	30db	25db	19db
15 kc/s	24db	19db	13db

ADJACENT CHANNEL INTERFERENCE.

The proposed channel spacing for f.m. stations operating as part of a national distribution scheme is 200 kc/s, and it is necessary to consider what degree of interference may be experienced from a station operating in the channel adjacent to that to which the receiver is tuned.

This will depend to a considerable extent on the details of receiver design, but in typical cases, for a wanted signal of 1 mV/m, the adjacent channel signal must be from 10 to 20 db less for interference to be quite inaudible. For weaker signals, of the order of 0.1 mV/m, the adjacent channel signal need be only from 0 to 10 db below the desired signal. On this basis it will not prove difficult to plan a national scheme, the geographical situation of the stations being so chosen that adjacent-channel interference is avoided.

RECEIVERS.

As mentioned earlier in this article, the adoption of a v.h.f. service would mean that listeners would have to buy new receivers or else fit adaptors if they are to take advantage of the service. In a first-class service area, i.e. where the field strength equals or exceeds 1 mV/m on f.m., experience in the U.S.A. and Germany, as well as in this country, indicates that inexpensive receivers can provide good service. In second-class service areas more expensive receivers are necessary.

Two essential requirements for a good f.m. broadcast receiver are:

(i) That it should be provided with a limiter set to operate efficiently at the minimum signal strength for which the receiver is designed.

(ii) That oscillator drift (a difficulty inherent in any v.h.f. receiver) should be reduced to reasonable limits.

Requirement (i) is of the greatest importance, for unless the limiter does become fully operative, the principal advantage of f.m. — that of noise suppression — is partially or wholly lost. Requirement (ii) is met, in the more expensive class of receivers by the provision of quartz stabilised oscillators, or by the provision of automatic frequency control. In the cheaper sets, some form of thermal element may be incorporated to prevent drift as the receiver warms up.

Experience of British-made f.m. receivers has not been extensive. Most of the listening tests on the Wrotham transmissions were carried out with receivers built to a B.B.C. specification. These receivers are fitted with automatic frequency control and incorporate the latest type of limiter for a.m. reception, which can be switched in or out of circuit at will. Other receivers used for the laboratory and field tests included one make with a crystal controlled superheterodyne oscillator and another of relatively simple design,* which was developed in the B.B.C. Research Department laboratories. Two models of this receiver were made, one being a (6 + 1)-valve receiver with external loudspeaker, and the other a 6-valve car receiver.

From the experience which has been gained with teams of listeners, both technical and lay, the conclusion is drawn that the tuning of an f.m. receiver need not be difficult, and that in receivers not provided with automatic frequency control little trouble is experienced with oscillator drift after the first few minutes of switching on. The degradation of quality due to incorrect tuning is comparable with that encountered in conventional medium-wave and long-wave receivers when maladjusted.

*** Spencer, J. G.: 'A simple F.M. Receiver for the 90-Mc/s Broadcast Band', Wireless World, Nov. and Dec. 1951.**

APPENDIX.

WROTHAM EXPERIMENTAL TRANSMISSIONS QUESTIONNAIRE.

Systems F.M. 91.4 Mc/s; A.M. 93.8 Mc/s; A.M.L. 93.8 Mc/s.

1. SITE	
1.1. Name	
1.2. Address	
1.3. How far is the site from motor traffic?	
1.4. Is the traffic continuous or occasional?	
1.5. On what floor is receiver installed?	
2. AERIALS	
2.1. Have any aerials other than that installed by the B.B.C. been tested? If so give details (type and position)	
3. RECEIVER	
3.1. Has any difficulty been found in tuning-in?	
3.2. Do you notice any difference in quality between f.m., a.m., a.m.l.?	
3.3. How does the quality compare with your local medium-wave station?	
4. RECEPTION CONDITIONS	
4.1. Receiver Hiss (a steady background 'rushing' noise). Do you notice receiver hiss on any of the transmissions? If so give the grade for all three systems and for your local medium-wave service. (See Note at end of questionnaire). If more than one type of aerial has been used, give the grade for each	
4.2. Interference from motor cars (sharp crackling interference as car passes). Do you notice car interference on any of the transmissions? If so give the grade for all three systems and for your local medium-wave service	

