Wireless World

Radio • Electronics • Electro-Acoustics

33rd YEAR OF PUBLICATION

Proprietors :
ILIFFE & SONS LTD.

Managing Editor :
HUGH S. POCOCK, M.I.E.E.

Editor :
H. F. SMITH.

Editorial, Advertising and Publishing Offices :
DORSET HOUSE, STAMFORD STREET, LONDON, S.E.1.

Telephone:
Waterloo 3333 (35 lines).

Telegrams:
"Ethaworld, Sedist, London."

△

PUBLISHED MONTHLY

Price : 1/3

(Publication date 25th of preceding month)

Subscription Rate Home and Abroad 17/- per annum.

MAY 1943

Branch Offices :

COVENTRY :
8-10, Corporation Street.
Telephone : Coventry 5210.
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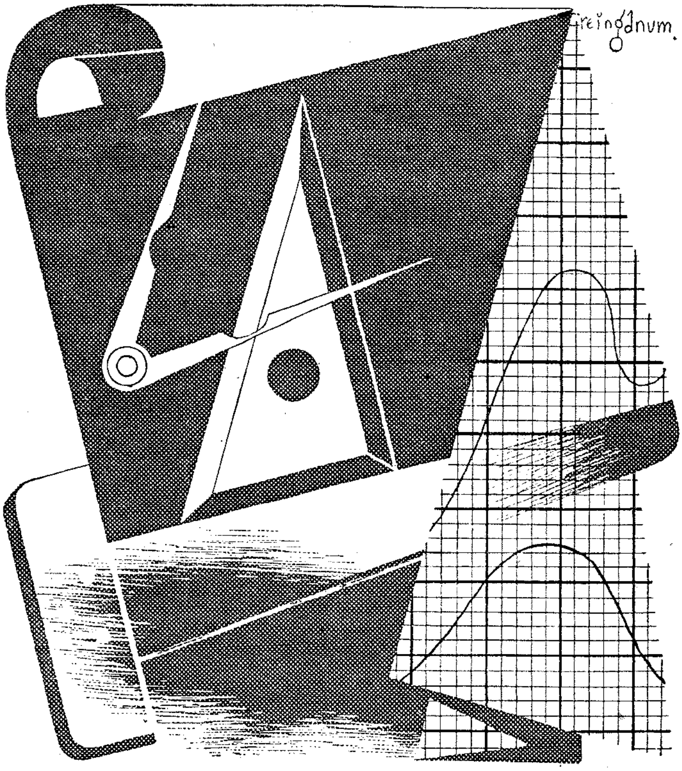

PLANNING

Through the whole wide sweep of Philips activities in the field of electricity there is evidence of inspired planning . . . not for the moment only, but also for those needs which will depend on discoveries and developments yet to emerge from the laboratory and the drawing board.

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Wireless World

Radio • Electronics • Electro-Acoustics

Vol. XLIX. No. 5 MAY 1943 Price 1s. 3d.

Broadcasting After the War

Some Problems of the Industry

WHEN the war ends, one of the basic problems—if not *the* basic problem—of the wireless industry will be to find the best means of employing the vastly increased productive power which it has acquired during the war years. Given post-war economic conditions of the kind we all hope to see, there will certainly be great expansion in all fields of radio, but there is no doubt that, with proper organisation, the industry will be able to meet all the demands made upon it.

The various problems with which the industry will be faced are already being considered in detail, and, more than a year ago, the Radio Manufacturers' Association appointed a Committee whose task it was to prepare suggestions; these were published as a part of the recent R.M.A. Annual Report, to which reference is made elsewhere in this issue.

The Committee's suggestions emphasise the dependence of the broadcast section of the industry on the transmitting side, particularly with regard to the technical means to be adopted after the war for distributing programmes. Throughout the report one can detect a feeling of uneasiness that future developments may react unfavourably on the industry. In particular, the possibility that wire distribution may take the place of "space" broadcasting is clearly viewed with apprehension.

There are obviously some grounds for these fears. It is stated in the report that "discussion with G.P.O. officials seemed to suggest that they favour the development of a wire broadcasting system in this country. It is not contemplated, however, that this will be developed to the exclusion of individual reception through space, and the continuance of both systems side by side seems certain." Apart from this, we know that the idea of wire broadcasting is still having influential support in other quarters. On the other hand, strong opposition is also forthcoming, but most of the objections voiced by the industry leave too many loopholes, and would fail to convince an unprejudiced arbitrator.

Our own opposition to wire broadcasting is founded on a rather different basis. When the subject last became pressing, in January, 1942, we ignored the purely technical arguments for and against, and were prepared to admit—but only for the sake of argument—that wire had all the virtues and none of the vices of wireless. But we maintained—and our conviction has since been strengthened—that, whatever may happen in the distant future, the world is not ready for the wire system. The freedom of wireless broadcasting is real and worth struggling for: after the war, it must, during the reconstruction period, have every chance to play its part in founding a permanent peace.

Data for Planning

Apart from the fundamental question of wire *versus* wireless, other important questions as to the means of broadcast transmission will arise. For example, we have been promised at least an experimental frequency-modulation transmission; has America's experience led us to believe that it would be desirable to provide a nation-wide service as soon as possible? What standards are to be employed in our post-war television service, and does the B.B.C. intend to devote to television such a proportion of its revenue that it will become comparable in importance to sound broadcasting? These factors would profoundly affect receiver manufacturing programmes. Without advance knowledge of what is going to happen, it is clearly impossible to plan production efficiently; indeed, to plan it at all. In our view, lack of long-term planning will react, during the post-war era, to the disadvantage of both industry and public. At present, the industry learns of impending changes in transmission methods merely as a matter of courtesy; not as a right.

Consideration of these questions, and many similar ones that arise, forces us to the conclusion that the voice of those who make the receivers should be heard at the councils of those who plan the transmission services. Reception and transmission are complementary; without co-operation, neither can function at its best.

INTERFERENCE FROM POWER LINES

Its Nature and Extent

By J. S. FORREST,
M.A., B.Sc., F.Inst.P.

In a recent paper* before the Institution of Electrical Engineers on "The Characteristics and Performance in Service of High-Voltage Porcelain Insulators," the writer of this article described some investigations which had been made on power line radio interference. The article is based on the information given in the paper and the ensuing discussion

PARTLY owing to the fact that there is, in the ordinary sense, no method of suppression, and partly because radio engineers and power engineers do not always appreciate each other's difficulties, radio interference from high-voltage power lines presents a difficult problem. When a case of power line interference arises the radio engineer may notice audible or visible discharges on the line insulators, and he frequently dismisses the matter by remarking that the line is "under-insulated." The power engineer, on the other hand, knows that the line is fulfilling its primary purpose efficiently, and is unable to see why slight "corona" or "brush discharge," involving a negligible leakage current, should cause the disturbance. Moreover, he knows that the complete elimination of all discharges on high-voltage lines is not possible under humid weather conditions even with a generous level of insulation, and the best of modern insulators. It is the object of this article to attempt to present the problem of radio interference from the dual point of view of one interested both in radio and in power engineering; the characteristics of the interference will be described and possible remedial measures will be discussed.

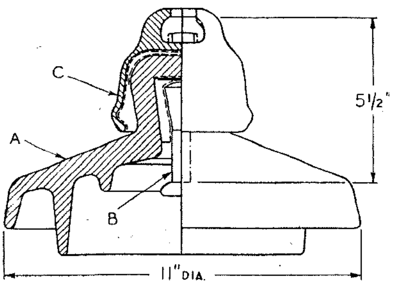


Fig. 1. Cap-and-pin insulator unit (Bullers) A, porcelain shell; B, steel pin; C, malleable cast iron cap.

It must be emphasised at the outset that power lines are not major sources of radio interference. Gill and Whitehead*, for example, report that in an analysis of 1,000 cases taken at random, only 2 per cent. were due to overhead power lines. The subject has nevertheless received much attention, due partly to the fact that when cases do arise suppression may be impossible, and partly because the elimination of the fundamental cause of power line interference would, *ipso facto*, result in an improved insulator in other respects.

Types of Interference

It is convenient to classify power line interference into "normal" and "abnormal" interference. The interference which is inseparable from the operation of high-voltage lines, even with all the power system equipment in perfect order, is termed "normal" interference. "Abnormal" interference, on the other hand, is due to some abnormal condition or fault on the power equipment which gives rise to spark discharges. Such discharges may be produced by inadequately earthed metalwork or faulty conductor joints. As an example of "abnormal" interference a case may be cited in which a spare conductor on a high river crossing was not efficiently connected to earth. A charge was induced on the spare conductor due to its proximity to the live circuit on the same towers, and a small spark discharge occurred from the conductor to earthed metal. Thus the arrangement constituted quite an efficient spark transmitter which caused widespread interference with broadcast reception. Although intense interference is produced in such cases, it does not give rise to a serious problem because the location of the cause is comparatively easy. "Normal" interference which is an inevitable concomitant of the operation of power lines, cannot be dealt with so easily, however, and it is with this type of interference that the remainder of the article is concerned. "Normal" interference is generated by the line insulators, and it may be helpful to describe briefly the various types of insulator used on high-voltage power lines.

Porcelain or glass is used for high-voltage line insulation, and the most widely used type of insulator is the cap-and-pin unit; details of a typical unit are shown in Fig. 1. Various numbers of such units are assembled in series in strings, a string of two or three units being used for 33-kV lines, and ten units for 132-kV lines. Cap-and-pin units are suitable for use

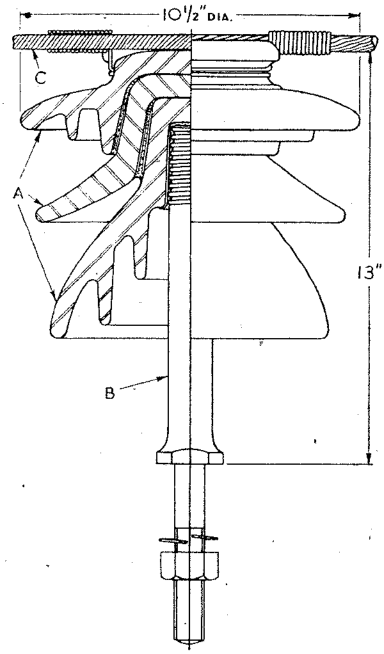


Fig. 2. 33-kV pin-type insulator (Taylor, Tunnicliff & Company) A, porcelain shells; B, steel pin; C, line conductor

both at suspension positions in which the insulator string hangs vertically, and at tension positions in which the string is horizontal.

* Journal I.E.E, 1938, Vol. 83, p. 345.

* Journal I.E.E., 1942, Vol. 89, Part II, p. 60.

For voltages of 33 kV and below, pin type insulators are commonly used (Fig. 2); this type of insulator consists of a porcelain shell, or several porcelain shells cemented together, and is fixed to the pole cross-arm by means of a steel spindle. The line conductor is attached to the head of the insulator by a wire binding. The pin insulator is not suitable for tension positions; an insulator such as the

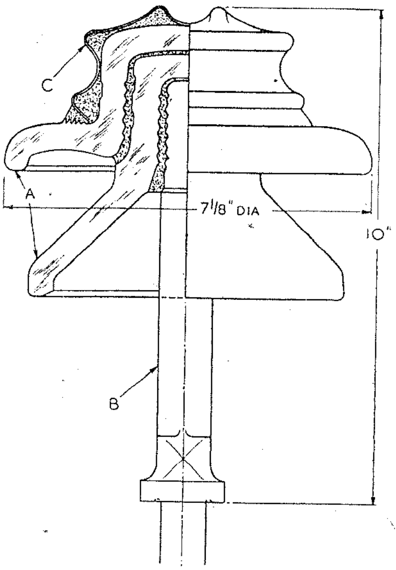


Fig. 3. 11-kV pin-type insulator with metal cap (Pilkington Bros.) A, toughened glass shells; B, steel pin; C, copper or aluminium cap.

cap-and-pin type which will sustain the conductor tension must be used at these points on the line. In some cases pin insulators are provided with a metal cap to which the conductor is attached, and Fig. 3 is an example of a toughened glass insulator of this type. The only remaining type of insulator which need be mentioned is the line post insulator, shown in Fig. 4; for the present purpose, the most significant feature about this insulator is that the capacitance between the conductor and earth is lower than in the equivalent pin insulator.

Effect of Dampness

When high-voltage power lines are in normal operation small spark discharges occur on the insulators, and these discharges, in common with all spark discharges, contain components of radio frequency, so that a radio frequency disturbing field is radiated from the line conductors. The intensity of the discharges increases under damp weather conditions, and when the insulators become dirty. The fundamental cause of the spark discharges, and hence of the interference, is to be found in the electrical properties of a porcelain or glass surface. Such a surface will, in foggy and humid weather—particularly in districts subject to industrial pollution or salt spray—become coated with a conducting film. The immediate effect of this film is to reduce the surface resistance of the insulator from, say, 1,000 megohms to 10 megohms. There is, however, a further secondary effect due to the fact that the resistance of the conducting film is not constant but increases as the applied voltage is increased. This effect may colloquially be described as being due to the "drying-out" of the surface film.

Now the voltage across an insulator unit under humid weather conditions is determined by the product of the leakage current, and the surface resistance of the unit. It follows, therefore, that the potential distribution over a string of units in series becomes unstable, as any tendency to depart from uniformity leads to a still further departure in the same direction. The ultimate result is that, as the humidity increases the distribution of potential becomes highly irregular. For example, Fig. 5 (a) shows the fairly uniform voltage distribution which is obtained on a 132-kV ten-unit string under dry weather conditions, while in polluted and humid atmospheres the distribution becomes very irregular, as shown in Fig. 5 (b). It will be seen that on five out of ten units the voltage is negligible, and, consequently, four of the remaining units are operating at much more than their normal working voltage. A similar argument applies to portions of the surface of each individual unit so that spark discharges occur on the surfaces of the units, and also across the highly stressed units. The surface leakage current flowing under such conditions is approximately 1 mA, although sudden surges of current having a value of approximately 50 mA occur when spark-over of a few of the insulator units in the string takes place.

