RADIO and ELECTRONICS

DECEMBER 1st, 1946

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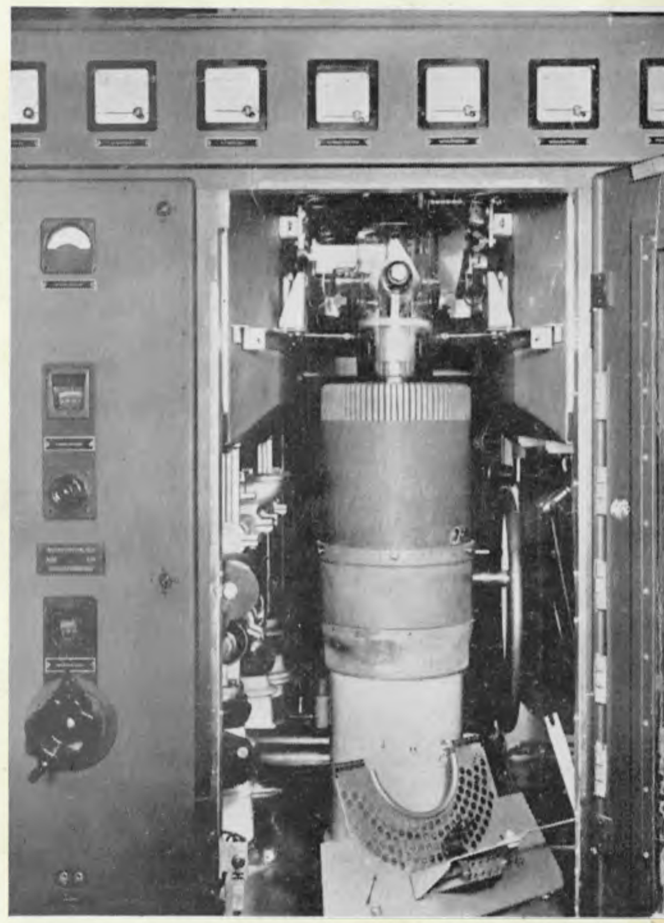

OUR COVER this month portrays a high-powered stage in one of the short wave transmitters at P.C.J. Eindhoven, Holland. The tubes (the front one being clearly visible in the photograph) are cooled by forced draught through cooling fins attached to the external anode and surrounded by a metal sheath.

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Electronics in the Post-war World

For too many years now has the importance of electronics been overshadowed in the public mind by the entertainment value of one of its greatest manifestations—radio broadcasting. It is only natural that this, one of the marvels of the century, should capture the public imagination to the extent that it has done, but at the same time there is no reason why kindred, and even more important branches of electronics, should be relatively so little known. The vast part played in the world's economy by radio communication (as distinct from broadcasting) is hardly even guessed at by the layman.

Radio communication itself is now only one item in an ever-growing list of electronic applications, the importance of which is daily increasing. In the last decade, uses have been developed for electronic techniques which were previously undreamed of. Industrial men, doctors, engineers and workers in all branches of pure and applied science, have been provided with powerful new tools for investigating and solving their problems—problems which, in many cases, have defied solution till electronics supplied the key to them.

To some, this may seem a sweeping statement, and so it is, but it is none the less true, and in direct proportion to its truth is the importance of electronics to the world at large and to this country in particular. This being the case, the importance of having a sufficiently large body of men trained in electronic engineering can hardly be overestimated. At present a vicious circle exists, whereby the full exploitation of electronic techniques is hindered by the lack of men with good enough qualifications and sufficiently advanced training. The incentive to suitable young men to study advanced electronics is likewise hindered by the lack of positions for them once they are fully trained.

There are signs, however, that a break is occurring in this vicious circle—a break due solely to the growing realisation among industrialists and others that electronic methods can be of great assistance to them. One very tangible sign is the provision at Canterbury University College of a post-graduate course in electronics, and the probable future creation of a chair of electronics in the Engineering School at the same College. Another is the retention by the Department of Scientific and Industrial Research of a nucleus of the war-time Radio Development Laboratory as an electronics division of the Dominion Physical Laboratory. These things are encouraging, and are possibly all that can be expected at present.