APPENDIX *(Continued)*

4.3. Other electrical interference (from domestic appliances such as vacuum cleaners, refrigerators). Do you notice interference from these appliances on any of the transmissions? If so give the grade for all three systems and for your local medium-wave service	
4.4. Fading or distortion. Has any fading or bad distortion been observed? If so on which system was it most noticeable? Did you associate any such fading with the proximity of aircraft?	
4.5. If you have a television receiver, does car interference affect either the sound or vision signal? Give grade of interference in each case	
5. PREFERENCE FOR SYSTEM 5.1. On which system would you prefer to listen for a broadcasting service? Give reasons 5.2. Do you prefer the chosen system to your local medium-wave service? Give reasons?	
6. OTHER OBSERVATIONS Have you any other observations to make on the tests? (If there is insufficient space here, use separate sheet)	

Note on grading of interference

In order to facilitate analysis of the information received, interference should be graded according to the following scale:

IP	(Imperceptible)	No interference heard.
JP	(Just perceptible)	Interference just audible in gaps in the programme when listening with attention.
P	(Perceptible)	Interference audible but not annoying.
SD	(Slightly disturbing)	Interference rather annoying but not so bad as seriously to degrade the programme value.
D	(Disturbing)	Interference very annoying and such as seriously to degrade the programme value.

Example of answer to Section 4.2. (This does not represent in any way the interference expected in practice).

f.m.	a.m.	a.m.l.	medium-wave
SD	SD	P (occasionally)	IP

RECEIVER NOISE FIGURES *(Continued from page 82.)*

By going into this matter a little more thoroughly. we can see just what this noise figure means expressed in figures. Assume we have some receivers with a bandwidth of 25 kilocycles. Let us assume also that we have an antenna with a radiation resistance of 100 ohms, and that this antenna is at room temperature. (I'm not going to explain this room-temperature statement — it is included just to keep this whole thing technically correct.)

The thermal noise power due to this 100 ohm radiation resistance is 0.0004 micro-microwatts (this corresponds to a 0.2 microvolt noise voltage). Now we will listen to a signal with a power of 0.002 micro-microwatts (about a 0.5 microvolt signal). The signal-to-noise ratio on the antenna in this case is therefore 0.002 to 0.0004 or 5 to 1. Now, let us connect two hypothetical receivers, having the bandwidth previously mentioned, to this antenna in turn, and see what happens. The first receiver is one having a noise figure of 13 db. This might be considered a fair receiver, by the way. What happens to the signal-to-noise ratio with this receiver? Well, 13 db is a power ratio of approximately 20 to 1, so that the noise will be increased 20 times, up to 0.008 micro-microwatts. The signal-to-noise ratio with this receiver will be 0.002 divided by 0.008 or 1:4. The noise is four times as strong as the signal. Well, let's try the other receiver.

Assume we have a receiver with a noise figure of 6 db (the six-metre receiver described in Radiotronics, April, 1952, for example). Six db is a power ratio of four to one, so now our signal-to-noise ratio will be 0.002 divided by 0.0016, or 1.25 to 1. The signal is louder than the noise, so we stand a good chance of hearing the signal with this receiver.

What are typical noise figures for various types of receivers? This is an interesting question, and you may be surprised at the answer. Very good receivers have noise figures of about 5 to 10 db. Receivers have been built with noise figures as low as a fraction of a db, but these were laboratory receivers — at least, none are available commercially. An average fair superheterodyne that you might call a communication receiver is liable to have a noise figure as poor as 30 db. Going further, a broadcast-band, table-model, a.c.-d.c. set might have a noise figure as high as 50 db! You pay your money and you take your choice. Of course, you don't need a low-noise local station receiver for the broadcast band because there are so many high power broadcast stations.

New RCA Releases

Radiotron-6161 is a very compact, forced-air-cooled power triode of the grounded-grid type designed for uhf service in television and cw applications. It has a maximum plate dissipation of 250 watts in cw and television service. The 6161 can be operated with full plate voltage and plate input at frequencies as high as 900 Mc, and with reduced ratings up to 2,000 Mc.