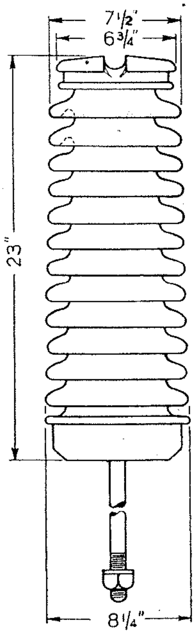
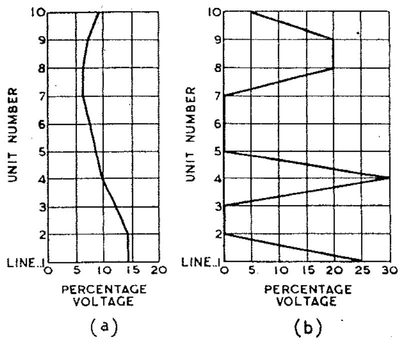


Fig. 4. Line post insulator (Lapp Insulator Company, U.S.A.)



Courtesy "Journal I.E.E."

Fig. 5. Potential distribution on 10-unit insulator string. (a) Relative humidity 42% (b) Relative humidity 95%.

It follows from the preceding discussion that the intensity of the interference from a power line should be profoundly affected by the weather conditions. In practice, this is found to be the case; in dry weather the interference is negligible, while the interference is most intense under foggy conditions in industrial districts. Similar conditions sometimes occur on lines in coastal areas due to salt spray. These facts are expressed quantitatively in Fig. 6, which gives the value of the interfering field under a 132-kV line insulated with strings of ten cap-and-pin units. The measurements were made with a Marconi-Ekco Type TF379 Interference Measuring Set.

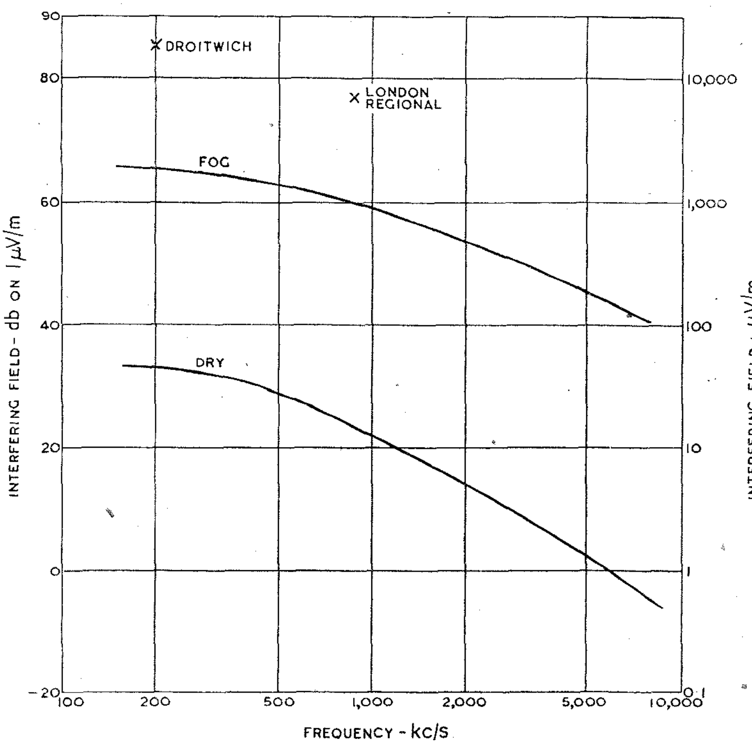
The results obtained exhibit a number of interesting features. It will be noted, for example, that in fog the interfering field increases to one hundred times the dry weather value, i.e., increases by 40 db. For comparison purposes, the field strengths (pre-war) of the long wave and medium wave broadcasting stations are also plotted on

Interference from Power Lines—
the diagram, and it is seen that for a receiver situated under the power line a background of interference would be obtained on both these stations in foggy weather. Further, it would be impossible to receive stations having field strengths of less than 100μV/m. The results also show that the interfering field decreases as the frequency increases, so that transmission line interference has relatively little effect on short-wave reception. This is in sharp contradistinction to interference due to motor cars, which is most intense on short waves and negligible on medium and long.

Fortunately, the interfering field attenuates rapidly at right angles to the line, and Fig. 7 gives the results of some measurements made at various distances from the line in dry and in foggy weather on a frequency of 1,000 kc/s. (The approximate intensity of the interference at other frequencies can be obtained with the help of Fig. 6.) It will be noted that at a distance of 50 yards from the power line the interfering field in foggy conditions is reduced to less than one-tenth (25 db. below) the value under the line, while at a distance of 100 yards from the line the interfering field has a value of only a few microvolts per metre.

It is extremely difficult to make measurements even under the worst weather conditions at distances of 100-150 yards from a power line as the interference level is very low and the noise due to the line is difficult to distinguish from the general background of noise due to other sources of interference. It seems, however, that the field strength of the "normal" interference at a distance of several hundred yards from the line must be very low, and the writer knows, of no well-authenticated case of "normal" interference at distances of more than half-a-mile from a line. It should be remarked that although the interference is generated on the insulators it is propagated with little attenuation along the conductors, and so does not vary greatly along the line. A line therefore produces a band of interference of uniform width, and Fig. 8 may be helpful in visualising this.

Interference due to 33-kV and 66-kV lines insulated with cap-and-pin insulators is similar to that which has just been described. Lines insulated with pin-type insulators, however, often give rise to much more intense interference. Moreover, this intense interference occurs in dry weather, and may decrease in wet or humid weather. In this case, the interference is due to discharges between the conductor or tie wires and the insulator head. If there is imperfect contact between the conductor and the head, the charging current of the insulator gives rise at the point of contact to a spark discharge which produces intense interference. In humid weather, on the other hand, the insulator head is covered with a conducting film, with the result that these discharges may be reduced in intensity.



Courtesy "Journal I.E.E."

Fig. 6. Interfering field underneath a 132-kV line.

Investigating Interference

Cases of power line interference present many pitfalls for the inexperienced investigator. The power line is usually the most obvious possible source of the trouble, and many instances have occurred in which it has been wrongly convicted.

For example, if a line insulated with strings of cap-and-pin units is involved it should be verified that the interference is most intense in humid weather, and that it varies with frequency in accordance with Fig. 6. Caution should be exercised in coming to conclusions on the variation of the interference with frequency as the sensitivity of most receivers varies considerably over the various wave-bands, and a peak in the sensitivity characteristics of the receiver may easily be mistaken for a peak in the intensity of the interference. Receivers with automatic gain control may also give misleading indications.

Cases are often reported in which the power line is "proved" to be the source of the interference on the grounds that DF bearings taken on the noise intersect on a certain tower. It has been explained above that the interfering field is radiated from the whole length of the line conductors so that DF bearings in the usual sense cannot be obtained, and any results of this type are likely to be spurious.

Finally, the investigator should carry out a test in co-operation with the supply authority in order to determine whether or not the interference disappears when the line is switched-out and earthed.

The results of this apparently simple test must be interpreted with care owing to the variable nature of most interfering noises, and it is best to arrange for an observer to make a continuous log of the noise level while independent arrangements are made to carry out the switching operations on the line. By comparing the observer's log with the times of switching a definite conclusion can usually be reached.

When the interference has been traced to a power line, consideration must be given to means of eliminating, or at least reducing, the trouble. In cases of "abnormal" interference the cure is usually obvious when the source of the interference has been located, but there is, unfortunately, comparatively little that can be done when "normal" interference is involved. Sometimes, however, reception conditions can be improved to some extent by the application of reme dial measures either at the receiver or on the power system.

If a site can be found for the aerial sufficiently remote from the power line (see Figs. 7 and 8) to give the desired signal-to-noise ratio then satisfactory reception can be obtained by using a screened aerial feeder, and by screening thoroughly the receiver and its power supply. Improved reception conditions can also be obtained when it is possible to increase the strength of the received signals, or to work on a higher frequency. In addition, frequency modulation should prove beneficial.

Regarding measures which can be applied to the power line, it must be emphasised that it is useless to make any modifications at a single pole or tower; several miles of line must be modified if any benefit is to be derived. The interference can be eliminated by replacing a section of the line by underground cable, but in the case of high-voltage lines this solution is usually inadmissible on account of cost or for technical reasons. An improvement can often be effected by cleaning the insulators, although this improvement is clearly temporary, and it is usually difficult for the supply authority to arrange for insulator cleaning at frequent intervals. Insulators incorporating an oil bath have much improved radio interference characteristics in humid weather, but, for obvious reasons, this type of insulator is not favoured by transmission line engineers. Further, it is not applicable at tension positions. The line insulation may be increased by adding extra units, but a limit is soon reached due to the reduction in the clearance between the conductor and the tower, and the improvement in interference obtained by this method is usually disappointing. In the case of lines insulated with pin-type insulators, some improvement can be effected by using insulators with metal caps (Fig. 3) or by installing line post insulators (Fig. 4). The latter type of insulator has a much lower capacitance than the normal pin type so that the energy in the spark discharges, and consequently, the interference, is reduced. The interference from ordinary pin-type insulators can also be reduced by the use of a conducting paint, or conducting glaze, on the head of the insulator in order to eliminate spark discharges at this point. These remedial measures are, however, all palliatives rather than cures.

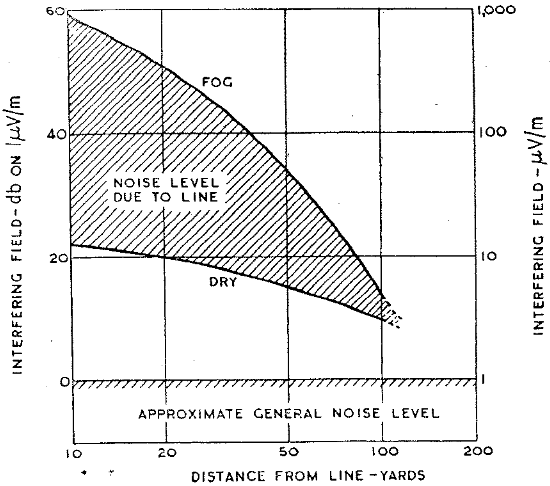


Fig. 7. Variation of interfering field (at 1,000 kc/s) with distance from 132-kV line.

It has been explained that the fundamental cause of the "normal" type of interference lies in the highly irregular potential distribution which occurs on a vitreous surface in a humid atmosphere. Under such conditions, the potential distribution may become so non-uniform that the insulator gives rise not only to radio interference, but may even flash-over and interrupt the electricity supply. The ideal insulator would be one in which a uniform potential distribution was maintained under all conditions, and it has been shown by full-scale tests that this end can be achieved if each unit or element of a complete insulator is given a fixed and relatively low value of resistance—of the order of 1 megohm per kilovolt of applied voltage. One method of manufacturing such "stabilised" insulators is to use a glaze having a suitable value of resistivity. The development of a glaze with the required properties is a difficult ceramic problem, but it is anticipated that a satisfactory solution to the problem will be found before long. The stabilised insulator will not only be a great improvement from the point of view of the power engineer, but will also be "interference-free." Radio engineers can therefore be assured that insulation technicians are doing everything possible to bring this development to a satisfactory conclusion.

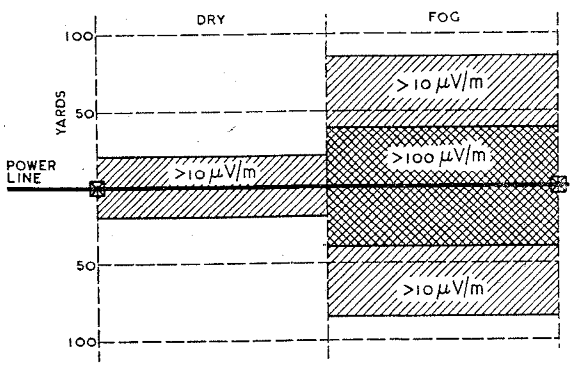


Fig. 8. Interfering field contours in dry weather and in fog at 1,000 kc/s.

RADIO DATA CHARTS—7

Tuned Circuits at Audio Frequencies

By
J. McG. SOWERBY,
B.A., Grad. I.E.E.
(By Permission of the Ministry of Supply)

THE tuned circuit is not in such general use at audio frequencies as it is at radio frequencies, but there are occasions when a parallel or series tuned circuit has application in the audio range, and the purpose of this abac is to reduce the labour of computation. It is especially useful when a number of calculations have to be made. Such a case might arise in the design of an audio test oscillator to give a number of fixed frequencies by switching a number of condensers in rotation into circuit with a fixed inductance.

The chart is based upon the almost universally known formula:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

However, it is sometimes not fully realised that this formula is only an approximation of the general relation:

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{r^2}{4L^2}}$$

A little calculation will show that the error introduced by neglecting the resistance r of the coil will, except for very accurate work, be quite unimportant. Even when the "Q" of the coil falls to 4, the tuned frequency as calculated by the approximate formula is still within 1 per cent. of the truth as given by the exact relation; and when the "Q" falls as low as this the exact resonant point becomes rather indeterminate, as the resonance curve becomes very "flat." Nevertheless, for accurate work it should be remembered that the chart gives only the approximate answer.

The uses of tuned circuits at audio frequencies are various, and examples that spring immediately to the mind are audio test oscillators, detectors for AC bridges, selective amplifiers for various purposes, and tone-control circuits. Possibly their widest use is in the last-named application. For example, it is quite feasible to introduce a tuned circuit resonating at about 8,000 c/s to boost the treble previously cut by the selective circuits of a receiver. This can also be arranged to give a very sharp cut-off at about 10,000 c/s, with consequent benefit. If, in addition, the tuned circuit can be damped by a variable resistance, variable boost can be obtained, and with the increased flexibility some improvement can be expected in receiver performance even under widely varying conditions. One high-fidelity set of a few years ago had a treble boost of this nature (though without the variable feature) in operation on radio reception, with quite acceptable results, in spite of possible transient distortion.

There is no reason, of course, why a series circuit should not be used to provide an attenuation when and where required. Some pick-up "stratch" filters come into this category. Circuits have been devised using a tuned circuit in conjunction with positive or negative feedback to provide large gains or attenuations in the audio range to compensate for peaks or troughs in the overall response curve due to other components.

