Wireless World

RADIO AND ELECTRONICS

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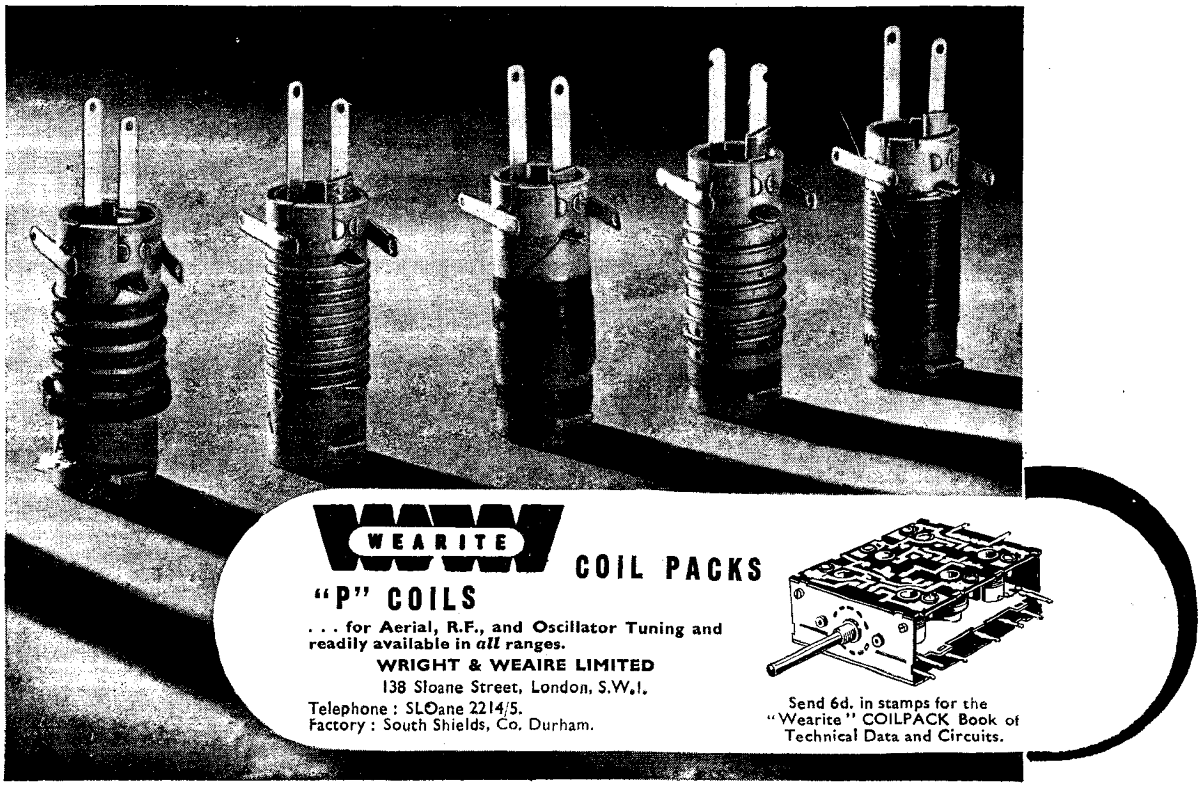

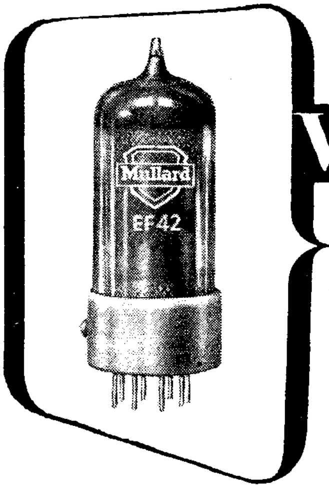

Valves and their applications

TELEVISION SYNCHRONIZING & TIME BASE CIRCUIT USING EF42, ECC34 & EL38. No. 3.

SYNCHRONIZING PULSE SEPARATOR USING EF42.

The circuit of Fig. 1 with its associated waveforms in Fig. 2 will be recognised as part of the complete circuit in last month's issue of the "Wireless World".

The effectiveness of the time base synchronization profoundly affects the quality of the final picture. With the system of synchronization described in this series of reports a clean vertical edge and steady interlace are secured even in the presence of considerable interference, thus realising the full benefits of high definition obtained from specially designed signal circuits.

The process of synchronization is achieved in four major stages. In the first stage a slicing action takes place in which the composite video signal is truncated with the elimination of the picture signal and the tips of the synchronizing pulses which contain noise and interference.

In the second stage, the synchronizing pulses are fed to the line time base in such a way that the time base is synchronized or fired at the correct instants of time by the leading edges of the pulses.

In the third stage, amplitude differentiation of the line pulses and the chain of frame pulses is obtained. In the transmitted signal the differentiation is one of pulse length.

The fourth and final stage is a further slicing operation. The results of the third stage are sliced so that a single pulse of about 400μs duration, corresponding to the chain of eight frame pulses, is passed on and other pulses, corresponding to the line pulses, are eliminated.

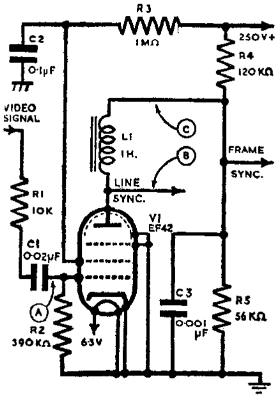

FIG. 1.
CIRCUIT OF FIRST LIMITER IN SYNCHRONIZING PULSE SEPARATOR.

In the circuits discussed these stages are somewhat interrelated but the conception of the four steps will assist in following the more detailed description of the circuits which is given in the additional notes and next month's advertisement.

The first limiter (see Fig. 1) has a double clipping action by driving the EF42 well into grid current on the tips of the pulses and having a sufficiently short grid base so that the base of the pulses and the vision signal are beyond cut-off. The inductor L1 causes the valve to bottom as if it had a very large resistive anode load which gradually decreases in value during the period of a synchronizing pulse. This has the effect of increasing the limiter base (the range of grid potential between cut-off and bottoming) during the pulse and the maximum amount of noise and interference is cut off at the beginning of the pulse period when the line blocking oscillator is fired and is taking current. If a large value resistor were used instead of an inductor to obtain this short limiter grid base the frame pulses would not be effectively developed across the capacitor C3 for lack of sufficient anode current. With the circuit employed large frame pulses are obtained, the amplitude of the first being practically equal to that of the last.