However, there is certainly no lack of appreciation in Great Britain or America, either of scientific development generally, or of electronics in particular. It is recognised that in defence alone electronics will, in the future, play a part bigger by far than was its share in the last war.

For this reason alone, quite apart from any other, New Zealand should take care to keep in the forefront of peace-time electronics, just as she did during the war. For, whether peace or war is to be our future lot, we now live in an electronic age, when none can say that this branch of applied science will not ultimately exceed all others in its effects upon mankind.

RADAR—Height Finding by Radar

The first use to which radar was put was that of giving long-range warning of the approach of enemy aircraft. We have shown in earlier articles in this series how the range and bearing of an aircraft from the radar station may be measured with considerable accuracy. However, if the position of an attacking aircraft is to be specified exactly, its height must be known as well as its range and bearing. This may at first sight appear to be rather an academic requirement, since the "hostile" can be tracked perfectly well without its height being known. However, when the matter is considered from the point of view of a fighter force despatched to intercept the enemy before he can reach his objective, it can be seen that information on the enemy's height is really essential if easy interception is to be realised, and in some cases if it is to be successful at all.

This fact was early realised by those responsible for designing Britain's air warning system, with the result that much effort was expended in developing a successful radar height-finding device.

Fig. 1 gives a pictorial statement of the problem of finding an aircraft's height from a radar station at A. By the usual method, the range R, of the target is known, so that, if some means can be found of estimating the angle of elevation of the target, its height may be calculated from the simple trigonometrical relationship $h = R \sin \phi$ where is the angle of elevation.

In order to find , the well-known vertical directional pattern of an aerial is used. Suppose we have an aerial at a certain height on a mast. It will produce a vertical radiation pattern consisting of a number of lobes, such as the ones drawn on Fig. 1. The angle of elevation of the tip of the lowest lobe depends upon the height of the aerial, and is lower the higher the aerial. Thus, referring again to Fig. 1, the solid lobe would be produced by an aerial much higher than another which would give the dotted lobe.

Now, considering the radiation pattern of the higher aerial, i.e., the solid lobe in Fig. 1, this shows that, if an aircraft is on the ground, there will be no signal received by the receiving aerial. However, as the aircraft becomes higher, a signal will appear, and will become progressively greater until the angle of elevation of the aircraft is 5 degrees, corresponding with the maximum of the aerial's pattern. Then, as the aircraft flies higher still, the signal will become smaller, until at some still greater angle of elevation it will disappear altogether.

Now, let us consider the lobe (shown dotted) belonging to the lower aerial. In this case, also, the signal will be zero when the target is at ground level, and will increase as its height increases. This time, however, the strongest signal

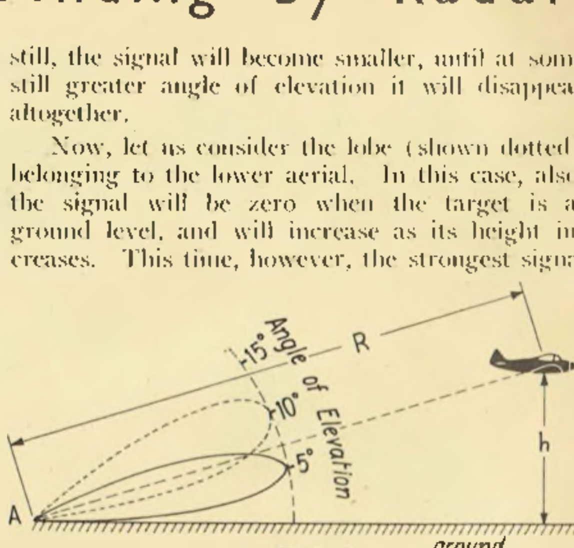


FIG.1

is not received until the target is at an angle of elevation of 10 degrees. Now, suppose we are able to observe simultaneously and separately echoes received on both the high and low aerials. If this is done, as the aircraft increases its height from zero feet up, we should notice that the relative strengths of the echoes received on the two aerials will be constantly changing. For instance, when the angle of elevation of the target is lower than about 7 degrees, the signal from the high aerial will be stronger than that from the low aerial, but as the aircraft approaches 7 degrees, the ratio between the signals from the high and low aerials will become smaller. When the aircraft reaches this angle of elevation (which is its position drawn in Fig. 1), the signals from the two aerials will be equal. As the aircraft goes higher still, the signal from the low aerial becomes stronger than that from the high one, and so on.