In the construction of tone-control arrangements with tuned circuits there are one or two practical points which are worth repeating here. The coils should not, as a general rule, be iron-cored components (unless iron dust cores are used), because the iron core adds materially to the effective resistance of the coil thus lowering the "Q."

ABACS WHICH HAVE ALREADY APPEARED IN THIS SERIES:—

"Output Transformer Ratios"	Oct. 1942
"Effect of a Screening Can on the Inductance and Resistance of a Coil"	Nov. 1942
"The Characteristic Impedance of Transmission Lines"	Jan. 1943
"Attenuation of Transmission Lines"	Feb. 1943
"'Q' of Quarter-wavelength Resonant Line"	Mar. 1943
"Length of Capacity-loaded Quarter-wavelength Transmission Line"	Apr. 1943

A high "Q" may easily be reduced by a shunt resistance, whereas a low "Q" cannot be raised without the use of other components (such as an extra valve stage with positive feedback). In addition, the coil will have a varying inductance with changing signal strength—unless very special alloys are used for the core—and the resonant peak will shift correspondingly. This may be of importance in some applications.

The losses in the condenser side of the circuit will, of course, add to the effective resistance, but in general these can be ignored in comparison with coil losses. It is fairly safe to say that at audio frequencies all reasonably good condensers can be regarded as perfect.

Coming back to coils, there is the question of hum pick-up. As far as possible a coil used for tone control should be well shielded by a screen or box of iron or magnetic alloy, and it should not be placed near transformers and chokes carrying AC power. In cases where hum is already present, relief can often be obtained by orienting the axis of the coil to a new position—to be found by experiment. Finally it only remains to emphasise the oft-repeated advice to do the tone controlling at an early stage where the signal level is low.

Now for the chart. In this case the operation is so simple that no key is required. It is only necessary to join the respective values of inductance and capacity with a ruler, and the tuned frequency is shown on the centre scale. Similarly, capacity and frequency, or inductance and frequency, may be used in conjunction to find inductance and capacity respectively. A single illustrative example should suffice.

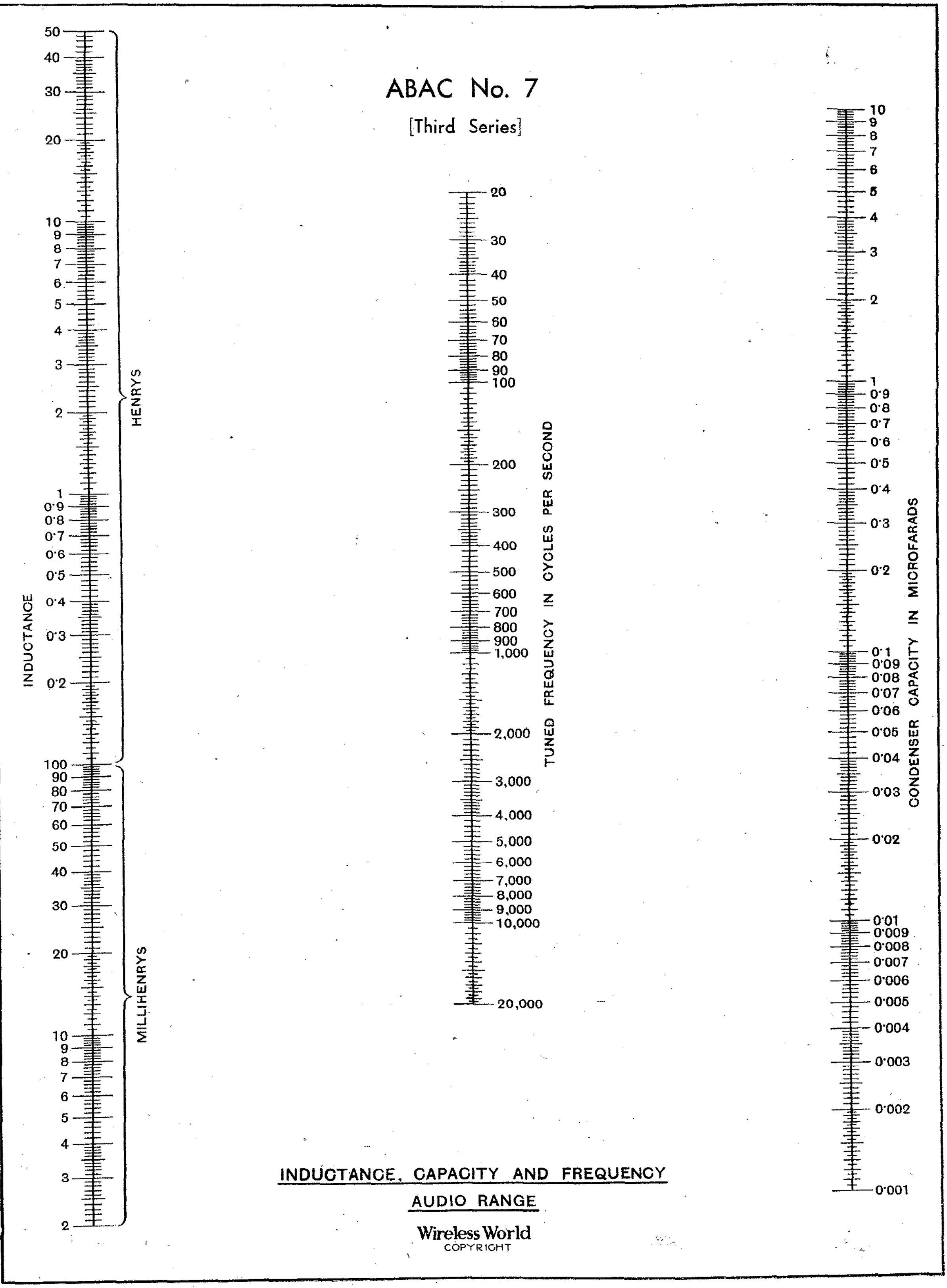
Example.

A slab coil of 0·32 Henrys (320 mH) is to be tuned to 7,500 c/s for treble boost in a receiver. What is the value of the condenser required for this set-up?

Set the ruler on 0·32 on the inductance scale at the right, and 7,500 c/s on the frequency scale, and the answer is read off the right hand capacity scale. It is 0·0014μF.

ABAC No. 7

[Third Series]



INDUCTANCE, CAPACITY AND FREQUENCY

AUDIO RANGE

SHORT-WAVE BROADCASTING STATIONS

Arranged in Order of Frequency

Some of the stations listed are of comparatively low power, while others, owing to their geographical position, operating frequencies and times of working, are heard in this country only under favourable conditions. They are, however, included in order that the list may be as comprehensive as possible. Owing to paper restrictions this list cannot be repeated for some time. Any major changes will be noted in our pages.

Station	Call Sign	Mc/s	Metres
Accra (Gold Coast)	ZOY	4.915	61.04
Vatican City	HVJ	5.970	50.25
Moscow (U.S.S.R.)	RNE	6.000	50.00
Mexico City	XEBT	6.000	50.00
Montevideo (Uruguay)	CXA2	6.000	50.00
Colon (Panama)	HP5K	6.005	49.96
Johannesburg (South Africa)	ZTJ	6.007	49.94
Pretoria (South Africa)	ZRH	6.007	49.94
Pernambuco (Brazil)	PRA8	6.010	49.92
Sydney (Nova Scotia)	CJCX	6.010	49.92
British Oversea Service	GRB	6.010	49.92
Delhi (India)	VUD3	6.010	49.92
Havana (Cuba)	COCO	6.010	49.92
Moscow (U.S.S.R.)	RW96	6.030	49.75
Lourenco Marques (Mozambique)	CR7AA	6.035	49.71
Moscow (U.S.S.R.)	—	6.040	49.67
Boston (U.S.A.)	WRUL*	6.040	49.67
British Oversea Service	GSA	6.050	49.59
Philadelphia (U.S.A.)	WCAB	6.060	49.50
Antananarivo (Madagascar)	—	6.063	49.48
Motala (Sweden)	SBO	6.065	49.46
Toronto (Canada)	CFRX	6.070	49.42
British Oversea Service	GRR	6.070	49.42
Vancouver (Canada)	CFKX	6.080	49.34
Cincinnati (U.S.A.)	WLWO	6.080	49.34
Lima (Peru)	OAX4Z	6.082	49.32
Nairobi (Kenya)	VQ7LO	6.083	49.31
Pereira (Colombia)	HJFK	6.090	49.26
Toronto (Canada)	CRCX	6.090	49.26
Cape Town (South Africa)	ZRK	6.097	49.20
Moscow (U.S.S.R.)	—	6.100	49.18
Bound Brook (U.S.A.)	WNBI†	6.100	49.18
Fortaleza (Brazil)	PRE9	6.105	49.14
British Oversea Service	GSL	6.110	49.10
Kharbarovsk (U.S.S.R.)	—	6.115	49.06
Brentwood (U.S.A.)	WCBX§	6.120	49.02
Montevideo (Uruguay)	CXA4	6.125	48.98
Perth (Australia)	VLW	6.130	48.94
Kuibyshev (U.S.S.R.)	—	6.130	48.94
Noumea (New Caledonia)	FK8AA	6.130	48.94
Moscow (U.S.S.R.)	—	6.140	48.86
Hull (U.S.A.)	WBOS	6.140	48.86
Medellin (Colombia)	HJDE	6.145	48.82
British Oversea Service	GRW	6.150	48.78
Winnipeg (Canada)	CJRO	6.150	48.78
Teheran (Iran)	EQB	6.155	48.74
Kuibyshev (U.S.S.R.)	—	6.155	48.74
Quebec (Canada)	CBFW	6.160	48.70
Schwarzenburg (Switzerland)	HER3	6.165	48.66
San Pedro (Costa Rica)	TILS	6.165	48.66
Brentwood (U.S.A.)	WCBX§	6.170	48.62
British Oversea Service	GRO	6.180	48.54
Buenos Aires (Argentina)	LRA2	6.180	48.54
Schenectady (U.S.A.)	WGEA‡	6.190	48.47
Vatican City	HVJ	6.190	48.47
San Francisco (U.S.A.)	KGEI	6.190	48.47
British Oversea Service	GRN	6.190	48.47
Lisbon (Portugal)	CS2WD	6.200	48.39
Havana (Cuba)	COCW	6.320	47.47
Santa Clara (Cuba)	COHI	6.455	46.48
Guatemala City	TGWB	6.480	46.30
Geneva (Switzerland)	HBQ	6.675	44.94
Cairo (Egypt)	SUR	6.784	44.24
Moscow (U.S.S.R.)	—	6.975	43.01
Kuibyshev (U.S.S.R.)	—	6.980	42.98
Moscow (U.S.S.R.)	—	6.980	42.98
British Oversea Service	GRS	7.065	42.46
Valladolid (Spain)	FET1	7.070	42.43
Tangier (Spanish Morocco)	—	7.090	42.31
British Oversea Service	GRM	7.120	42.13
British Oversea Service	GRT	7.150	41.96

Station	Call Sign	Mc/s	Metres
British Oversea Service	GRK	7.185	41.75
Moscow (U.S.S.R.)	—	7.200	41.67
Moscow (U.S.S.R.)	—	7.210	41.61
Calcutta (India)	VUC2	7.210	41.61
Sydney (Australia)	VLQ4	7.220	41.55
British Oversea Service	GSW	7.230	41.49
San Francisco (U.S.A.)	KWID	7.230	41.49
Bombay (India)	VUB2	7.240	41.44
San Francisco (U.S.A.)	KGEI	7.250	41.38
British Oversea Service	GSU	7.260	41.32
Lisbon (Portugal)	CSW8	7.260	41.32
Madras (India)	VUM2	7.270	41.27
Delhi (India)	VUD3	7.290	41.15
Moscow (U.S.S.R.)	—	7.300	41.10
British Oversea Service	GRJ	7.316	41.01
U.S.A. Service	WBS	7.355	40.79
Moscow (U.S.S.R.)	RWG	7.360	40.76
Point-à-Pitre (F.W.I.)	FG8AH	7.440	40.32
Moscow (U.S.S.R.)	RKI	7.520	39.89
Moscow (U.S.S.R.)	—	7.545	39.76
Moscow (U.S.S.R.)	—	7.560	39.68
U.S.A. Service	WDJ	7.565	39.66
Lobita (Angola)	CR6AA	7.614	39.40
Moscow (U.S.S.R.)	—	7.770	38.61
Cairo (Egypt)	SUX	7.865	38.14
Beirut (Syria)	—	8.035	37.34
Kuibyshev (U.S.S.R.)	—	8.050	37.27
Moscow (U.S.S.R.)	RIA	8.070	37.17
Rabat (Morocco)	CRN2	8.188	36.64
Casablanca (French Morocco)	CNP	8.795	34.11
U.S.A. Service	WJP	8.810	34.05
Santiago (Cuba)	COKG	8.960	33.48
Algiers	TPZ2	8.965	33.46
Moscow (U.S.S.R.)	—	8.990	33.37
Moscow (U.S.S.R.)	—	9.010	33.30
Havana (Cuba)	COBZ	9.030	33.22
Libreville (French Eq. Africa)	FHK	9.320	32.19
Geneva (Switzerland)	HBL	9.345	32.10
Dakar (French W. Africa)	FGA	9.405	31.90
British Oversea Service	GRI	9.410	31.88
Havana (Cuba)	COCH	9.437	31.79
British Oversea Service	GRU	9.450	31.75
Moscow (U.S.S.R.)	—	9.465	31.70
Ankara (Turkey)	TAP	9.465	31.70
Brentwood (U.S.A.)	WCBX§	9.480	31.65
St. John's (Newfoundland)	VONG	9.482	31.64
Moscow (U.S.S.R.)	—	9.500	31.58
Chungking (China)	XGOY	9.500	31.58
Rio de Janeiro (Brazil)	PRF5	9.500	31.58
Mexico City	XEWW	9.500	31.58
Rio de Janeiro (Brazil)	PRL8	9.505	31.56
British Oversea Service	GSB	9.510	31.55
Moscow (U.S.S.R.)	RW96	9.520	31.51
Pretoria (South Africa)	ZRG	9.523	31.50
Schenectady (U.S.A.)	WGEA‡	9.530	31.48
Moscow (U.S.S.R.)	—	9.530	31.48
San Francisco (U.S.A.)	KGEI	9.530	31.48
Calcutta (India)	VUC2	9.530	31.48
Motala (Sweden)	SBU	9.535	31.46
Suva (Fiji)	VPD2	9.535	31.46
Schwarzenburg (Switzerland)	HER4	9.535	31.46
Melbourne (Australia)	VLG2	9.540	31.45
Schwarzenburg (Switzerland)	HER10	9.545	31.43
San Francisco (U.S.A.)	KGEI	9.550	31.41
Moscow (U.S.S.R.)	—	9.550	31.41
Vatican City	HVJ	9.550	31.41
Bombay (India)	VUB2	9.550	31.41
Lima (Peru)	OAX4T	9.562	31.37
Kharbarovsk (U.S.S.R.)	—	9.566	31.36
Hull (U.S.A.)	WBOS	9.570	31.35
Madras (India)	VUM2	9.570	31.35