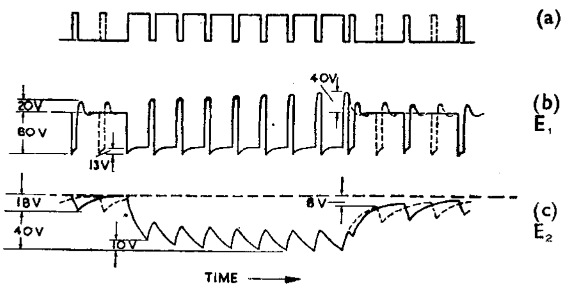

FIG. 2.
WAVEFORMS OF POTENTIAL ASSOCIATED WITH THE FIRST LIMITER STAGE OF THE SYNCHRONIZING PULSE SEPARATOR.

(a) *Transmitted Synchronizing Pulses.*
(b) *Waveform at Anode of Valve V1.* (E_1)
(c) *Waveform showing Amplitude Differentiation of Frame and Line Pulses (at point C, Fig. 1).* (E_2)

Mullard

Reprints of this report from the Mullard Laboratories, together with a fuller description of the circuit, may be obtained free of charge from the address below.

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Wireless World

RADIO AND ELECTRONICS

DECEMBER, 1949

Monthly Commentary

G.P.O. AND INTERFERENCE

A CORRESPONDENT whose letter is printed elsewhere in this issue draws attention to a matter that has become of increasing importance since the Wireless Telegraphy Act was passed.

As everyone knows, the General Post Office has long undertaken to investigate complaints of interference with broadcast reception, and to give help, within its power, in removing the cause. It is less generally known that this help has been mainly restricted to dealing with interference affecting reception of B.B.C. stations, though we believe that no official pronouncement has been made to support the statement, quoted by our correspondent, that reception of foreign broadcast stations is no concern of the P.O. engineers.

Even before the passing of the Wireless Telegraphy Act such an attitude seemed hardly tenable, or at least highly arbitrary. In law, the listener pays his licence fee, not for the B.B.C. programmes, but for the use of a very small part of the Postmaster-General's monopoly in wireless telegraphy. If the licensee chooses to listen to foreign stations, he is surely entitled to equal protection within reason, though it would clearly be unreasonable to expect a signal of excessively low field strength to be effectively protected.

Although the Postmaster-General's obligations to protect his broadcast listener licensees may not be sensibly affected by the passing of the Wireless Telegraphy Act, his powers to afford effective protection are now greatly increased. These powers should, we submit, be wielded in such a way as to encourage the development of broadcast listening in every direction. The P.M.G. has always had authority to curb encroachments on the broadcast band by stations licensed by him, but it would seem that British beacon stations do at present interfere with the reception in this country of non-B.B.C. stations. As to machine-made interference, it is hoped that the new powers of suppression will be wielded in such a way as to confer the greatest possible benefit to all, and not in a dictatorial or arbitrary manner.

QUICK-TUNING SYSTEMS

COMMENTING last month on the trend of design of broadcast receivers, as exemplified at the Olympia Exhibition, we referred to a tendency to provide the simplest possible form of tuning for the selection of B.B.C. programmes. This, as we said, is a change we have long expected to see. Domestic broadcasting is, at present, organized on a basis of three programmes—or two programmes for a large proportion of the population. Therefore there would seem to be a need for some quick and easy change-over device from one to the other, irrespective of the complexity or otherwise of the main tuning system of the receiver—and also irrespective of the skill of the user.

A surprisingly large number of readers seem to agree with the desirability of this innovation. A few of our correspondents, it must be admitted, chide us gently for detecting a summer when only one or two swallows in fact exist; they say, in effect, that the very small number of sets in which this feature is included hardly warrant its being hailed as a trend in design. Be that as it may, no dissentient voice is raised against the value of the feature, and our regular contributor, "Cathode Ray," suggests the general public lack the spirit to demand a facility of which he assumes the value to be self-evident. We think, now that the ordinary listener has been shown that switch selection of the main B.B.C. programmes is practicable, he will soon expect to find it in every type of receiver, at every price level.

SUPPRESSED AIRCRAFT AERIALS

Various Methods of Reducing "Drag"

By G. E. BECK, *B.Sc., A.M.I.E.E.*

(Marconi's Wireless Telegraph Company)

ONE of the principal ways of improving the overall performance of aircraft—and hence increasing the payload of civil aircraft—is to reduce "drag" to a minimum, by eliminating or suppressing external fittings on wings and fuselage. Conventional radio and radar aerials have proved serious offenders in this matter of "drag," so that the immediate need has been to produce aerials which do not project beyond the normal skin of the aircraft. For example, by eliminating 1 lb of "drag" from a medium-sized airliner whose cruising speed is 230 knots, the pay-load can be increased by 20-30 lb, and this might well be achieved by replacing an existing external aerial with a suppressed aerial. Again, by suppressing all the aerials on a modern airliner it is possible to eliminate 25 lb or more of "drag." Apart from this, suppressed aerials have obvious mechanical advantages at high speeds, when it is difficult to secure such things as projecting rods or wires.