From this it can be seen that, if we know the exact patterns of the high and low aerials, we can work out what the ratio of the signals should be for any angle of elevation of the target. When this has been done, and we then observe, say, that the signals are equal, we know in the example used that the target must be at an angle of elevation of 7 degrees. This principle is the basis of the height-finding systems used on all but microwave radar sets.

In one of the G.C.I. or Ground Controlled Interception types of radar set, two receiving aerial systems are used, one 7½ft. high and one at 12½ft. By means of electronic switching, these aerials are used alternately at a rate of many times a second, and the echoes from each are displayed side by side on the time-base of the A-scope display tube in the set. Thus, each aircraft is shown as two side-by-side echoes whose height, and therefore relative signal strength, can be found directly by simple measurement. From the A-scope, the range also is measured, and the two quantities, range and ratio of signals from the two height aerials are applied to a special chart from which the aircraft's height can now be read.

AMBIGUITIES

The system outlined works very well indeed under favourable conditions, but in practice there are a number of difficulties which occur. Chief among these is the question of ambiguity, which can be seen from Fig. 2. Although our discussion has been confined solely to the lowest lobes in the patterns of each aerial, it must be remembered that there will be one lobe for every half-wave-length that the aerial is elevated above the ground. In Fig. 2, the lobes have been drawn differently, showing the two lowest lobes of the high aerial and the lowest lobe of the low aerial. In Fig. 1 the second lobe of the high aerial was omitted in the interests of clarity. Here again, the bottom lobe of the high aerial has its maximum response at 5 degrees elevation, and that of the low aerial comes at 10 degrees. In addition, however, the second lobe of the high aerial has its maximum at 15 degrees. Now, taking the simplest case where the responses from the two aerials are equal, we find that the angle of elevation of the aircraft could be either 7 or 13 degrees, or if the second lobe of the low aerial is taken into account, even 19.8 degrees. The question now arises as to which of these answers is the correct one!

It will be remembered that some way back we assumed that we could tell which of the echoes belonged to each aerial, and in the practical equipment this is a fact, so that a good many cases of ambiguity are ruled out for a start. However, in the case we are now considering, this knowledge does not help. Instead, use is made of the fact that the signal produced by the bottom lobes of the two aerials are in phase, while that from the second lobe of the high aerial is out of phase with that of the two bottom lobes. Thus, if a switching arrangement enables us to combine the responses from the two aerials before they feed into the receiver, and to compare this combined signal with the one from the high aerial alone, the ambiguity will be resolved. The reason for this is that if the aircraft is in the bottom lobe of both aerials, the combined signal will be greater than that from the high aerial, but if the aircraft is in the second lobe of the high aerial, combining the signals will give a smaller resultant signal,

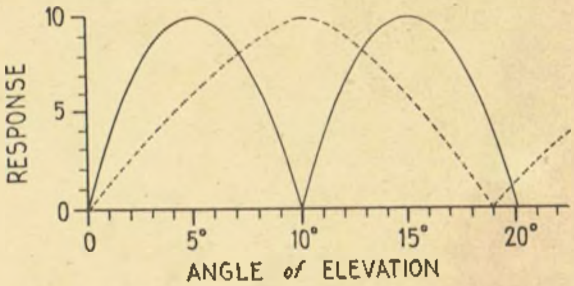


FIG. 2

since the individual ones are out of phase and tend to cancel each other. In this way, if we throw our aerial switch to this new position and find that we have an increased signal, then the correct angle of elevation is 7 degrees and not 13 degrees.