Station	Call Sign	Mc/s	Metres
British Oversea Service	GSC	9.580	31.32
Sydney (Australia)	VLQ6	9.580	31.32
Melbourne (Australia)	VLG	9.580	31.32
Cincinnati (U.S.A.)	WLWO	9.590	31.28
Delhi (India)	VUD4	9.590	31.28
Philadelphia (U.S.A.)	WCAB	9.590	31.28
British Oversea Service	GRY	9.600	31.25
Moscow (U.S.S.R.)	RAL	9.600	31.25
Rio de Janeiro (Brazil)	PRF5	9.600	31.25
Cape Town (South Africa) ..	ZRL	9.606	31.23
Panama City	HP5J	9.610	31.22
San Jose (Costa Rica)	TIPG	9.615	31.20
Sydney (Australia)	VLQ	9.615	31.20
Montevideo (Uruguay)	CXA6	9.620	31.19
Quebec (Canada)	CBFX	9.630	31.15
Bogota (Colombia)	HJCT	9.630	31.15
Chungking (China)	XGOY	9.635	31.14
Colonia (Uruguay)	CXA8	9.640	31.12
Brentwood (U.S.A.)	WCBX§	9.650	31.09
Vatican City	HVJ	9.660	31.06
Buenos Aires (Argentina) ..	LRX	9.660	31.06
Perth (Australia)..	VLW5	9.665	31.04
Bound Brook (U.S.A.)	WNBI†	9.670	31.02
San Francisco (U.S.A.)	KGEI	9.670	31.02
avana (Cuba)	COCQ	9.670	31.02
heran (Iran)	EQC	9.680	30.99
Mexico City	XEQQ	9.680	30.99
Sydney (Australia)	VLQ5	9.680	30.99
Moscow (U.S.S.R.)	RW96	9.684	30.98
Guatemala City	TGWA	9.685	30.98
British Oversea Service	GRX	9.690	30.96
Buenos Aires (Argentina) ..	LRA1	9.690	30.96
Boston (U.S.A.)	WRUL*	9.700	30.93
Valparaiso (Chile)	CE970	9.700	30.93
Forte-de-France (F.W.I.) ..	—	9.705	30.92
Lourenco Marques (Mozambique)	CR7BE	9.710	30.90
Chungking (China)	XGOA	9.720	30.86
Moscow (U.S.S.R.)	—	9.720	30.86
Lisbon (Portugal)	CSW7	9.740	30.80
Durban (Natal)	ZRO	9.750	30.77
New York (U.S.A.)	WDL	9.750	30.77
Baghdad (Iraq)	HNF	9.820	30.55
British Oversea Service	GRH	9.826	30.53
Lourenco Marques (Mozambique)	CR7BE	9.830	30.52
Havana (Cuba)	COCM	9.835	30.51
Moscow (U.S.S.R.)	—	9.860	30.43
Aranjuez (Spain)	EAQ	9.860	30.43
Sverdlovsk (U.S.S.R.)	—	9.865	30.42
U.S.A. Service	WHL5	9.897	30.32
U.S.A. Service	WRX	9.905	30.28
Vatican City	HVJ	9.980	30.06
Quito (Ecuador)	HCJB	10.000	30.00
Kuibyshev (U.S.S.R.)	—	10.040	29.88
Cairo (Egypt)	—	10.055	29.83
Leopoldville (Belgian Congo) ..	OPM	10.140	29.59
Rio de Janeiro (Brazil)	PRF5	10.220	29.35
lize (British Honduras) ..	ZIK2	10.600	28.30
guela (Angola)	CR6RY	10.869	27.60
bon (Portugal)	CSW6	11.040	27.17
Geneva (Switzerland)	HBO	11.402	26.31
Havana (Cuba)	COCY	11.460	26.18
Santa Clara (Cuba)	COHI	11.500	26.09
Moscow (U.S.S.R.)	—	11.500	26.09
Moscow (U.S.S.R.)	RIC	11.640	25.77
British Oversea Service	GRG	11.680	25.68
Kuibyshev (U.S.S.R.)	—	11.700	25.64
Panama City	HP5A	11.700	25.64
Motala (Sweden)	SBP	11.705	25.63
Montreal (Canada)	CBFY	11.705	25.63
Melbourne (Australia)	VLG3	11.710	25.62
Cincinnati (U.S.A.)	WLWO	11.710	25.62
Moscow (U.S.S.R.)	—	11.710	25.62
Winnipeg (Canada)	CJRX	11.720	25.60
Rio de Janeiro (Brazil)	PRL8	11.720	25.60
San Francisco (U.S.A.)	KGEI	11.730	25.58
Boston (U.S.A.)	WRUL*	11.730	25.58
Buenos Aires (Argentina) ..	LRA3	11.730	25.58
Vatican City	HVJ	11.740	25.55
Santiago (Chile)	CB1174	11.740	25.55
Loanda (Angola)	CR6RC	11.740	25.55
British Oversea Service	GSD	11.750	25.53
Guatemala City	TGWA	11.760	25.51
Lyndhurst (Australia)	VLR8	11.760	25.51

Station	Call Sign	Mc/s	Metres
Santa Clara (Cuba)	COHI	11.765	25.50
Moscow (U.S.S.R.)	RNE	11.766	25.50
Boston (U.S.A.)	WRUL*	11.790	25.45
Santiago (Chile)	CB1180	11.800	25.42
British Oversea Service	GSN	11.820	25.38
Colonia (Uruguay)	CXA11	11.820	25.38
Bound Brook (U.S.A.)	WNBI†	11.820	25.38
Moscow (U.S.S.R.)	—	11.830	25.36
Delhi (India)	VUD4	11.830	25.36
Brentwood (U.S.A.)	WCBX§	11.830	25.36
Perth (Australia)..	VLW3	11.830	25.36
Lourenco Marques (Mozambique)	CR7BF	11.835	25.35
Lisbon (Portugal)	CSW5	11.840	25.34
Lyndhurst (Australia)	VLR7	11.840	25.34
Schenectady (U.S.A.)	WGEA‡	11.847	25.33
Rio de Janeiro (Brazil)	PRF5	11.855	25.31
British Oversea Service	GSE	11.860	25.30
Schwarzenburg (Switzerland) ..	HER5	11.865	25.28
Hull (U.S.A.)	WBOS	11.870	25.27
Sydney (Australia)	VLQ2	11.870	25.27
Sydney (Australia)	VLQ7	11.880	25.25
Kharbarovsk (U.S.S.R.) ..	—	11.885	25.24
Bound Brook (U.S.A.)	WNBI†	11.890	25.23
Montevideo (Uruguay)	CXA10	11.895	25.22
Suva (Fiji)	VPD2	11.895	25.22
Moscow (U.S.S.R.)	RNE	11.900	25.21
Chungking (China)	XGOY	11.900	25.21
Moscow (U.S.S.R.)	—	11.910	25.19
Rabat (Morocco)	CNR2	11.940	25.13
Brazzaville (French Eq. Africa)	FZI	11.970	25.06
Moscow (U.S.S.R.)	RNE	12.000	25.00
British Oversea Service	GRV	12.040	24.92
British Oversea Service	GRF	12.095	24.80
Algiers	TPZ	12.110	24.77
Aden	ZNR	12.115	24.76
Moscow (U.S.S.R.)	—	12.190	24.61
Sverdlovsk (U.S.S.R.)	—	12.225	24.54
Reykjavik (Iceland)	TFJ	12.235	24.52
Moscow (U.S.S.R.)	—	12.240	24.51
Quito (Ecuador)	HCJB	12.455	24.09
Rabat (Morocco)	CNR	12.831	23.38
Kuibyshev (U.S.S.R.)	—	13.010	23.06
Moscow (U.S.S.R.)	—	13.210	22.71
U.S.A. Service	WHL6	13.442	22.32
Moscow (U.S.S.R.)	—	13.770	21.79
U.S.A. Service	WDO	14.470	20.73
Geneva (Switzerland)	HBJ	14.538	20.63
Lisbon (Portugal)	CSW	14.600	20.55
Moscow (U.S.S.R.)	RKI	14.717	20.38
Moscow (U.S.S.R.)	RKI	15.040	19.95
Teheran (Iran)	EPB	15.100	19.87
Vatican City	HVJ	15.120	19.84
Boston (U.S.A.)	WRUL*	15.130	19.83
British Oversea Service	GSF	15.140	19.82
Motala (Sweden)	SBT	15.150	19.80
Bound Brook (U.S.A.)	WNBI†	15.150	19.80
Melbourne (Australia)	VLG7	15.160	19.79
Mexico City	XEWW	15.160	19.79
Suva (Fiji)	VPD2	15.160	19.79
Fortaleza (Brazil)	PRE9	15.165	19.78
Guatemala City	TGWA	15.170	19.78
Moscow (U.S.S.R.)	RW96	15.180	19.76
British Oversea Service	GSO	15.180	19.76
Quebec (Canada)	CBFZ	15.190	19.75
Rio de Janeiro (Brazil)	PRF5	15.190	19.75
Bound Brook (U.S.A.)	WNBI†	15.190	19.75
Ankara (Turkey)	TAQ	15.195	19.74
Chungking (China)	XGOX	15.200	19.74
Hull (U.S.A.)	WBOS	15.210	19.72
San Francisco (U.S.A.)	KGEI	15.210	19.72
Lisbon (Portugal)	CSW4	15.215	19.72
Kharbarovsk (U.S.S.R.).. ..	—	15.230	19.70
Melbourne (Australia)	VLG6	15.230	19.70
Cincinnati (U.S.A.)	WLWO	15.250	19.67
Lourenco Marques (Mozambique)	CR7BD	15.255	19.66
British Oversea Service	GSI	15.260	19.66
Brentwood (U.S.A.)	WCBX§	15.270	19.65
Lourenco Marques (Mozambique)	CR7BG	15.285	19.63
Delhi (India)	VUD3	15.290	19.62
Buenos Aires (Argentina) ..	LRU	15.290	19.62
Montevideo (Uruguay)	CXA18	15.300	19.61
British Oversea Service	GSP	15.310	19.60
Sydney (Australia)	VLQ3	15.315	19.59

Station	Call Sign	Mc/s	Metres
Schenectady (U.S.A.)	WGEA‡	15.330	19.57
San Francisco (U.S.A.)	KGEI	15.330	19.57
Boston (U.S.A.)	WRUL*	15.350	19.54
British Oversea Service	GRE	15.385	19.50
Moscow (U.S.S.R.)	RW96	15.410	19.47
British Oversea Service	GRD	15.448	19.42
Moscow (U.S.S.R.)	—	15.490	19.37
New York (U.S.A.)	WCP	15.565	19.27
Tunis (N. Africa)	—	15.650	19.17
Moscow (U.S.S.R.)	—	15.715	19.09
New York (U.S.A.)	WCW	15.850	18.93
British Oversea Service	GRA	17.710	16.94
Boston (U.S.A.)	WRUL*	17.750	16.90
Bound Brook (U.S.A.)	WNBI†	17.780	16.87
Hull (U.S.A.)	WBOS	17.780	16.87
British Oversea Service	GSG	17.790	16.86
Chungking (China)	XGOX	17.800	16.85
Guatemala City	TGWA	17.800	16.85
Sydney (Australia)	VLQ8	17.800	16.85
Cincinnati (U.S.A.)	WLWO	17.800	16.85
British Oversea Service	GSV	17.810	16.84

Station	Call Sign	Mc/s	Metres
Brentwood (U.S.A.)	WCBX§	17.830	16.83
Rio de Janeiro (Brazil)	PRL8	17.850	16.81
Moscow (U.S.S.R.)	—	17.910	16.75
Lourenco Marques (Mozambique)	CR7BI	17.915	16.74
British Oversea Service	GRQ	18.030	16.64
British Oversea Service	GVO	18.083	16.59
Geneva (Switzerland)	HBF	18.450	16.26
Geneva (Switzerland)	HBH	18.480	16.23
Moscow (U.S.S.R.)	—	18.540	16.18
Leopoldville (Belgian Congo) ..	OPL	20.040	14.97
Boston (U.S.A.)	WRUL*	21.460	13.98
British Oversea Service	GSH	21.470	13.97
Schenectady (U.S.A.)	WGEA‡	21.500	13.95
Philadelphia (U.S.A.)	WCAB	21.520	13.94
British Oversea Service	GSJ	21.530	13.93
Hull (U.S.A.)	WBOS	21.540	13.93
British Oversea Service	GST	21.550	13.92
Brentwood (U.S.A.)	WCBX§	21.570	13.91
Schenectady (U.S.A.)	WGEA‡	21.590	13.89
Bound Brook (U.S.A.)	WNBI†	21.630	13.87
British Oversea Service	GRZ	21.640	13.86

* These frequencies shared with WRUS and WRUW.
† These frequencies shared with WRCA.
§ These frequencies shared with WCRC and WCDA.
‡ These frequencies shared with WGEO.