Types of aerial.—Aeronautical radio services use frequencies in a great many wavebands. Some idea of the complexity of the problem this presents to radio designers and engineers can be obtained from a study of the table. This table gives some of the services concerned, the frequency coverage of those services, and the types of aerial that the fre-

TABLE OF AERONAUTICAL RADIO AND RADAR SYSTEMS

Service	Frequency Coverage Mc/s.	Type of Aerial
Automatic direction finding	0.15 to 2.0	Sense aerial and rotating loop.
M.F. weather reports and "Consol" navigation.	0.15 to 2.0	Reception only, omni-directional, vertically polarized.
H.F. communication	2.0 to 20.0	Transmission (150W) and reception, omni-directional.
V.H.F. communication.	118 to 132	Transmission and reception, vertical polarization.
Instrument landing system. Marker.	75	Reception, downward-looking.
Instrument landing system. Localizer.	108 to 118	Reception, omni-directional, horizontal polarization.
Instrument landing system. Glide path.	329 to 336	Reception, forward-looking, horizontal polarization.
Secondary radar homing system. (Rebecca).	208 to 234	Directional aerials for vertically polarized transmission and reception.
Radio altimeters.	1,600 to 1,700	Downward-looking, transmission and reception.
Cloud and collision warning radar.	10,000	Narrow rotatable beam transmission and reception.

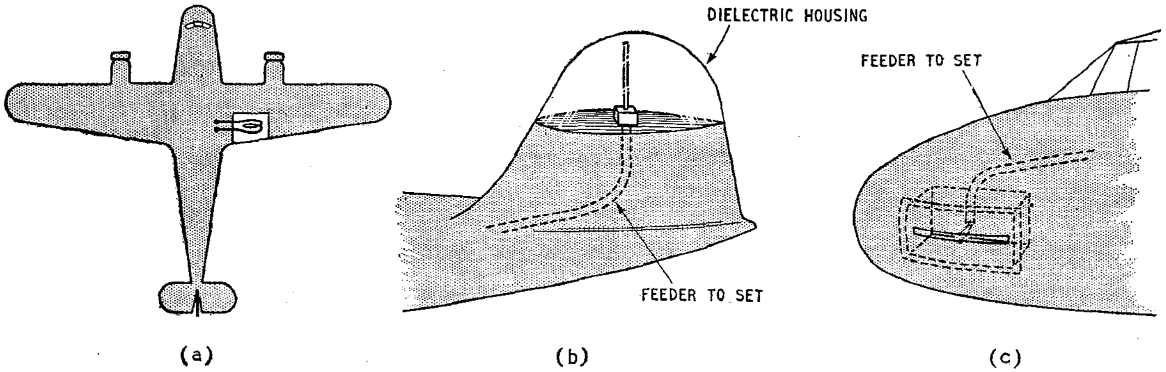


Fig. 1. Types of suppressed aerial : (a) wing radiator, (b) buried aerial, (c) slot aerial.

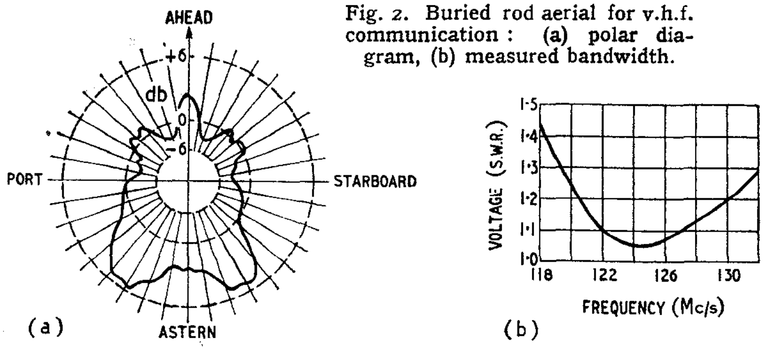


Fig. 2. Buried rod aerial for v.h.f. communication: (a) polar diagram, (b) measured bandwidth.

quencies demand. It is by no means a complete list, but all the items on it—or their equivalents—are required by aircraft flying on the international air routes of the world.

To cover such a wide range of frequencies it is obvious that the aerials of an aircraft must be of diverse forms, and some of the possibilities of suppressing these aerials are discussed below.

Wing radiators (Fig. 1 (a)).—Below 20 Mc/s the conventional aerials are trailing wires up to 200ft in length, or a fixed horizontal wire carried a few feet above the fuselage. The trailing type has a high loss resistance and the fixed wire a very low effective height, but it is not easy to produce as good a radiator within the aircraft structure. This structure is nearly always wholly metallic and the insulation of an appreciable part of it is not generally possible for mechanical or structural reasons.

One interesting approach to this problem is to excite the whole structure of the aircraft as an aerial.[1] If the aircraft span is considered as a single "turn" secondary of a transformer whose primary is a small coil at the root of the wing, there will be some transference of energy which will be radiated. The same method can be applied to the excitation of the fuselage, and, if the wing and fuselage are energized in the correct phase relation, a "crossed dipole" system is produced from which the radiation pattern will be more or less uniform in azimuth.

Considerable success has been reported for this method over the frequency range for which the wing span is not less than 0.2 wavelengths (*loc. cit.*). Communication ranges equal to those with a fixed wire aerial have been obtained, and the radiation pattern deviates from circular by less than ±2 db.

Buried aerials (Fig. 1 (b)).—Rod or loop aerials may sometimes be mounted in a way which does not cause any additional "drag" if a small part of the aircraft skin (such as the tip of a wing or a tail fin) is made from an insulating material. This is of value in the frequency band 100-200 Mc/s where an aerial approaching a quarter-wave in length can be housed inside a section not exceeding one or two feet long. Fig. 2 shows the polar diagram and measured bandwidth of a buried rod aerial for v.h.f. communication. It will be seen that the polar diagram variations do not exceed ±6 db and the voltage standing wave ratio is below 1.5:1 over the band. This compares favourably with an external aerial of the whip type.

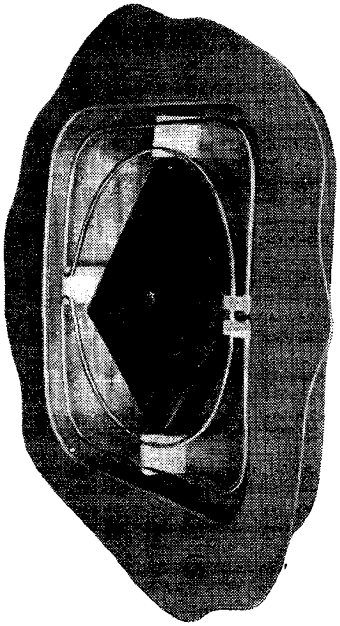


Fig. 3. Recessed iron-cored D/F loop and sense aerial; external view.