Featured in the 6161 is a coaxial-electrode structure designed especially for use with circuits of the coaxial-cylinder type. The design provides low-inductance, large-area, r-f electrode terminals for insertion into the cylinders, and permits effective isolation of the plate from the cathode. The latter feature makes the 6161 particularly suitable for grounded-grid circuits.

The 6161 supersedes the type 5588 for new equipment design.

Radiotron-20MP4 is a directly viewed, rectangular, glass picture tube utilizing low-voltage, electrostatic focus and magnetic deflection. It has a Filterglass faceplate; an external conductive bulb coating which with the internal conductive coating forms a supplementary filter capacitor; an ion-trap gun requiring an external, single-field magnet; and a screen size of 17¼″ × 13¼″ with slightly curved sides and rounded corners.

The focusing electrode in the 20MP4 has its own base-pin terminal so that designers can have a choice of focusing voltage for best results. Because the focusing electrode (grid No. 4) operates at low voltage and takes very low current, the focusing voltage can conveniently be obtained from a potentiometer between the boost voltage and the negative terminal of the grid-No. 1 supply voltage, or from a fixed tap on the low-voltage d.c. supply for the receiver. When fixed focus is used, the designer can set the focusing voltage at a value which will give good results for his particular operating voltages. If somewhat better performance is desired, he can provide for adjustment of the focusing voltage. With either method, focus can be maintained automatically with variation in line voltage and with adjustment of picture brightness.

Radiotron-21MP4 is a directly viewed, rectangular picture tube of the metal-shell type utilizing low-voltage, electrostatic focus and magnetic deflection. It has a frosted Filterglass faceplate; an ion-trap gun requiring an external, single-field magnet; and a screen size of 18⅜″ × 14″ with slightly curved sides and rounded corners.

The focusing electrode in the 21MP4 has its own base-pin terminal so that designers can have a choice of focusing voltage for best results. Because the focusing electrode (grid No. 4) operates at low voltage and takes very low current, the focusing voltage can conveniently be obtained from a potentiometer between the boost voltage and the negative terminal of the grid-No. 1 supply voltage, or from a fixed tap on the low-voltage d.c. supply for the receiver. When fixed focus is used, the designer can set the focusing voltage at a value which will give good results for his particular operating voltages. If somewhat better performance is desired, he can provide for adjustment of the focusing voltage. With either method, focus can be maintained automatically with variation in line voltage and with adjustment of picture brightness.

Radiotron-6082 is a new, low-mu, high-perveance, twin power triode designed with a 26.5-volt heater for use as the regulator tube in stabilized d.c. power-supply units of aircraft receivers.

Featuring conservative ratings, the 6082 consists of two triode units in one envelope. Each unit has a mu of 2, a transconductance of 7,000 micromhos, and a plate dissipation rating of 13 watts.

The 6082 employs a compact design in which special attention has been given to features which improve its strength not only against shock but also against vibration. Use is made of a button stem to strengthen the mount structure and to provide relatively wide inter-lead spacing for reduction in susceptibility to electrolysis. These features all contribute to the dependability of the 6082 and to its suitability for use in military aircraft.

Radiotron-6173 is a "pencil-type", high-perveance, uhf diode intended particularly for use in pulse-detection and pulse-power-measuring service. In such service, it may be operated at frequencies as high as 3,300 megacycles per second. Because of its small size and frequency capability, the tube is especially useful in r-f probes of electronic voltmeters.

The "pencil-type" design of the 6173 features a coaxial-electrode structure of the double-ended metal-glass type having minimum transit time, low lead inductance, and low interelectrode capacitance. Other desirable features include very low heater wattage (0.85 watt), and a weight of only ⅕ ounce.

Radiotron-12BH7 is a medium-mu twin triode of the 9-pin miniature type used in the vertical deflection circuits of television receivers. In such circuits, one unit of the 12BH7 may be used as the vertical deflection amplifier; the other unit can serve as vertical oscillator.