In practice, the heights of the aerials, and therefore the manner in which the patterns overlap, are adjusted so that a minimum number of ambiguities will occur. Thereafter, the remaining ones can be resolved (a) by knowing which echo belongs to which aerial, and (b) by comparing the combined response from the two aerials with that from the high one.

OTHER DIFFICULTIES

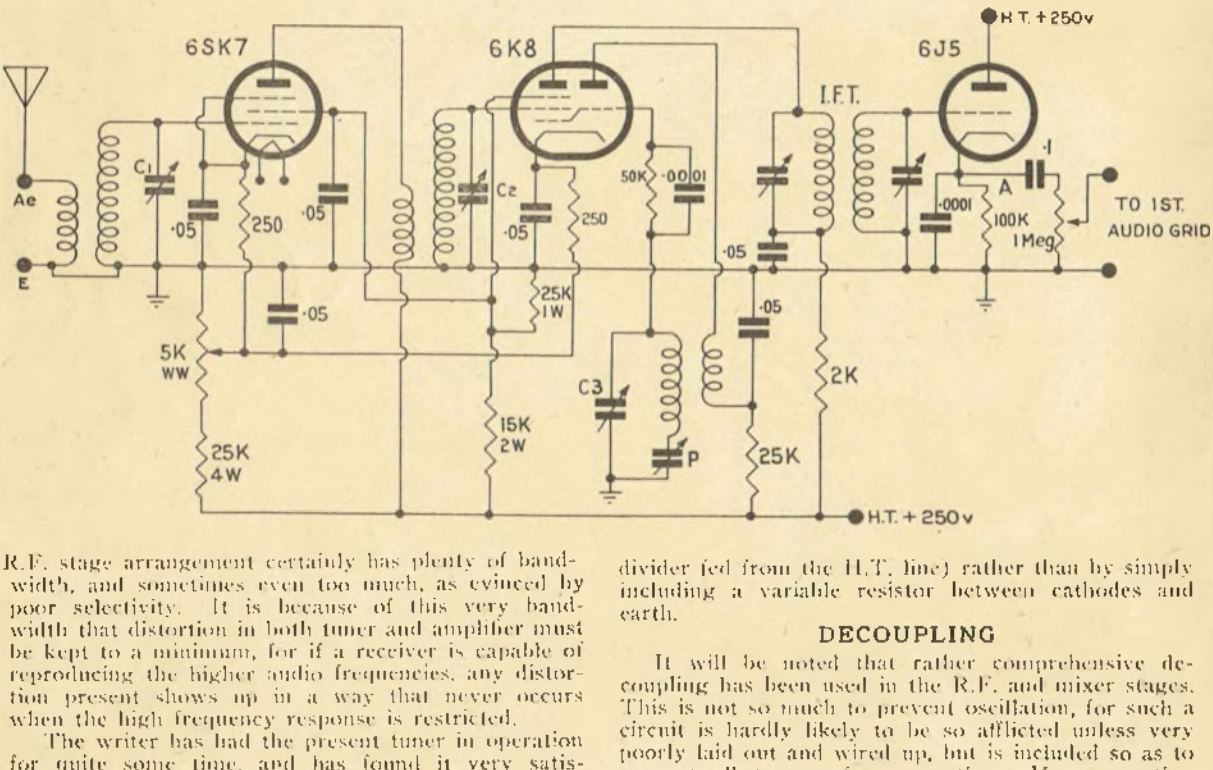
Enough has now been said of this one method of height-finding to indicate that it is the most difficult radar measurement to make accurately, and is also less precise than the measurement of range and bearing. The main reason for the comparative inaccuracy of the method is that it depends for its success on the knowing as exactly as possible the exact shape of the radar's radiation pattern in vertical plane. This, in turn, depends upon the site of the radar, and on a poor site will be different for different bearings. For instance, for successful height-finding, the site must be perfectly level for some distance round the radar set, and there must be no obstructions in the way of buildings, hills, or overhead wires within certain well-specified distances. Again, although the earth may be quite level, its reflection properties may change at different bearings.

(*Continued on page* 48.)