Another example of a buried aerial is the rotating loop for medium-frequency direction finding. By the use of a dust-iron core sufficient pick-up is obtained from a shallow loop mounted in a tray below the aircraft skin. The skin of the aircraft is continued over the loop aperture with insulating material. The photograph (Fig. 3) also shows a symmetrical arrangement of rods inside the aperture which gives the vertical signal for sense determination.

All parts of the aircraft surface carry some mechanical stress and so the material for covering these aerials must possess good mechanical as well as electrical properties. This need is met by a laminate of woven glass cloth bonded together with a resin of good dielectric properties.

Slot aerials (Fig. 1 (c)).—It has been shown[2] that a rectangular slot cut in a metal plate will radiate if fed from an energized cavity placed behind it, or by a transmission line directly connected to opposite sides of the slot. The slot exhibits resonance similar to a half-wave dipole if it is a half-wavelength long at the operating frequency. If its width is small compared with a wavelength the radiation is polarized in a direction perpendicular to the length of the slot. (The slot is filled with a woven-glass type dielectric, otherwise the opening would defeat the purpose of suppressed aerials and create "drag.")

Radiation will take place from both sides of the sheet carrying the slot so that even when direct connection to the transmission line is used, as in Fig. 1 (c), a resonant cavity must be placed behind it to prevent unwanted radiations into the aircraft. The size of this cavity and the length of the slot which can be cut without weakening the structure make the applications to aircraft useful only for wavelengths less than 2 metres (frequencies greater than 150 Mc/s). A pair of directional receiving aerials formed by slots on

Suppressed Aircraft Aerials—

either side of the aircraft nose will give an equisignal course for homing on a radar beacon (Rebecca-Eureka system). Fig. 4 shows the polar diagram and bandwidth of this type of aerial. The incoming signal energizes the slot which, in turn, energizes the cavity behind it. Within the cavity lies a probe which is energized by the cavity and provides receiver coupling.

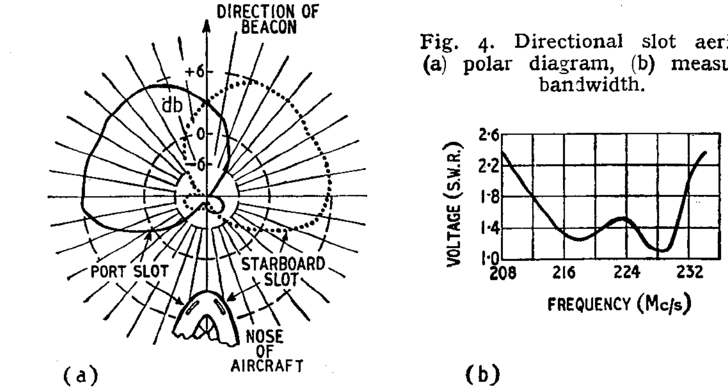


Fig. 4. Directional slot aerial: (a) polar diagram, (b) measured bandwidth.

Design methods.—One feature common to all these types of aerial is the dependence of aerial characteristics on the contours of the aircraft. The curvature of the metal skin surrounding a slot, the shape of a dielectric housing within which a rod aerial must be fitted, the presence of adjacent wings or tail fins; all have an effect on the aerial performance, so that the development of suppressed aerials must be based upon considerable experimental work.

A suppressed aerial which has been designed for one type of aircraft can rarely be used for any other type.

The final test of an installation is made on flight trials, but all the preliminary data can be obtained from experiments with models and full-size mock-ups of those parts of the aircraft which are concerned. The directional properties of an aerial can be gauged with considerable accuracy from a scale model of the aircraft and by using operating frequencies in proportion to the scale used.

Using a scale factor of 1/24, an aircraft of 100ft wing span would be represented by a model a few feet across and an aerial intended to operate on 100 Mc/s in such an aircraft would be tested in the model at 2,400 Mc/s. The model can be raised sufficiently clear of the ground to simulate actual flying conditions. Fig. 5 shows such an arrangement.

A full-sized mock-up consisting of a framework formed in the shape of an aircraft nose is generally used to find the impedance characteristics of the aerials. The metal skin is represented by close-mesh wire netting over the framework. The figures thus obtained are those at ground level, but the change in impedance when flying is generally small enough to be neglected.

Team work in design.—Suppressed aerials are so much a part of the structure of an aircraft that the radio engineer and the aircraft designer must begin collaboration at a very early stage. The alternative designs which can be suggested, and the structural problems they raise, can be adequately resolved only while the aircraft is still on the drawing board. The possibilities of fitting suppressed aerials to machines which are already constructed are very limited.

This situation is now realized by the aircraft and radio manufacturers, and the aircraft of the future will carry suppressed aerials which are the result of good team work by the design staffs of both industries. Care must also be taken to see that potential users of the aircraft have been consulted at this early stage, so that the radio services they are likely to require may be catered for.

In all cases the performance of the suppressed aerials must not be inferior to that of the original external aerials which they are intended to replace, both as regards polar diagram and impedance variations within the specified frequency band. The most desirable terminal impedance depends on the particular equipment concerned, and so it is of the utmost importance that characteristics of aircraft aerials should be properly standardized throughout the radio industry if the aerials are to be suitable for any changes in equipment that may be required.

It should be pointed out, however, that already this matter has been greatly assisted by the publication of recommended aerial feeders and characteristics by the Air Radio Panel of the Radio Communication and Electronic Engineering Association[3].

References

[1] Johnson, W. A. "Recent developments of aircraft communication aerials." *J.I.E.E.*, Part IIIA, Vol. 94, p. 452, 1947.

[2] Booker, H. G. "Slot aerials and their relation to complementary wire aerials." *J.I.E.E.*, Part IIIA, Vol. 93, p. 620, 1946.

[3] Report of Sub Panel "H." (*Minutes of Air Radio Panel meeting, R.C. and E.E.A.*, 6.10.47.).