NEWS IN ENGLISH FROM ABROAD

REGULAR SHORT-WAVE TRANSMISSIONS

Country : Station	Mc/s	Metres	Daily Bulletins (BDST)
America			
WRUW (Boston) ..	6.040	49.67	0900
WLWO (Cincinnati)	6.080	49.34	0700, 0800, 0900, 1000, 1100
WBOS (Hull) ..	6.140	48.86	1000, 1100
WCRC (Brentwood)	6.170	48.62	0700
WGEA (Schenectady)	6.190	48.47	0700
WBS	7.355	40.79	0700, 0800, 0900, 1000
WDJ	7.565	39.66	0200, 0300, 0400, 0600, 0800, 0900, 1000
WJP	8.810	34.05	0200, 0300, 0400
WGEO (Schenectady)	9.530	31.48	2200, 2300
WCBX (Brentwood)	9.650	31.09	0600, 0700
WNBI (Bound Brook)	9.670	31.02	0100
WRUW (Boston) ..	9.700	30.93	0000, 2200
WDL	9.750	30.77	1100
WHL5	9.897	30.32	0000, 1100, 1200
WRX	9.905	30.28	0700, 0900, 1000
WLWO (Cincinnati)	11.710	25.62	2000, 2100, 2200, 2300
WRUL (Boston) ..	11.790	25.45	0000, 2200
WCDA (New York)	11.830	25.36	0000, 1200, 1300, 1400, 1630‡, 1830, 2200
WGEA (Schenectady)	11.847	25.33	1400, 1500, 1600, 1700, 1800, 1900, 2000
WBOS (Hull) ..	11.870	25.27	1300, 2000, 2200, 2300‡
WHL6	13.442	22.32	1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2100, 2200
WDO	14.470	20.73	1500, 1800, 1900, 2100
WBOS (Hull) ..	15.210	19.72	1500, 1800
WCBX (Brentwood)	15.270	19.65	1630‡, 1830, 2200
WGEO (Schenectady)	15.330	19.57	1500, 1800
WRUL (Boston) ..	15.350	19.54	1200, 1300, 1400, 1500, 1600
WCW (New York) ..	15.850	18.93	2000
WLWO (Cincinnati)	17.800	16.85	1600, 1700, 1800
WCRC (Brentwood)	17.830	16.83	1200, 1300, 1400, 1630‡, 1830, 2200
Australia			
VLQ5 (Sydney) ..	9.680	30.99	0755
VLG3 (Melbourne) ..	11.710	25.62	0755
Brazil			
PRL8 (Rio de Janeiro)	11.720	25.60	2130
China			
XGOY (Chungking)	11.900	25.21	1500, 1700, 1815, 2230

Country : Station	Mc/s	Metres	Daily Bulletins (BDST)
French Equatorial Africa			
FZI (Brazzaville) ..	11.970	25.06	2145
India			
VUD3 (Delhi) ..	7.290	41.15	0900, 1400, 1650
VUD4	9.590	31.28	0900, 1400, 1650
VUD3	15.290	19.62	1400
Mozambique			
CR7BE (Lourenco Marques) ..	9.830	30.52	1255, 1812, 2015
Switzerland			
HER3 (Schwarzenburg)	6.165	48.66	2150
HER5 (Schwarzenburg)	11.865	25.28	2150
Spain			
EAQ (Aranjuez) ..	9.860	30.43	1915
Sweden			
SBU (Motala) ..	9.535	31.46	2320‡
Syria			
Beirut	8.035	37.34	1920
Turkey			
TAP (Ankara) ..	9.465	31.70	1900
U.S.S.R.			
Moscow	6.980	42.98	0000, 0035, 1340, 1800,
	7.300	41.10	0000, 1900, 2100, 2200, 2300
	7.360	40.76	0000
	7.560	39.68	0000
	11.830	25.36	1700
	12.190	24.61	0035, 0200
Kharbarovsk	15.230	19.70	05.15, 1340
Kuibyshev	8.050	37.27	2130
	11.700	25.64	0700, 1500, 1545
	13.010	23.06	0700, 1500, 1545
Vatican City			
HVJ	5.970	50.25	2015

MEDIUM-WAVE TRANSMISSIONS

Ireland	kc/s	Metres	
Radio Eireann ..	565	531	1440‡, 1945, 2310

It should be noted that the times are BDST—**two hours** ahead of GMT. ‡ Sundays excepted.

NEEDLE ARMATURE PICK-UP

Design Giving Good Frequency Response and Low Amplitude Distortion

By

G. A. HAY, B.Sc.

THE great improvements in the fidelity of mechanical recordings which have appeared in the past few years make it possible for the best music to be enjoyed at home under more comfortable conditions than in the average concert hall. The complete appreciation of such, however, demands the greatest absence of distortion in the acoustic output of the gramophone. It is now a relatively simple matter to make the electrical circuits of a reproducing system almost completely 'istortionless, and, as usual, the weak links are the loud speaker and gramophone pick-up. The writer feels that least attention has been devoted to the pick-up, although its design is in many ways simpler than that of the speaker, due to the fact that there is no question of power efficiency involved. An article[1] describing the design of a high-quality moving coil pick-up has been published recently in this journal, and it is the purpose of this article to show how the problem has been tackled from an entirely different angle.[2]

A pick-up is essentially a device for transferring the vibrations from the record groove to a moving system, and then converting these vibrations into electrical output. The first process presents the more difficult problem, as we are not able to fix the needle rigidly to the walls of the groove, but must rely contact provided by mere pressure. The choice of the value of this downward pressure is important, as it affects the whole design of the pick-up. It depends mainly on two considerations: (1) the wear produced on the record and needle, and (2) the force required to prevent the needle from jumping out of the groove. The first is a function of the *pressure* (i.e., force per unit contact area), and the second depends on the *total downward force* on the needle point.

Needle Contact

There are three courses open to the pick-up designer. Either we can use a soft needle such as a fibre and tolerate needle wear with consequent loss of high notes and general lack of clarity, or we can use a very hard needle such as a diamond point, which will give record wear but no needle wear. The third course is to use a needle of moderate hardness, such as steel, and allow mutual wear on both record and needle. This seems rather a drastic course, but a necessary corollary is to reduce the pressure at the needle point to as small a value as possible consistent with stable operation. The total downward force on the needle head is fixed by the maximum amplitude on the record groove at any given frequency, and hence to ensure a small pressure it is essential to provide the maximum contact area between needle point and groove walls and bottom. It is for this reason that the writer views with dislike the recent attempts to use a broad needle which rides on the walls of the groove, when the pressure must be very high due to the small contact area.

Downward Force

Turning now to the force required to keep the needle in the groove, as the record groove is roughly triangular in cross-section, any sideways force produced on the needle point is also accompanied by an upward vertical component due to the inclined plane effect of the groove wall. Assuming the angle of this to be 45 degrees (an underestimate), the downward force necessary will be exactly equal to the lateral force on the needle. In practice it will be advisable to make it many times greater to ensure complete freedom from groove jumping. It has been found with the type of needle suspension discussed below that a downward force of about ten grams is entirely adequate for all modern recordings. Actually, adjustment is provided by the movement of a counterweight.

The mass of the pick-up and arm depends on (a) this downward force, (b) the lateral force exerted by the needle on the body of the pick-up, and (c) the possible mechanical resonances of the pick-up as a whole. Factor (a) would seem to indicate an optimum mass of pick-up head equal to the required downward force on the record surface. This, of course, would result in an extremely light pick-up. Factors (b) and (c), however, indicate that a rather different course should be pursued. In the first place, a sideways force on the needle due to the record groove will first tend to move the needle sideways, and then the whole body of the pick-up. If the mass of the latter is small, then the total resultant angular motion of the needle relative to the body of the pick-up will be reduced by the sideways motion of the arm as a whole. This effect in any practical case will be small, but it can still be further minimised by making the tone arm and head relatively heavy, and counterbalancing by means of a weight. Secondly, the whole bass characteristic of the pick-up depends on its mass, and if we are to avoid a pronounced resonance in the audible bass region we must make the instrument relatively heavy. This point will be elaborated later. The only disadvantage, so far as the writer knows, of a heavy counterbalanced pick-up was pointed out by Mr. Brierley,[1] that of difficulty in following the groove in the case of a badly warped record. Against this may be set the writer's experience, and that of others,[3] that it requires a very badly warped record to cause groove jumping, and this is likely to be unsatisfactory for other reasons.

Mechanical Resonances

The mechanical resonances present in a pick-up affect its performance considerably. Such resonances are harmful, not only because they give rise to a large increase in electrical output at the resonant frequency, but also because the increased amplitude of needle movement causes excessive record wear where notes of the resonant frequency occur. This causes distortion of all other notes existing on the record at that point. There are three possible modes of vibration of a conventional pick-

Needle Armature Pick-up—

up,[4] (1) the so-called bass resonance, due to the whole instrument vibrating about the tone arm pivot, controlled by the elasticity of the needle in its suspension ; (2) the torsional vibration of the pick-up head about the axis of the tone arm, controlled in the same way ; (3) the treble resonance, caused by the vibration of the needle system about its axis, controlled by the needle suspension and stiffness of the needle itself.

False Bass

The bass resonance affects the trend of the lower part of the curve materially. Modern recordings have a falling characteristic below 250 c/s to about 14 db. down at 50 c/s. It has been the custom in the past to compensate for this by placing the bass resonance at about 50 c/s, giving a false increase in output, and hence a more or less complementary lift in the bass. Not only does this increase record wear, but the increased amplitude of needle vibration is liable in certain circumstances to cause bad amplitude distortion. The alternative course is to aim at a flat response and correct for the recording electrically in the amplifier. It is impracticable completely to eliminate the bass resonance, and the method of placing it at 15-20 c/s results in the output being well maintained at 50 c/s. No record wear is caused, as frequencies of 15-50 c/s are not recorded. This requires a heavy pick-up and light damping of the needle, the latter also greatly reducing the tendency towards groove jumping.

The torsional resonance is relatively unimportant, as its effect is inaudible and only measurable if a gliding tone record is used. It will, however, cause record wear, and for this reason it is advisable to reduce it in magnitude as far as possible. The most satisfactory method of doing this, which the writer believes is original, is to make the tone arm axis as near as possible to the surface of the record. This reduces the moment of torsional forces due to the elasticity of the arm about the needle point, and in practice a peak and trough not more than 1 db. high are obtained. With the tone arm about 1in. above the record surface, this peak was 10 db. high, and other irregularities appeared below the resonant frequency, which had a value of about 250 c/s.

The treble resonance is the most troublesome of all. In the average commercial moving iron pick-up it appears between 2,000 and 3,000 c/s, and causes record wear, excessive and unnatural brilliance, and excessive scratch due to the shock excitation of the needle resonance by the random surface irregularities.[5] There are two methods of driving this up beyond the audible range ; either the stiffness of suspension can be increased or the armature mass reduced. We have already decided that a free suspension is desirable, and so we must choose the second alternative. The limit is reached when the armature is formed by the needle itself—the so-called needle armature pick-up. By adopting this construction it has been found possible to make the treble resonance of the order of 15,000 c/s, at which frequency it does no harm.

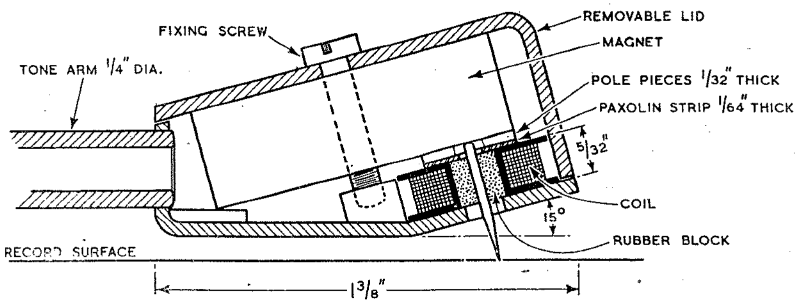


Fig. 1. Lay-out and approximate dimensions of pick-up.

Finally, the pivoting arrangements must be considered. In order to reduce record wear on the sides of the groove, it is essential that the pivots should be of the highest quality, both laterally and vertically, and in practice ball bearings are necessary. Moreover, the turntable must be dead level to reduce any tendency for the pick-up to swing and press against one wall of the groove more than the other.

Turning now to the final design, the following is a brief summary of the requirements. The pick-up as a whole should be relatively heavy, pivoted very lightly, the bearings being exactly horizontal and vertical, and counterbalanced to reduce the downward force on the needle point to about ten grams. The needle, which should fit the groove closely and also act as armature, should be of small dimensions and mass, and consist of a suitable magnetic material. It should be suspended in a magnetic field by a fairly light but well-damped suspension, and the clearance between needle and pole pieces must be relatively large to reduce amplitude distortion. The tone arm should be as near to the record surface as possible to reduce the forces tending to stimulate torsional resonance.

Design Details

The design shown in Fig. 1 has been found to cover the above requirements, and to give remarkably good reproduction. The magnetic field is provided by an "Eclipse" horseshoe magnet which is roughly 1in. in diameter and $\frac{3}{8}$in. thick. Any reasonably small magnet taken from an old pick-up will serve the same purpose, although the dimensions of the case will have to be adjusted to suit. The pole pieces and coil form one unit, the former being cut out of $\frac{1}{32}$in. Stalloy transformer laminations to the shape shown in Fig. 2. These pieces are cemented on to a paxolin supporting piece, which has a hole cut in the middle to clear the needle. This piece is cemented in turn to the coil, which in the writer's model was removed from an old B.T.H. Minor pick-up. Suitable data are given in Fig. 2 for a similar coil if this has to be wound.

The needle is embedded in a rubber block, being held in place merely by the friction between the needle and rubber. Originally an interchangeable unit was used, the whole unit, rubber and all, being removed when changing the needle. This was subsequently found to be unnecessary, and the latest model consists of a permanently fixed rubber block into which needles are pushed, being held by a pair of fine-nosed pliers. When inserting the needle for the first time into the block, it is essential to take the greatest care to place the needle centrally between the pole pieces, or amplitude distortion will

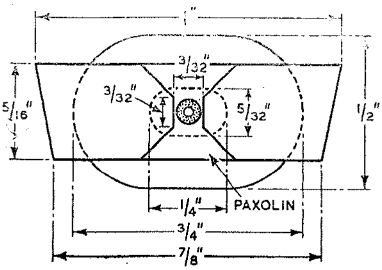


Fig. 2. Details of pole pieces and coil. The coil has approximately 3,000 turns of 47 SWG enamelled wire.

result. Subsequent insertions will follow the original hole if reasonable care be taken.