The 12BH7 features two similar triode units in one envelope; separate base-pin terminals for each cathode; and a mid-tapped heater to permit operation from either a 6.3-volt or 12.6-volt supply.

The 12BH7 may also be used in other applications including phase-inverter circuits and multivibrator circuits.

One-Tube Keying Monitor

General features

Compactness and broad frequency coverage are the two main features of the keying monitor illustrated in Fig. 1. The monitor picks up radio-frequency signals of any wavelength and automatically produces an audio-frequency tone which may be used to monitor your keying.

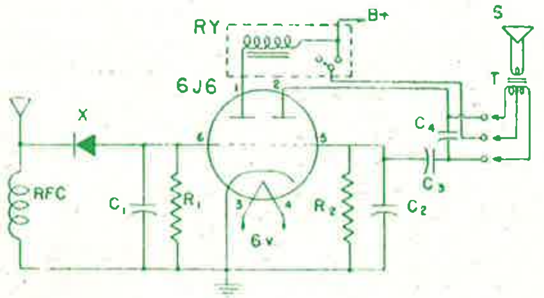

Fig. 1.

With reference to the circuit diagram above, a sensitive relay, *RY*, is connected in the plate circuit of the first section of a 6J6. When no r-f is present on the antenna, sufficient plate current flows to energize the relay, preventing the plate voltage from reaching the second section of the 6J6. (The relay is shown in the energized position.) When a signal is impressed on the antenna, the crystal, *X*, rectifies the r-f signal and impresses a voltage on the grid which cuts off the flow of plate current. This de-energizes the relay and applies plate voltage to the second section of the 6J6, which acts as an audio oscillator.

This keying monitor has the advantage that it operates only when your transmitter is on the air, and for this reason is superior to a monitor which merely produces a tone when your key is down, which would be true if you were keying a relay, one pole of which keyed your rig with the other pole keying an audio oscillator. Using the 6J6 monitor, it is immediately apparent if your crystal is sluggish.

Circuit components

The crystal, *X*, may be any sort of small rectifier crystal, such as the GEX44/1, etc. Its action is not critical. The relay, *RY*, may be any type of sensitive relay which incorporates a single-pole, double-throw switch, or a switch which is "on" when the relay is not energized. The relay should be capable of picking-up on a current of approximately 4 mils. The relay shown has a coil resistance of 2,400 ohms and a pick-up current of exactly 4 mils.

The plate circuit of the right-hand section of the 6J6 uses an audio transformer as a "tank circuit." Practically any type of transformer will work. The highest impedance winding should be used on the plate side, and the low impedance winding used to drive the speaker. A permanent magnet speaker should be used. (Earphones may be used instead of a speaker.)

The value of C_4 is not specified because the exact value will depend upon your preference for the correct audio note and also upon the transformer used. Some transformers have a high enough internal capacitance that no condenser is needed. Try the circuit without any condenser at C_4. If the tone is too high, add capacitance in steps of 0.05 μF until the tone is suitable.

Operating details

The keying monitor is small enough to fit inside many receivers, or in an odd corner of your speech amplifier. Voltage requirements are low and the power can be taken from your receiver in most cases. The filament requires 6.3 volts at 0.45 ampere. The plate voltage may be any value from 45 volts to 150 volts at a current of approximately 10 mils. This value will depend somewhat on the resistance of the coil in the relay.

In operation, a single wire may be taken from the antenna post, and brought near the final stage. If increased coupling is required, a link may be used, connecting the link across the r-f choke. Coupling should be increased until the audio tone is present (when your transmitter is on). No further adjustments need be made, even when changing bands.

Circuit constants

C_1, C_2	=	500 $\mu\mu$F postage stamp mica
C_3	=	0.1 μF paper
C_4	=	See text
R_1	=	0.6 megohm, ½ watt
R_2	=	10,000 ohm, ½ watt
RFC	=	2.5 mH r-f choke
RY	=	Sensitive relay, see text
S	=	Speaker, see text
T	=	Audio transformer, see text
X	=	Crystal rectifer, see text.