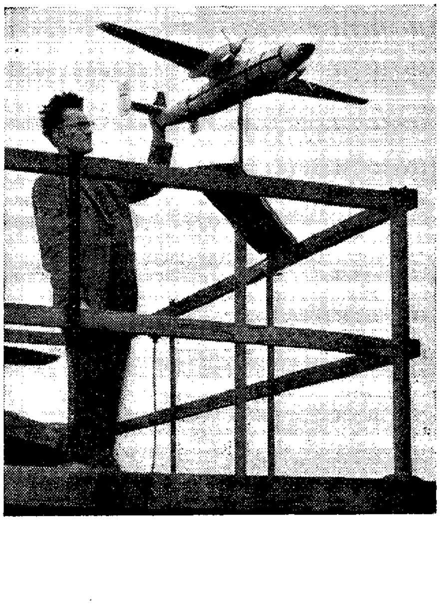


Fig. 5. Scale model aircraft used for polar diagram measurements.

MEASURING TURNTABLE SPEED FLUCTUATIONS

By E. W. BERTH-JONES, B.Sc.
(E.M.I. Studios)

A Sensitive Method of Checking "Wow" and "Flutter"

ONE of the most distressing forms of distortion which can occur in the reproduction of a sound recording, particularly a recording of music, is that caused by speed fluctuations. When this takes the form of slow cyclic variations, it is usually known as "wow," whereas rapid fluctuations are commonly referred to as "flutter." Erratic, non-cyclic speed changes are frequently called "watering."

The precise measurement of these variations in speed has offered considerable difficulty. The ear is particularly sensitive to this form of distortion, and anybody with a reasonably good sense of musical pitch will notice quite small variations, often as small as a tenth of one per cent, on a sustained note. In high-quality equipment it is commonplace to maintain speed constancy to within a twentieth of one per cent, and in order to measure the residual error with any accuracy, it is necessary to have a measuring instrument with a sensitivity of the order of one hundredth of one per cent, or one part in ten thousand.

Moreover, it is not sufficient to measure slow changes in the mean speed over a complete revolution. It is necessary to make the measuring period as short as possible in order to get accurate information of any rapid flutter which may occur, but this makes very severe demands upon the measuring apparatus. Fortunately, due to the inertia of the turntable, it is unlikely that speed changes will take place very rapidly, and a measurement averaged over one-tenth of a revolution would appear to give a satisfactory compromise.

A method which has met with some success employs a phonic wheel mounted concentrically with the turntable, the teeth of which are used to generate an alternating electrical signal whose frequency will be proportional to the speed of rotation. This frequency may then be measured by bridge methods with the required degree of accuracy, and will be an indication of the speed. To attain an accuracy of one part in ten thousand, each tooth of the phonic wheel must be cut with this accuracy of tooth spacing, which makes the wheel a very costly item. With a wheel of normally realizable accuracy, the method is excellent, though expensive, for the measurement of "wow," but it is useless for the more subtle forms of "flutter."

Change of Wavelength

For disc-recording purposes, a method which gives more reliable results at much lower cost consists simply of recording a continuous tone, at the same time playing back from a point slightly displaced from the point of application of the recording. It may safely be assumed that the oscillator producing the tone can be made to give a train of waves which are substantially identical in shape and spacing, to the required degree of accuracy. Methods of stabilizing oscillators have been described in the literature, and the problem becomes resolved into choosing the type which will maintain the required degree of constancy. The waveform is relatively unimportant, the governing factor being the precision of repetition.

The fundamental frequency of the reproduced wave may be measured as before, and if the speed is constant this will be identical with the oscillator frequency, since recording and reproduction are taking place at the same speed. If the rotational speed changes while the element is moving from the recording point to the reproducing point, the reproduced frequency will differ from that of the oscillator during the period of change. For instance, supposing that the disc is accelerating: the speed of an element when it passes the reproducer point will be higher than it was at the recording point, and the reproduced frequency will be correspondingly higher than that of the oscillator. This change in frequency can be made to give us a reading, not of the absolute speed, but of acceleration measured between recording and reproducer points. For normal cyclic variations, the amplitude of the speed change can be derived from this. It is unnecessary to measure the reproduced frequency directly. It may be compared with the original oscillator frequency on a ratio basis, or more conveniently on a difference basis, by means of beats. In the latter case, the beat frequency would be proportional to the acceleration.

Unfortunately, in practice, in any good recording system the accelerations to be measured have only a very low order of magnitude, so that a very high initial frequency has to be used in order to obtain a beat which will fall within a measurable range, and this high frequency may fall outside the limits of the recording system.

However, this method is capable of a modification which overcomes this limitation, and which can be made to yield a display which represents the speed deviation directly. For the purpose of this description, the method will be considered in its application to the measurement of flutter on

Measuring Turntable Speed Fluctuations—

78 r.p.m. gramophone recording. It is a simple matter to adapt it to other problems.

The first requirement is an audio-frequency oscillator capable of supplying a tone of known frequency, constant to within a tolerance rather closer than the errors it is required to measure. This is fed through the recording channel to the cutter head, which is mounted in position on the recording lathe which is to be tested. A pickup is also mounted on the machine, in such a manner that it will track the groove cut by the recording head, at a distance of a few inches behind it, preferably adjustable. The output of this pickup is amplified until it can be matched in level with a second output tapped off from the recording channel. The recording machine is adjusted to run at correct mean speed, either by counting the number of revolutions in a given time, or by stroboscopic methods.

Procedure

Cutting is now commenced, and the pickup is slipped into the groove, a little behind the recording point. Now if the turntable speed is constant, the output from the pickup will be, theoretically at least, a duplicate of the input wave, displaced from it only in time. Either by adjusting the oscillator frequency, or by moving the pickup mounting slightly, it is possible to arrange that both reach their maxima at the same moment, that is, they are in phase. Assuming no distortion of wave shape, the two outputs can be connected back-to-back, giving a resultant of zero.

Suppose now that the turntable speeds up, by a very small amount. Any individual wave peak, cut by the recording stylus, will now reach the reproducing point sooner, due to the increased speed of travel. This increase is very small, so that the saving in time is less than the duration of a single wave, but it is sufficient to ensure that the reproduced wave is now out of phase with the oscillator wave, and when the two are connected back-to-back, cancellation no longer occurs. There is a residual resultant whose amplitude is a function of the change in speed, and which can be made to operate a meter. This is illustrated diagrammatically in Fig. 1.