The needles originally used were the H.M.V. Silent Stylus miniature type, but the Columbia Type 99 are exactly equivalent. The type of rubber has naturally a big effect on the response, and it has been found that the rubber used in pencil erasers is the most suitable. In the writer's experience there is little deterioration in high note response after fifty 12in. playings on heavy orchestral records, and this probably represents a good compromise between quality and economy. The rubber block will eventually need renewal, but this ...l certainly not be necessary ...re than once a year with fairly constant use.

The pole pieces are not fixed to the magnet poles, but are merely held down by magnetic attraction. In addition, the bolting down of the cover on top of the magnet clamps the whole assembly together and down to the base-plate. The tone arm consists of a ¼in. diameter brass tube, soldered into the brass pick-up case, and bent horizontally to give correct tracking. The use of a longer arm than usual is beneficial in reducing the angle of inclination of the pick-up to the tone arm axis, and thus reducing the overhang of the needle point over the turntable axis at the centre of the record. With a tone arm 11½in. long, the pick-up must be inclined to the tone arm axis at an angle of 18 deg., and the needle must be ½in. in advance of the record centre: the tracking error is then about 1½ degrees.[6]

The trailing angle of the needle is important. The cutting stylus used in recording is vertical, and it is reasonable to suppose that best results would be obtained with a vertical reproducing needle. Actually, the best compromise between high note response and scratch seems to be obtained with an angle of about 15 degrees from the vertical.

The pivoting arrangements in the writer's present instrument are not satisfactory. They consist of inferior ball races as fitted to medium quality pick-ups, and a relatively big force is required to move the pick-up sideways. It is particularly important that the vertical movement should be free, as the heavy counterweight imposes a relatively large downward force on this pivot. Connection to the coil is made by means of a single cotton-covered stranded flex, to give freedom of movement. The earthy end of the coil is connected to the metal frame of the instrument. The case is built up of $\frac{1}{16}$in. brass sheet, bent and soldered, this in conjunction with the magnet giving a satisfactorily large mass. The counterweight was cast in one-half of an aluminium container in which 35 mm. Leica films were sold: it is merely a tight push fit on a brass rod forming a back extension of the tone arm, enabling small adjustments to be easily made.

Hum

Due to the all-metal construction of the case, troubles from electrostatic pick-up are negligible. There is a certain amount of magnetic hum pick-up from power transformers, however, and, although not noticeable during playing on account of the low sensitivity and the high gain needed, this is rather troublesome to get rid of completely. Experiments with hum-bucking coils have not so far proved successful in reducing this to zero, but screening with Mumetal would probably be effective.

The response curve given by the author's pick-up is shown in Fig. 3. This is the actual output from a Decca EXP55 test record corrected below 250 c/s for the constant amplitude characteristic. The region between 6,000 and 8,000 c/s and the torsional resonance were deduced from an H.M.V. gliding tone record, DB4037. The average output from normal orchestral records is of the order of 10 mV RMS. Although measurements above 8,000 c/s were impossible, it is believed that the treble resonance lies at about 15,000 c/s, and being used in conjunction with a speaker with an excellent top response, gives rise to excessive scratch. It has been found that most recordings are improved by a gradually falling characteristic in the treble, and this greatly reduces the effect of the treble resonance. In addition, full compensation in the bass is required, for which suitable circuits and data have been given from time to time in this journal.[7]

In use, the pick-up gives a high degree of fidelity. Top response, as judged by the upper strings, is excellent, while double basses and organ pedal notes are reproduced at correct pitch, instead of an octave higher. A musical, but non-technical friend, who is also an organist, has discovered pedal notes

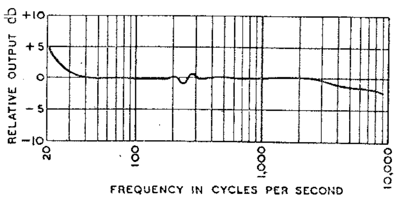


Fig. 3. Response curve of finished pick-up taken with HMV DB4037 and Decca EXP55 and corrected for recording characteristic. Zero db corresponds to about 15 mV.

on organ records which he has never heard before using a crystal pick-up. Due to the large gap, audible harmonic distortion is entirely absent.

There is only one fault: bad records do really sound awful. Perhaps this is not such a disadvantage, after all?

References to "Wireless World" Articles

1 "A Moving Coil Pick-up," J. Brierley, July 1942.
2 Correspondence, G. A. Hay, September 1942.
3 Correspondence, J. H. Mole, August 1942.
4 "Getting the Best from Records," P. G. A. H. Voigt, March 1940.
5 "Gramophone Record Scratch," M. G. Scroggie, November 1939.
6 "Pick-up Alignment," E. A. Chamberlain, March 26th 1030.
7 "An Electric Gramophone," M. G. Scroggie, May 11th and July 27th 1939.

Frequency Modulation—V

DEMODULATION: THEORY OF THE DISCRIMINATOR

A graphical method of demonstrating the effect of variations in circuit constants is used to explain the principles underlying the design of the discriminator circuit now in general use.

By CHRISTOPHER TIBBS, A.M.I.E.E.

THERE are a number of circuits for demodulating an FM transmission, some have a small distortion factor, others may be simple to line up or offer a high efficiency; each has its own merits. There is, however, one arrangement that has become so popular in America that it can for all practical purposes be regarded as the standard frequency-modulation discrimination. It was first introduced as a method of developing the control voltage required by receivers incorporating AFC[1,2].

The discriminator circuit shown in Fig. 1 is almost exclusively used in the modern FM receiver. It represents a very satisfactory compromise, combining as it does, high efficiency and production stability.

The circuit arrangement is such that the waveform applied to the two diodes produces voltages across the loads R1 and R2, which tend to cancel each other out. When the signal applied to both diodes is equal there will be zero voltage across the output. If, however, the signal applied to D1 is larger than that applied to D2 then the voltage across R1 will be larger than that across R2. This will result in a positive voltage across the output terminals. If the voltage applied to D2 is the larger then the output will be negative.

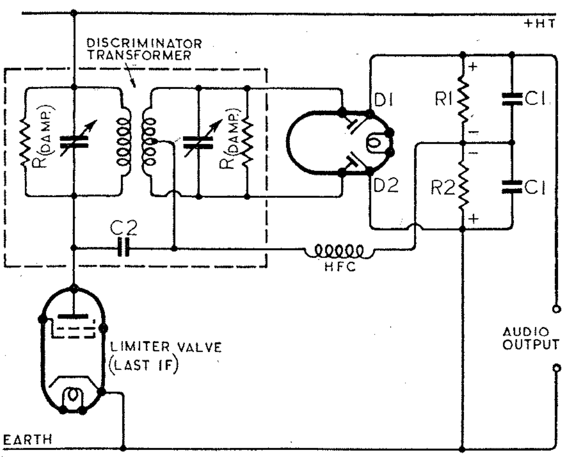


Fig. 1. Type of discriminator circuit used in modern American frequency-modulation receivers.

Before it is possible to discuss the means by which the voltage applied to the two diodes is to vary with frequency, it is necessary for one to investigate some of the fundamental properties of a parallel tuned circuit. Below resonance the inductive arm has the lower impedance, while at frequencies above resonance it is the capacity which has the lower, and therefore controlling impedance. In short, at frequencies below resonance the circuit is inductive and above it is capacitive. The conditions existing result in a gradual change of phase angle from lagging to leading as the frequency is increased, the actual change-over taking place at the circuit's resonant frequency.

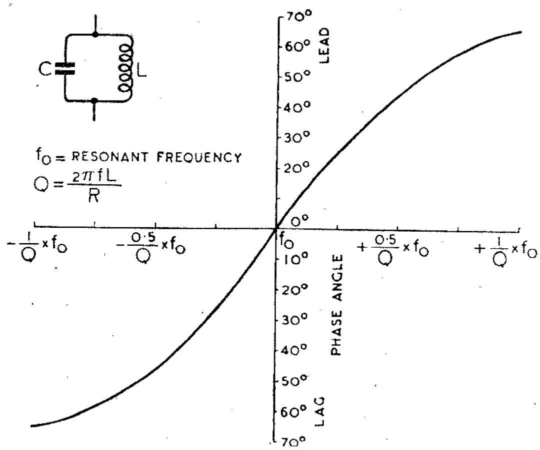


Fig. 2. Universal frequency/phase angle curve for a parallel tuned circuit. It will be noted that there is a substantially linear relation between frequency and phase, provided the band ± 40 to ± 45 degrees is not exceeded.

Fig. 2 shows this change of phase angle plotted against a frequency base which is expressed in terms of the circuit Q. By expressing the frequency in this way it is possible to apply the curve to any resonant frequency or circuit Q. This curve is in fact the universal phase angle curve for all parallel tuned circuits.

The first important point to note is that this phase angle curve [is] not strictly linear anywhere; b[ut] that the departure from straightness is fairly small if the band used does not exceed ± 40 to ± 45 deg. The second point, is that the frequency band occupied by [a] given phase change is direc[tly] dependent on the circuit Q. If, as an example, the resonant frequency is taken as 5 Mc/s and the circuit Q as 25, then the working range of the phase angle curve (*i.e.* ± 45 deg.) will correspond to a frequency change of approximately $\pm \frac{0.5}{Q} \times 5$ Mc/s $= \pm 100$ kc/s. Similarly if the Q is increased to 50 then a phase change of ± 45 deg. will take place when the frequency is modulated over ± 50 kc/s.

Having briefly considered the phase shift occurring in a parallel tuned circuit, it is possible to return to the functioning of the discriminator proper. The whole basis of its operation is the phase change which results from the modulation of the incoming carrier above and below the frequency to which the discriminator transformer is tuned. The detail functioning will be explained with the aid of two examples. The first case is that for no frequency modulation and the second that for maximum frequency modulation.

The conditions existing in the discriminator transformer when there is no frequency modulation are shown in Fig. 3. Diagram (*a*) emphasises the fact that at resonance the only phase shift between primary and secondary voltages results from the 90 deg. lag due to the mutual inductive coupling. The actual voltages applied to the odes are shown in Fig. 3(*b*).

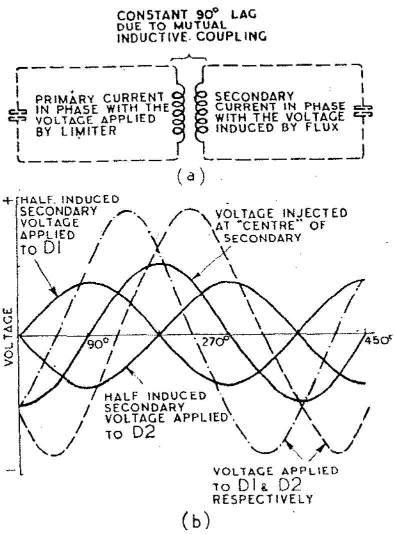


Fig. 3. (a) Phase shift conditions existing in the discriminator transformer at resonance. The total lag between the primary, and the induced secondary voltage is 90 degrees. (b) Induced voltages applied to the two diodes, and voltage injected at the centre of the secondary winding. The addition of this 90-degree leading voltage produces an exactly equal increase on both diodes.

Referred to the centre tap, half the induced secondary voltage is fed as a positive signal to one diode, while the other half is applied as a negative signal to the second diode.

Due to the 90 deg. lag between the primary and the secondary, the voltage injected through C2 (Fig. 1), to the secondary centre tap, will be 90 deg. in advance of the secondary induced voltage. The phase relations of the injected and induced secondary voltages are shown in Fig. 3(*b*). The vector addition of these signals forms the actual voltage applied to the diodes and is indicated by the dotted waveforms. As a result of applying these equal voltages to both

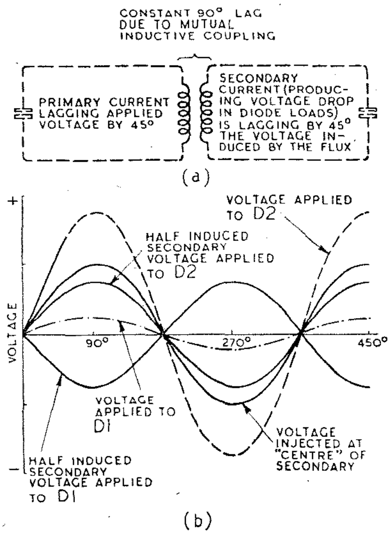


Fig. 4. (a) Showing the phase shift conditions existing in the discriminator transformer when passing a carrier frequency of $-\frac{0.5}{Q} \times f_0$ (see Fig. 2). There is a total lag of 180 degrees between the applied primary voltage resulting from the induced secondary current. (b) Addition of the induced voltage and the injected voltage produce a far larger signal on D2 than on D1.

diodes, there are equal but opposing voltages across the two loads (R1 and R2). The total voltage across the discriminator output terminals is therefore zero. To sum up, a carrier having a frequency the same as that to which the discriminator is tuned, produces zero output voltage.

The second example assumes the condition existing at a maximum frequency modulation. This frequency is assumed to be that which will produce a phase lag of 45 deg. between the voltage and current in a parallel tuned circuit. With the aid of Fig. 2 it has earlier been shown that such a phase lag is produced by a carrier $\frac{0.5}{Q} \times f_0$ below the circuit resonant frequency. One of the previous examples given shows that with an IF of 5 Mc/s and a Q of 25 this frequency will be — 100 kc/s.

Fig. 4(*a*) shows that under the above conditions there is a phase lag of 180 deg. between the applied primary voltage and the induced secondary voltage. This lag takes place in three steps. In the primary of the discriminator transformer, the "flux producing current" will lag the applied voltage by 45 deg. To this must be added the constant 90 deg. lag due to the mutual inductive coupling. In the secondary, the current (which in flowing through the diode loads produces the output voltage), is lagging 45 deg. behind the voltage "applied" by the flux. Adding up these three component phase shifts there is a total lag of 180 deg. between the primary voltage applied by the last IF valve (the limiter) and the induced secondary voltage.

The voltage conditions existing at maximum frequency modulation as the result of this lag are shown in Fig. 4(*b*). Again the centre-tapped secondary results in half the induced voltage being applied as positive to one diode, and half as negative to the other. The total voltages applied to D1 and D2 are shown by the dotted curves.