A HIGH QUALITY BROADCAST TUNER

Many people who have built good quality audio amplifiers for gramophone or other use wish to take advantage of the quality of the amplifier in order to obtain higher fidelity from local broadcast stations. A time-honoured method of doing this is to construct a tuner consisting only of a stage of R.F. amplification, followed by a diode or infinite impedance detector. However, this scheme has several disadvantages. Although such a tuner is able to give good quality from the stronger local stations, it sometimes shows up very badly in receiving the weaker locals, such as the auxiliaries 2YC, 3YL, etc. One reason for this is that both the diode and infinite impedance detectors require a rather large signal if their distortion is to be kept very low. The single detector is a 6J5 used as an infinite impedance detector. The output of the latter is taken to the input of the audio amplifier.

The circuit is quite conventional, except that it uses a manual gain control instead of A.V.C. It would have been possible to use a separate diode for the latter and to omit the manual gain control, but this was considered inadvisable, as it would not be particularly effective, and would probably allow overloading to occur in the mixer stage on very strong local signals, with consequent heavy distortion. Therefore, it was omitted and recourse was had to the manual control. This is rendered more effective by taking the common cathode lead of the 6K7 and 6K8 to a source of positive voltage (a voltage



R.F. stage arrangement certainly has plenty of bandwidth, and sometimes even too much, as evinced by poor selectivity. It is because of this very bandwidth that distortion in both tuner and amplifier must be kept to a minimum, for if a receiver is capable of reproducing the higher audio frequencies, any distortion present shows up in a way that never occurs when the high frequency response is restricted.

The writer has had the present tuner in operation for quite some time, and has found it very satisfactory indeed. It has much more gain than the usual simple T.R.F. affair, so that a good strong signal is delivered to the diode from all the local stations, and at night from the other main stations as well. For this reason, distortion is very low. The bandwidth is quite great enough to allow a high frequency response not achieved in ordinary sets, so that a real advantage occurs in using the tuner to feed a good quality amplifier and loud speaker.

THE CIRCUIT

The tuner is a superheterodyne in which the I.F. stage has been omitted. The mixer section of the 6K8 feeds straight to the second detector through a single 465 kc/sec. I.F. transformer. The second divider fed from the H.T. line) rather than by simply including a variable resistor between cathodes and earth.

DECOUPLING

It will be noted that rather comprehensive decoupling has been used in the R.F. and mixer stages. This is not so much to prevent oscillation, for such a circuit is hardly likely to be so afflicted unless very poorly laid out and wired up, but is included so as to prevent all traces of regeneration. If regeneration is present, even though it may not be sufficient to cause oscillation, it can seriously affect the performance of the tuner by causing the selectivity curve to be lop-sided, so that only one side-band can be tuned in properly, the other being partially lost. In this connection, it is important that bypass condensers be connected as shown in the cathode circuit. The cathodes of the 6SK7 and 6K8 are both bypassed **at the pins themselves**, and a third 0.05μf. condenser is used right at the moving arm of the 5k. gain control potentiometer. Similarly, the 2k. and .05μf. decoupling circuit in the 6K8 plate lead should on no account be omitted.

OUTPUT ARRANGEMENTS

A big advantage of the infinite impedance detector is that, like the cathode follower, it has a low output impedance. In the circuit a 0.1μf. blocking condenser and 1 meg. volume control pot. are shown at the output of the 6J5. However, these are necessary only if the amplifier with which the tuner is to be used has no volume control at the input. They have been included in the circuit only for the sake of completeness, **and should not be mounted on the tuner unless the output lead is very short.** The point A is the place where the output lead from the tuner should be taken off if there is more than a few inches between the tuner and the amplifier. In the writer's case, the tuner successfully feeds two amplifiers, one in the same room and the other in a different room about a hundred feet away. A pair of twisted wires is used to feed the remote amplifier from the points A and earth, and even though this wire is unshielded, there is no noticeable loss of high frequency response, and so little hum as to be negligible. This is a direct consequence of the low output impedance of the detector circuit. Any other detector would need either a transformer or a cathode follower to enable a long open line to be connected to it without introducing excessive hum, or causing high frequency loss.