Putting this in another way, supposing we set up the apparatus so that with correct mean turntable speed there are exactly 100 waves between recorder and reproducer points. If now the speed increases by, say, one tenth of one per cent, the wavelength will increase by one tenth of one per cent, and the length of 100 waves will increase by one tenth of one wave, which is 36° of phase difference, and easily measurable.

As an example of the dimensions involved, consider a gramophone recording turntable revolving at 78 r.p.m. The linear velocity of the groove under the needle point is given by

$$V = \frac{2\pi RN}{60} \text{ in/sec} \quad .. \quad (1)$$

where R is the radius of the groove, measured from the disc centre, and N is the speed in revolutions per minute. At a radius of about 4in, the linear velocity will be, say 30in/sec. If a 6,000 cycles per second tone is applied, then 6,000 cycles occupy 30in of arc on the disc, and the wavelength measured along the groove will be 0.005in. If now the spacing between recording and reproducing styli, again measured along the arc, is made exactly two inches, there will be exactly 400 waves between the two points, and the output will be in phase with the input.

Suppose now that the turntable speed is increased by, say, 0.01%, so that the linear velocity becomes 30.003in/sec. Now 6,000 cycles occupy 30.003in of arc, and the wavelength becomes 0.0050005in, so that there are now only 399.96 waves between the two points. The reproduced signal will be 0.04 of a wave in advance of the oscillator, which is a difference in phase angle of 0.04 × 360°, equal to 14.4°, which is capable of giving a measurable output. At the present stage of the art, a speed fluctuation of 0.01%, which we have presumed, is generally considered to be quite inaudible.

It is worth noting here that this measurement has been averaged over an arc of only 2in, on a circumference of 23.1in, that is, less than one-tenth of a revolution. The very high order of sensitivity of the method thus becomes evident.

General Relationships

Generalizing from this example, it may be seen that, if we designate the number of waves between the two styli as W, and the distance along the arc in inches as D, then

$$W = D/\lambda \quad .. \quad .. \quad (2)$$

where λ is the wavelength measured along the arc, in inches.

From (1) we have seen that $V = \frac{2\pi RN}{60}$, and we have also

$$V = f\lambda \quad .. \quad .. \quad (3)$$

where f is the applied frequency.

Hence, the number of waves between the points is given by

$$W = \frac{60Df}{2\pi RN} \quad .. \quad .. \quad (4)$$

Letting the suffix o denote the desired condition, for which the system is set up, we have N_0 as the mean speed, in revolutions per minute, and W_0 as the number of waves between the points when the speed is correct (which may be made any integral number of half wavelengths.)

The phase difference producing output, measured in degrees, will be the angle ϕ, where

$$\phi^\circ = 360\,(W_o - W) \quad .. \quad (5)$$

or, measured in radians

$$\phi_{\text{rad}} = 2\pi\,(W_o - W) \quad .. \quad (6)$$

Substituting from (4), this latter becomes :—

$$\phi_{\text{rad}} = 60f\,\frac{D}{R}\cdot\left(\frac{1}{N_o} - \frac{1}{N}\right) \quad .. \quad (7)$$

$$= 60f\cdot\frac{D}{R}\cdot\frac{N - N_o}{NN_o}$$

$$= -\frac{6f}{10}\cdot\frac{D}{R}\cdot\frac{n}{N}$$

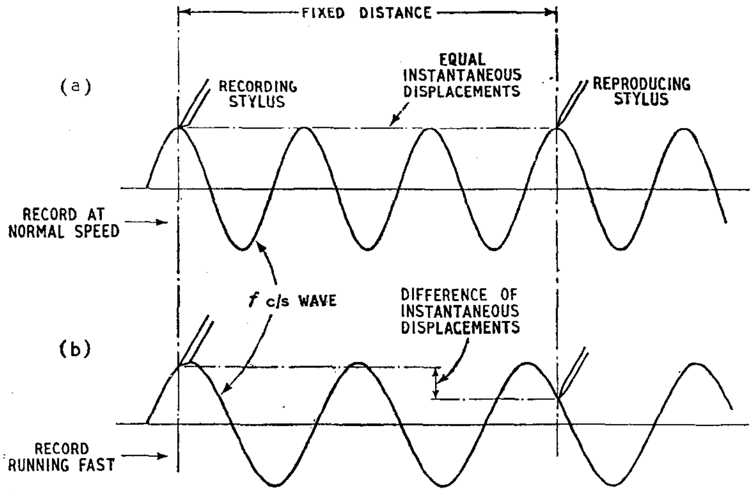
where '*n*' is the percentage change in speed.

Since the actual change of speed is very small, it is permissible to write N_o for N in this equation, which then becomes

$$\phi_{\text{rad}} = -\frac{6f}{10}\cdot\frac{D}{R}\cdot\frac{n}{N_o} \quad .. \quad (8)$$

From equation (8) it will be seen that the phase angle changes in direct proportion to the percentage change of speed, so that any meter suitable for measuring the phase difference between the

Fig. 1. Illustrating the principle underlying the method of measurement.



two waves may be calibrated directly in percentage change of speed.

If the phase change exceeds π radians (or 180°), the output will commence to fall again, and it is not, therefore, possible to deal with phase variations greater than this. For illustration, Fig. 1(b) shows a phase change of about 280° from the peak of the third wave measured from the recorder point, which is the initial condition shown in Fig. 1(a). The meter reading for 280° (360° — 80°) would be indistinguishable from that obtained for 80°, and the amount of flutter would therefore be underestimated. This can, however, easily be dealt with by reducing the oscillator frequency, so that the wavelengths become larger, and the phase changes proportionately smaller. For large amplitudes of flutter, therefore, we require a low frequency, and for high sensitivity a high frequency, as equation (8) suggests.

Radial Tracking Essential

In practice, there remain several difficulties in the method outlined. For example, for a linear relationship between phase angle and percentage speed variation to be maintained, it is essential that the ratio D/R remains constant, unless readings are always taken at one particular radius. This involves precisely radial tracking of both recording and reproducing heads, which is difficult to achieve, and which leads to mechanical complications at small radii. Also this method is confined to disc recorders.