The application of a large signal

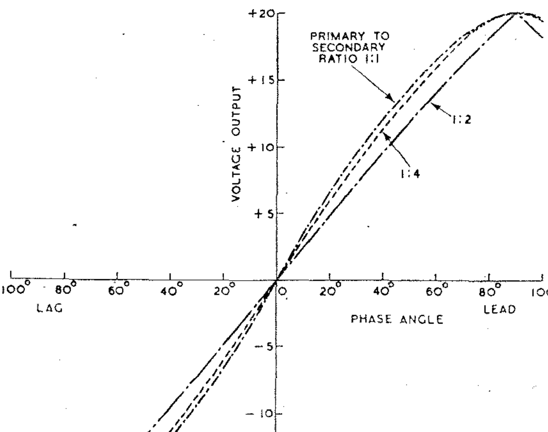


Fig. 5. Basic discriminator phase/output curves for three representative primary to secondary ratios.

Frequency Modulation.—V

to D2 and a small one to D1 results in the voltage across R2 being large while that across R1 is positive and correspondingly small. The output is therefore built up of a small positive voltage across R1, which is swamped by the large negative voltage across R2.

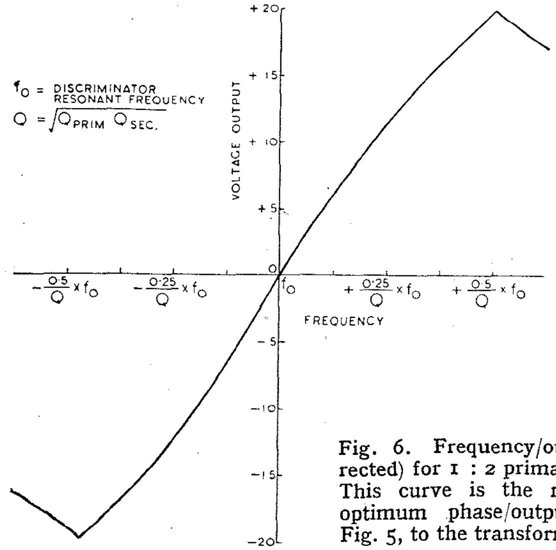


Fig. 6. Frequency/output curve (uncorrected) for 1 : 2 primary to secondary ratio. This curve is the result of adding the optimum phase/output curve shown in Fig. 5, to the transformer's frequency/phase curve.

Conversely an increase in frequency will produce a positive output voltage. The overall frequency to output voltage curve of the discriminator is shown in Fig. 8.

In order to make clear the effect which circuit variations have on the performance of the discriminator, it has been broken down into its three main controlling factors. These factors in order of their importance are: (1) the mean tuned circuit Q; (2) the ratio of primary to secondary voltage (determined by the primary-to-secondary turns ratio); (3) the transformer selectivity curve (as determined by its coupling).

The series of curves which follow demonstrate the contribution made by each of these factors to the overall characteristic.

Transformer Turns Ratio

The three curves drawn in Fig. 5 show the discriminator voltage output plotted against the phase difference between the injected and induced secondary voltages. These curves form the basis of the discriminator characteristic; they show the actual relation between phase shift and output voltage. The first is that obtained with equal primary and secondary signals; it will be noted that this curve and that calculated for a 1 : 4 step-up ratio both depart widely from the ideal straight line response. The third, that for an equal primary and half secondary voltage, approaches very close to the ideal. By employing this turns ratio minimum correction will be required to produce an overall linear characteristic. It can therefore be stated that the optimum primary to secondary turns ratio is that which produces the same voltage across the primary as across the half secondary (*i.e.*, an approximate ratio of 1 : 2 between the primary and full secondary turns).

It should be noted that fairly good results can be obtained with any reasonable turns ratio. If, however, a ratio of other than 1 : 2 is used the extra correction which has to be provided by other discriminator variables is larger than it need be. The amount by which the response is liable to vary throughout a production run is therefore unnecessarily increased.

Effect of Q

The curve shown in Fig. 6 combines the optimum phase-change to output curve (Fig. 5) with the transformer's frequency-change to phase-change curve. As the phase shifts of the primary and secondary are directly additive, this curve has the same shape as the universal phase angle curve shown in Fig. 2. The only alteration is that the phase shift scale has now to be multiplied by two. That portion of the universal phase shift curve between 0 and ± 45 deg. (with its scale doubled to read 0 to 90 deg.) is therefore added to the optimum phase change to output curve (Fig. 5). The result, which takes the form of the uncorrected discriminator frequency to output curve is shown in Fig. 6.

It should be noted at this point that the shape of the frequency-to phase angle curve (Fig. 2) is nc materially altered by any reasonable changes in transformer coupling. The 90 deg. lag mentioned earlier, between primary and secondary, is added to a further 90 deg. lag between the energy transferred back from the secondary to the primary. This reflected energy balances out part of the primary energy and in so doing produces the familiar double humped response curve. It does not, however, greatly affect the shape of the frequency to phase change curve for either primary or secondary.

As pointed out earlier the circuit Q controls the frequency band over which any given change of phase angle occurs. The value of Q selected should therefore be such that a ± 40 deg. phase change occupies a frequency band comfortably in excess of the FM swing it is desired to demodulate. This

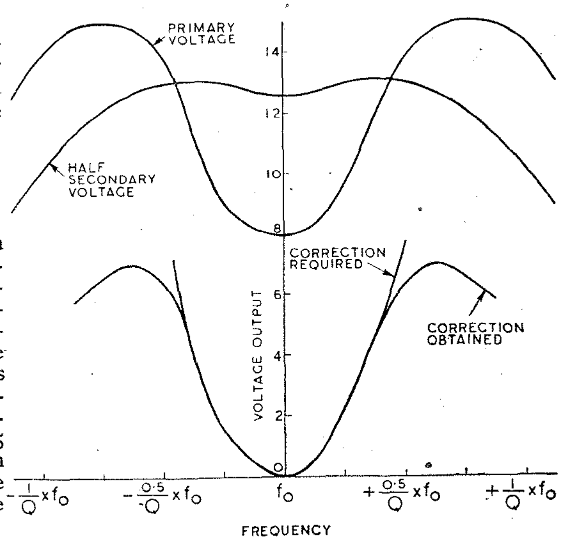


Fig. 7. Correction curve giving the voltage necessary to correct for the non-linearity of the basic frequency/output curve shown in Fig. 6. This compensation is obtained with a transformer coupling 1.5 times critical which gives the double humped response curves shown.

is necessary in order to cover slight mistuning and transmitter overmodulation.

Effect of Coupling

There is only one further variable to be taken into account before the final characteristic can be drawn. The curves so far developed have

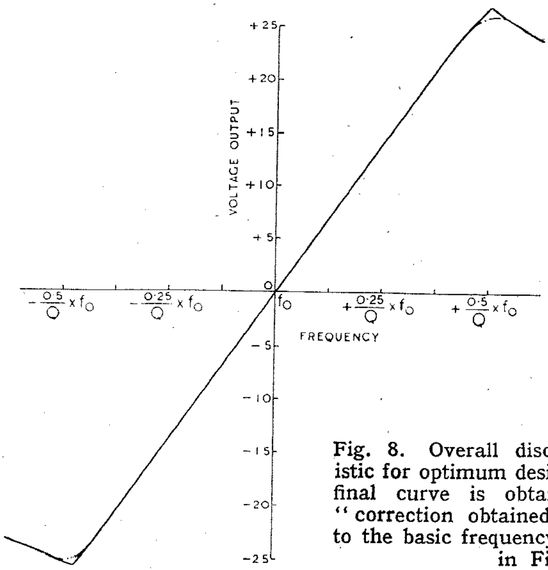


Fig. 8. Overall discriminator characteristic for optimum design throughout. This final curve is obtained by adding the "correction obtained" shown in Fig. 7, to the basic frequency/output curve shown in Fig. 6.

all assumed a constant input voltage over the frequency band. While it is unnecessary to consider the IF response proper, as it is blanketed by the limiter stage, it is very necessary to take into account the response of the discriminator transformer itself. This remark should not be taken to mean that the IF response is unimportant. The amplitude changes caused by a bad IF response will not directly affect the output tage, but the phase changes ch accompany them may wreck the receiver performance.

As the basic frequency to output curve (Fig. 6) invariably departs from the limiter characteristic required, the discriminator transformer "amplitude" response, which so far has not been considered, must be made to provide the necessary correction. This is obtained by producing a double-humped response curve. In practice, therefore, the discriminator transformer is always overcoupled.

The frequency to output curve shown in Fig. 6 is some 20 to 25 per cent. down on a strictly linear output. The actual error over the frequency band is shown in the form of a "correction required" curve in Fig. 7. By overcoupling it is possible to provide almost exactly the correction voltage required. The curves shown in Fig. 7 for primary and secondary response are obtained with a coefficient of coupling which is 1.5 times critical. Unlike the normal IF transformer the most important curve is that of the primary. Although the secondary curve shows some double humping it is the primary which is the more important. The correction provided by the combined primary and half secondary response curves is also shown in Fig. 7. The closeness with which it corresponds to the correction required should be noted.

Overall Characteristic

The overall discriminator characteristic for optimum design throughout is shown in Fig. 8. This curve is produced by the addition of the "correction obtained" curve in Fig. 7 to the frequency to output curve shown in Fig. 6. It should be noted that the strictly linear part of the curve extends over a band corresponding to approximately ± 40 degrees phase shift on the universal phase angle curve shown in Fig. 2. The windings must therefore be resistance damped to bring their Q down so that a ± 40 deg. phase shift occurs over the frequency band occupied by the maximum FM swing it is desired to demodulate.

All the features exhibited in this optimum curve have previously been shown in various characteristics published from time to time. There have, however, been very few curves published which demonstrate an optimum design. Such curves will in practice have slightly rounded extremities as shown by the dotted lines in Fig. 8.

The condenser C2, the RF choke and R1 and R2 are all uncritical.

The maximum output voltage from the discriminator is almost double that supplied by the limiter stage. In practice it is between 20 and 60 volts, depending on the operating conditions of the limiter valve. This large discriminator out put undoubtedly reduces the difficulties normally encountered in the audio amplifier, and at the same time it materially assists in securing the high fidelity reproduction which is one of the main claims made for FM.

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MISUSE OF VALVES

Code of Practice for the Guidance of Inexperienced Designers

WITH the growing use of valves in heavy engineering equipment and other "non-radio" applications, cases of failure are being reported from causes which could have been avoided if the responsible designer had realised that valves are not always miraculous fool-proof devices. Many are highly individualistic types whose idiosyncrasies must be studied and allowed for if the valves are to function reliably and without fuss.

To help newcomers to avoid the grosser errors which might result in valve failure, the British Radio Valve Manufacturers' Association has drawn up a code of practice covering such points as method of mounting, provision of ventilation, heater voltage regulation, heater-cathode insulation, control, screen and suppressor grid voltages and their method of application. Although most of the precautions indicated will be observed as a matter of course by radio designers, some may be new and there are a number of details, such as heater-cathode potential difference, maximum glass temperatures and permissible percentage heater voltage variation, the values of which may have slipped the memory.

The British Standards Institution has endorsed the code as a War Emergency British Standard and has issued it in the form of a leaflet (B.S.1106 : 1943) which may be obtained from the B.S.I., 28, Victoria Street, London, S.W.1, and for which a charge of 1s. is made.

Electromagnetic Fields in Radio—IV.

STATIONARY WAVES AND VELOCITIES OF TRAVEL

By
MARTIN JOHNSON,
D.Sc.

THROUGHOUT these articles we have been developing the single principle that radio transmission can be understood in terms of an electric field and a magnetic field mutually generating each other: the condition that they should do so emerged from experiments with electron beams, interpreted through a vector notation, and was summed up in a simplified treatment of Maxwell's equations. This condition required the two fields to move together with a unique velocity which is also the ratio between electrostatic and electromagnetic systems of measurement.

Two practical questions obviously call for attention: first, what proof is there that free-space radio transmission has this velocity which was theoretically related to a system of units?; second, what happens if the waves are confined to an enclosed region, or are "tied" to a conductor such as an aerial? The two questions are closely related, since the velocity of "travelling" waves can be inferred from measurements upon "stationary" waves. The modern use of the latter in UHF resonators, as well as the need to understand aerials and transmission lines, makes the turning of our previous "free-space" waves into "stationary waves by reflection" an urgent necessity.

Nodes and Antinodes at the Reflection of a Wave.—When a radio experimenter is ordered to confine his radiation within the interior of a closed building to avoid interfering with outside receivers, what happens to his travelling fields? Are they absorbed by, or are they reflected from, the walls? One possibility is seen when his deliberate shielding confines his moving electric and magnetic vectors to the interior of a box which becomes a region filled with "stationary waves": for very short waves, not more than a metre in length, the "box" may fit the wave pattern precisely and become the "closed resonator" which dominates modern UHF technique. An intermediate instance occurs in the coaxial feeders of short-wave sets, where the fields are confined in all directions but the far end at which they are allowed to emerge. An ordinary aerial is in this sense an unscreened transmission line, and may be the seat of a system of stationary waves.

Quantitative tracing of all these possibilities involves solving Maxwell's equations with particular "boundary conditions," that is to say, with conditions inserted to denote what happens to our E and H vectors at a discontinuity between air and metal or between one dielectric and another. Since we showed that Maxwell's equations can be solved in terms of a wave mechanism, we shall be able to see how travelling waves give rise to stationary waves by imagining how the amplitude of an E wave or an H wave behaves at any such boundary.

Suppose, then, that the radio wave, in which electric field vector E and magnetic field vector H are mutually perpendicular, strikes a copper plate across its track. Very little energy penetrates and most is reflected; but, since the conductor cannot maintain a large difference of potential along its low resistance face, the wave pattern adjusts itself so that E becomes zero at the metal surface. Now a property which we emphasised in the moving wave was that E and H are in phase, the maxima of each of them occurring at the same distance measured along the direction of travel. We therefore find a first distinction between stationary waves formed in front of a reflecting surface and the freely travelling waves in space: in the former E and H have lost their phase agreement. For the low resistance along the face of the conducting barrier, which made E zero there, makes this into a place of maximum current flow, and hence maximum amplitude in the H accompanying the current. The places in the wave pattern where amplitudes are zero are called nodes, and the places of maximum amplitude are the antinodes. This terminology is the same also for sound waves and other mechanical periodic patterns.