It may, however, be extended and rendered almost universal in its application by the substitution of magnetic recording methods. If an annular magnetic track is substituted for the disc record, and the cutting head and reproducer are replaced by a magnetic recording head and replay head, the validity of the method remains unaltered. If, in addition, an erasing head is added, to wipe out the wave after it has passed the replay head, the same piece of track will return fresh and unmodulated under the recording head again and again, while the positions of the various components remain unchanged. With some forms of phase-meter the waveform from the replay head can be allowed to depart considerably from the sinusoidal shape, particularly near the peaks, and it is therefore quite permissible to use d.c. for erasing and for recording bias, with considerable simplification of equipment. A magnetic track may be deposited on the underside of a gramophone turntable, for instance, and the heads mounted below with their gaps arranged radially, and just clear of the track. In order to obtain a strong enough signal in spite of this clearance, the recording head may be heavily overloaded, again because we are indifferent to waveform. This arrangement may be left *in situ*, and used to monitor the flutter on an attached meter while recording is in progress.

For the measurement of the phase changes in the laboratory, it is sufficient to feed the reproduced output to one input of a double-beam oscilloscope, the other input being fed from the oscillator output, and used to synchronize the time base. Then the difference in phase between the two traces can be read off the screen directly. If the gain of the oscilloscope is turned up so that the wave peaks fall outside the screen area, amplitude variations will be found to be less disturbing. For routine measurements, a phase-meter giving a direct scale reading has been devised, to simplify checking by non-technical operators.

Sense Discrimination

As so far described, it will no doubt be noticed that there is no discrimination between acceleration and retardation. Both positive and negative speed changes will produce a positive reading on the meter. However, by using a slightly different oscillator frequency, we can arrange that the correct mean speed shows a phase-shift of 45°, instead of zero, and the meter will give a half-scale reading, which can be calibrated as zero fluctuation. Then a slightly lower speed will give a lower reading, and a higher speed a higher reading on the meter, thus showing whether any flutter which may be present represents an acceleration or otherwise.

One of the great advantages of this method is that the sensitivity of the system can be so easily varied, simply by changing the frequency of the applied tone. Further, the magnetic track method is capable of resolving very much smaller deviations than others hitherto used, and its low cost and absence of loading enable it to be fitted to every channel in a commercial recording system, and to be used during actual recording, instead of only as an occasional test.

For film recording, a magnetic

(*Continued at foot of following page*)

TELEVISION RADIO RELAY

London - Birmingham Link

A DEMONSTRATION of the London to Birmingham radio-relay link was given on 3rd and 4th Nov. Designed and constructed by the General Electric Co. to a performance specification of the Post Office, the link comprises two terminal stations and four relay stations at Harrow Weald, Dunstable, Blackdown and Rowley Regis. It provides a single-vision channel which can be used in either direction; that is, it can be employed to send a picture from London to Birmingham or from Birmingham to London. When the remaining equipment is installed two reversible channels will be available and then it will be possible to send pictures simultaneously in both directions.

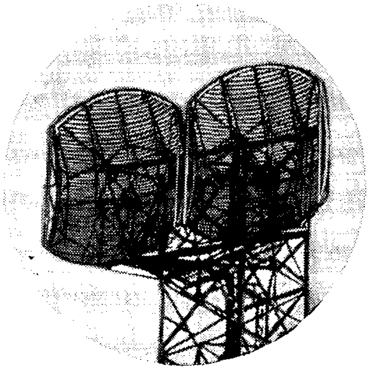
It is claimed that this link is the first television relay link in the world which is installed on a permanent basis and which has been designed throughout with reliability as a prime consideration. Many other television relaying schemes have been tried, but all have been primarily experimental in nature.

In this link all apparatus is duplicated. There are duplicate transmitters, duplicate receivers and duplicate power supplies. In the event of a failure, therefore, the spare can be brought immediately into service with the briefest of interruptions.

The relay stations are unattended and are operated by remote control from London or Birmingham. In the event of a major fault in such a station the unit affected is automatically taken out of circuit and replaced by its duplicate. At the same time the terminal stations are automatically notified. The change-over from one unit to another at a relay station can also be carried out at any time by an operator at one of the terminal stations, who has only to press a button to effect the change. Even power failures are allowed for. The relay stations are normally fed from the grid; should the supply fail, a petrol-electric generator is automatically started up and the station is again operating within two minutes!

Because of the great flexibility of control provided, the control circuits are exceedingly complicated and embody some 3,000 relays! The radio side of the equipment almost tends to be buried in the welter of control and indicator equipment—which is a pity, since it is highly ingenious.

Transmission is carried out on about 30cm. Frequencies of 870 Mc/s and 890 Mc/s are used and a change from one to the other is made at each relay station. At the terminal station the v.f. signal, containing frequencies up to 2.7 Mc/s, is used to modulate a 34-Mc/s carrier in frequency, the deviation being ± 1.5 Mc/s.

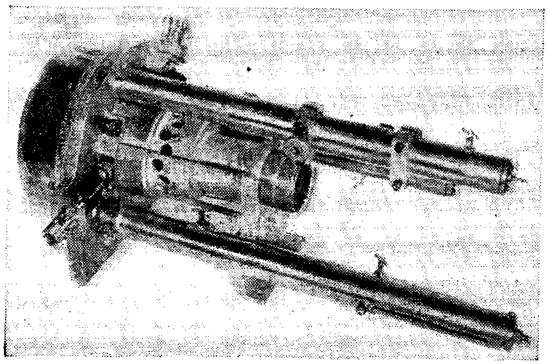


A pair of mirrors at a terminal station.

The modulated 34-Mc/s carrier varies in frequency between the limits of 32.5 Mc/s and 35.5 Mc/s and after amplification it modulates in amplitude a second carrier of, say, 904 Mc/s. The result is a 904-Mc/s carrier with sidebands centred on $904 \pm 34 = 938$ Mc/s and 870 Mc/s. The sidebands vary in frequency in accordance with the vision signal over the range of ± 1.5 Mc/s or 936.5 – 939.5 Mc/s for one set and 868.5 – 871.5 Mc/s for the other. Band-pass and band-stop filters allow the 868.5—871.5-Mc/s band to pass to the aerial and prevent the other frequencies from doing so.

I.F. Amplification

At a relay station the signal on, say, 870 Mc/s is received and passed to a crystal mixer and brought down to 34 Mc/s by the ordinary superheterodyne technique. It is then amplified in a somewhat elaborate i.f. amplifier of 10-Mc/s bandwidth which is provided with a.g.c. Then, just as in a terminal station, it is brought back to signal frequency



Typical r.f. component.

Measuring Turntable Speed Fluctuations.

(*Continued from foot of preceding page*)

track coated on to the film base allows fluctuations in speed of the film itself to be checked, and forms a valuable tool for the investigation of sprocket ripple.

A disc coated with magnetic material may easily be fitted to the sound drum of film recording systems, and the method is therefore equally applicable to this medium, or in fact to any problem involving the measurement of very small speed fluctuations.

by modulating an appropriate frequency. If the input is at 870 Mc/s, as in the example, the output is at 890 Mc/s and this can be obtained by modulating a 924-Mc/s carrier. At the next relay, the input is at 890 Mc/s and the output at 870 Mc/s, and so on. The arrangement is sketched in the block diagram.

The locally generated frequencies are derived from a crystal oscillator of high stability and by arranging for both signal frequencies to lie on the same side of the local frequencies, their frequency difference is virtually independent of any drift.

Station Details

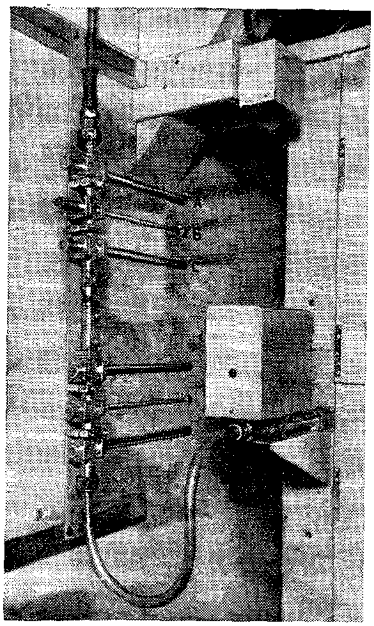
Coaxial circuits are used at signal frequency with triode valves. The transmitter output is 10W and the gain in a relay station is about 70db. Dipole aerials are used with reflectors, some 10ft by 14ft, giving about 28-db gain. The beam width to the half-power points is about 3° in elevation and 5° in azimuth. The reflectors are constructed of light alloy tubing and the tubes contain heating elements for de-icing.

During the demonstrations the relay stations had temporary masts for the aerials and all equipment was at ground level. In the final installation all equipment apart from power supplies will be at the mast head and feeder losses of some 12db at present existing will be eliminated. The final mast-head apparatus for the double link is to be four mirrors, four receivers and four transmitters, the two last being housed in a "room" about 9-ft square. The height of the masts vary from 60ft to 120ft in the different relay stations.

Two items of the equipment deserve especial mention; a filter and a switch. The former is a combined band-pass and band-stop filter which provides 70-db discrimination between the wanted and unwanted frequencies in the amplitude-modulation process. It is built of co-axial resonant circuits and two of the filters are shown in the photographs. There are three sections to the filter, A, B and C. The long tubes control the band-stop characteristics and relatively very short tubes opposite them control the band-pass characteristics. The sections A and C are alike, but the middle one, B, is of smaller diameter and has one-half the characteristic impedance of the end sections. These tubes have inner conductors and so form resonant lines; however, the dielectric is not uniform but consists of alternate short sections of air and polythene. By adopting such a series of abrupt discontinuities in the dielectric the length of the section has been reduced from the 10-ft required with air to something like 18in only. Screw "trimmers" are provided at the ends for adjusting the precise characteristics. Similar "trimmers" are also provided on the short tubes controlling the pass-band.

"Contact-less" Switch

The switch operates at radio frequency to switch the coaxial circuits of the transmitters and receivers. It has no contacts and operates by moving plungers into coaxial stubs. Two input (or output) coaxial lines are T-junctioned to a single outlet (or inlet). At the proper distance from the T on each inlet line a stub is fitted. Now the input impedance of such a stub depends on its length and on its termination. In this case the termination is a movable plunger and in its two extreme positions it makes the input impedance tend to zero on the one hand and to infinity on the other. When the impedance is zero the line to which it is attached is short-circuited, whereas when it is infinity the line is unaffected by the stub.

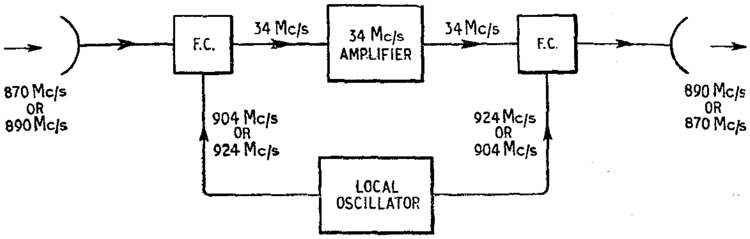


Two combined band-pass and band-stop filters are shown here.

The plungers in the stubs attached to the two lines move in opposite ways so that one line is blocked while the other is opened. Actually, two stubs $\lambda/4$ apart are used on each line to increase the attenuation in the "closed" line and some 70db is attained.

These "switches" are motor-driven and are used to change over the r.f. sides of the transmitters and receivers. They are used on the one hand to bring the duplicate units into circuit in the event of a fault, and on the other hand, to reverse the aerials to change the direction of transmission. This last feature makes great demands on the switches, as the output of the transmitter and the input of the receiver are necessarily coupled by any leakage through them. Some 70-db attenuation between paths in the switch is obtained and with the special circuitry employed the attenuation between aerials is kept down to 140db.

During the demonstration a



This block diagram illustrates the general arrangement of a relay station. The blocks labelled F.C. represent the frequency-changer on the receiving side and the modulation on the transmitting.