Before illustrating in Fig. 1 the way nodes of E fit antinodes of H instead of agreeing in phase, for stationary waves, let us return to the equations of simple waves derived from the foundations of such ideas in the preceding article: slight modification of these will serve to show the phase change and also why the pattern has become stationary instead of progressive.

Forward and Backward Waves.—By picturing the generation of vibrations from circular motion we showed that the pattern of any vectorial quantity such as E or H was represented along a distance x by an amplitude equal to $r \sin \frac{2\pi x}{\lambda}$ at any instant, and that a similar diagram represented the pattern at a given spot changing as time goes on, the corresponding function being $r \sin \frac{2\pi t}{T}$. Here λ is a wavelength, T is time for completion of a whole cycle, and r is the maximum amplitude of the vibration. Since we are concerned with what happens at distances in front of a reflecting plate, we take positive values of x as measured outwards from the plate. The wave approaching the latter is therefore moving in the direction of *diminishing* x. After time t, x must be replaced by $x+vt$ in the wave expression, since the shape of the wave remains constant when its description is transferred to a new reference point at $x=-vt$. Since distance λ is covered in time T, the velocity v is λ/T. The wave approaching the plate is therefore $r \sin \frac{2\pi}{\lambda}\left(x+\frac{\lambda}{T}t\right)$ or $r \sin 2\pi \left(\frac{x}{\lambda}+\frac{t}{T}\right)$. Travel in the opposite direction, or $r \sin 2\pi\left(\frac{x}{\lambda}-\frac{t}{T}\right)$ gives the other wave returning towards *increasing* x if the plate is neither transparent nor absorbing, but reflects the energy back to where it came from. The resulting pattern in front of the plate is the sum of these, and the two sines compound into the following product of the separate x and t terms

$$2r \sin\left(\frac{2\pi x}{\lambda}\right)\cos\left(\frac{2\pi t}{T}\right).$$

Whether or not one is familiar with the purely mathematical steps which turn such an addition into a product, the detail exhibited in this last expression for the amplitude of combined advancing and receding waves is worth noticing, for it shows that at any point at given distance the vibration goes through a complete sequence of values periodically as time goes on, repeating whenever t becomes a multiple of T. But only at certain places (the antinodes) is the full amplitude reached. Indeed at some other places (nodes) it remains permanently zero. Since a sine is zero for angles o, π, 2π, 3π, etc., but is unity for angles $\frac{\pi}{2}$, $\frac{3\pi}{2}$, $\frac{5\pi}{2}$, etc., whereas a cosine is zero for $\frac{\pi}{2}$, etc., and unity for o, π, etc., we see that our expression for the compounded pattern is justifiably "stationary," the maxima and minima occurring at fixed values of x and there being no longer any forward or backward travel. Yet the advancing and receding waves do not neutralise one another, and oscillation still occurs, but "on the spot" instead of "progressively in space." Inserting the above zeros of the sines and cosines, nodes are found at $x=0$, $x=\frac{\lambda}{2}$, etc., and antinodes at $x=\frac{\lambda}{4}$, $x=\frac{3\lambda}{4}$, etc.

This detailed picture is suited to express the behaviour of the E vector, since the metal boundary insisted that no electric intensity could be maintained there. But H has its maximum at the same spot, so in all our H expressions sines are to be replaced by cosines and vice versa, giving the stationary waves of magnetic flux as

$$2r \cos\left(\frac{2\pi x}{\lambda}\right)\sin\left(\frac{2\pi t}{T}\right).$$

This agrees with our earlier remark that the electric and magnetic fields fall out of phase by a quarter period when stationary waves are formed by the reflection. Current nodes therefore occur at $x=\frac{\lambda}{4}$, etc., and current antinodes at $x=0$, etc. Fig. 1 (*a*) shows five instantaneous "snaps" of the electric field in such a stationary system produced by reflection at the left-hand edge of the diagram, the instants being at o, $\frac{1}{8}$ cycle, $\frac{1}{4}$ cycle, $\frac{3}{8}$ cycle, $\frac{1}{2}$ cycle, while Fig. 1 (*b*) shows the state of the magnetic field at the same instants. It must be remembered, of course, that while any flat picture represents E and H in the same plane, one of them must actually be vibrating perpendicularly to the diagram.

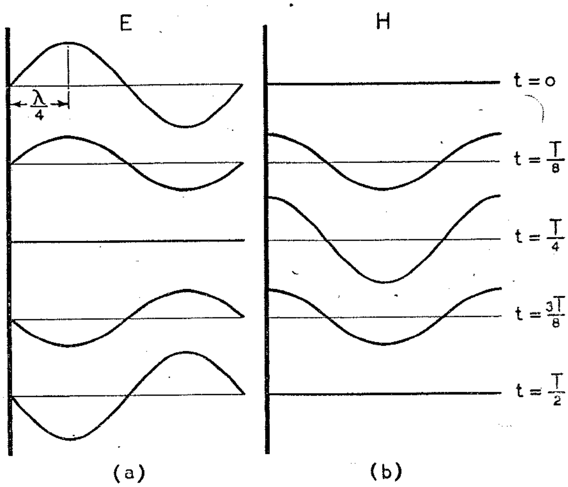


Fig. 1. Instantaneous diagrams of the way in which the amplitude of stationary waves varies with distance from a metallic reflector situated at the left-hand edge of each curve.

Waves on Aerials.—Instead of travelling in free space until the obstacle is met, a wave may be "guided" along a conductor, as in the previous article illustrating the lines of force terminating perpendicularly to a perfect conductor and being distorted along an imperfect one. A fresh kind of discontinuity then arises when the end of this guide is reached. Reflection of the wave again occurs, but at such an insulating termination an electric intensity can be maintained, but the current flow must be zero. Hence this "open" point of reflection will show a node in H and an antinode in E, whereas previously we found the "closed" or "short-circuit" barrier showed a node in E and an antinode in H.

Apart from this exchange in phasing, stationary waves of the pattern already illustrated can occur *along* a conductor such as an aerial just as they occur in front of a conducting barrier. The latter is obviously a plane mirror, but the optical analogy for the aerial is not so simple.

At the grounded end of an aerial the situation may again tend to the E node and current antinode, according to the nature of the earth and its reflecting power and the aerial's length as a fraction or multiple of wavelength. Useful analogy can be drawn from the stationary waves of sound, for instance, in organ pipes; perhaps enough has here been said for the reader to recognise in such and in conventional antenna diagrams the features of phase separation and stationary pattern for which we have been deriving detailed explanation. As discussed by the author in an earlier *Wireless World* series, an aerial as a "transmission line" has an impedance whose matching or mismatching controls the reflections at its ends and hence the stationary waves set up on it; but to digress here into how stationary waves decide when an aerial is a good radiator and when a transmission line is a good feeder would be to trespass from field theory into circuit theory.

Velocity Measurement from Stationary Waves.—We began this article by demanding proof that our theory connecting speed of travelling waves with the ratio of units "c" was confirmed in practice. A pattern of stationary waves such as we have been discussing gives excellent material for velocity measurement, although it does no travelling at all. For there is a universal relation in all wave motion, mechanical or electrical, connecting velocity of travel v, frequency n cycles per unit time, and λ the wavelength, such that $v=n\lambda$. Hence if a pattern of

Electromagnetic Fields—
stationary radio waves, preferably of very short λ, is made to form between two reflector plates and the frequency measured by any electrical meter device, it only becomes necessary to obtain λ in order to infer the velocity with which free waves would travel in that particular medium. This is done by locating antinodes of the E vector, for instance, by the glow of a neon lamp; we showed earlier that these antinodes occur at $\frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$, etc., so that their separation gives the size of $\frac{1}{2}\lambda$.

Velocity Measurement from Travelling Waves.—By different adaptations of the method just described, radio velocity in air has been inferred by many, from Hertz, the earliest "spark" worker, who gave 3×10^{10} cm. per sec., to a recent user of accurate valve generators who claims the greater precision 2.9978×10^{10}. It would satisfy our enjoyment of direct proof to confirm by actual speed measurement instead of relying on frequency and wavelength; but this speed (about 186,000 miles per second) is such that extremely fast shutters are required to interrupt the beam. We want apparatus compact enough to be mechanically movable at comparable speeds, so wavelengths far less than a millimetre are needed to be accurately confined and controlled by such. So we measure the velocity of light, remembering that light and radio waves are precisely similar electromagnetic phenomena differing only in their wavelength and frequency, not their velocity in empty space. It is relevant here to remind ourselves of the range of these wavelengths along the whole electromagnetic spectrum; in radio we descend from thousands of metres to a few centimetres, and certain experimental waves even shorter overlap the heat radiation spectrum which extends from below a millimetre to regions approaching the wavelengths of visible light, say 7×10^{-5} cm. at which the red end of the visible spectrum becomes detectable by eye. We cannot "see" beyond about 4×10^{-5} cm., and the waves pass into the ultraviolet to which photo plates and photo-cells and certain biological structures are sensitive. Between 10^{-6} and 10^{-7} cm. the properties of electromagnetic waves pass into the X-ray region, and finally at about 10^{-9} cm. into the rays from radium and the cosmic rays which appear to come from nuclear atomic reactions in distant parts of the universe. There seem conclusive reasons for thinking that "*c*" is the velocity of all these, so that the easiest to measure, visible light, affords the most accurate refinement in deciding on this universal natural constant, whether obtained by astronomical observation of Jupiter's satellites, for instance, or by some laboratory method.

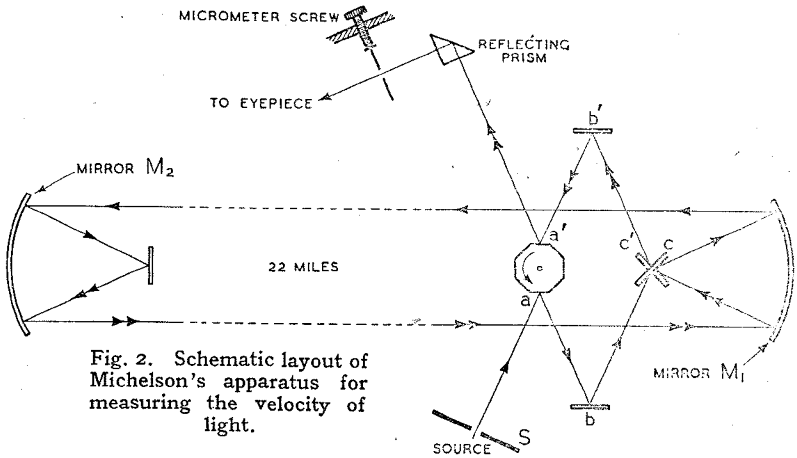


Fig. 2. Schematic layout of Michelson's apparatus for measuring the velocity of light.

We proceed to give one example of the latter. The essence of most such experiments is to revolve a reflector or a toothed wheel, whose serrations form an intermittent "cut-off" or shutter, fast enough for light returning from a measurable distance to find the neighbourhood of its origin altered since setting out, and therefore a shift of focus to be an indication of speed.

In an example of such general procedure, consider Michelson's apparatus of 1926 (Fig. 2). Light from an illuminated slit S is reflected from one face of an octagonal mirror rotating at about 500 revs. per second, and is then reflected at b and c and the large concave mirror M, of 30 feet focus and 2 feet aperture. The light travels thereafter in a parallel beam to another station 22 miles away, whence another concave mirror M_2 and a small flat reflector return it back to M_1. We have indicated by arrows the track of one possible ray only. This is ultimately sent by c′ and b′ to a′, a face of the octagon parallel to the original a, and is observed as an image of the slit S in an eyepiece in front of which a movable aperture is controlled by a micrometer screw. For the image to be visible with a given setting of the micrometer, either the octagonal reflector must be stationary or must be rotating at exactly the speed required for the light after its 44-mile journey to catch the *next* face of the rotating octagon, or the one beyond, in an orientation accurately in the same line as if the original face had remained stationary. The slightest alteration in speed brings imperfect parallelism at the instant light returns, and the micrometer needs adjustment to catch the deviated ray. Using the utmost refinement of distance measurement and of the speed of rotation (by means akin to the standardisation of radio frequencies) hundreds of experiments gave "*c*" as between 2.99756 and 2.99796×10^{10}, after correction, since 0.00067 in these figures is accounted for by the difference between air and vacuum or free space travel.

"c" as Ratio of Electromagnetic and Electrostatic Units.—At the very beginning of these articles on fields we showed that if the electric and magnetic effects moved together at all they could only travel with a speed equal to the ratio between the two ways of detecting electricity, that derived from a force which appears magnetic and that derived from a force which appears electrostatic. Hence if any quantity be measured accurately in these two kinds of unit, there ought to emerge a ratio giving numerically the speed of radio waves, or some close connection such as the square of "*c*." A simple example has been to measure *electromagnetically* the charge on a condenser whose capacity in *electrostatic* units is accurately calculable.

This latter, which we denote by C_e, can be computed as $kA/4\pi d$, where A is area of plates, k dielectric constant, and d the separation between plates. A cylindrical condenser with guard-rings to avoid " edge errors " is perhaps the best to use. To determine C_m, on the other hand, the capacity in electro magnetic units, recollect that a quantity of charge (which is the capacity multiplied by the voltage) can be estimated through the sudden kick θ of a ballistic (or impulse-recording) galvanometer. If the strength of the field magnet of this instrument is H, the area of its coil A, its natural period of swing T, the discharge of the condenser through it after applying voltage V gives $C_mV = \frac{GT}{2\pi AH}\theta$, in which G is a constant depending on the calibration of the particular galvanometer. This may be fixed by observing the steady deflection θ_1 when a fraction of V, say V/n, drives a current through a high resistance R, so that $G\theta_1 = \frac{AHV}{nR}$. Hence $C_m = \frac{T}{2\pi nR}\cdot\frac{\theta}{\theta_1}$. The earliest determination of C_e/C_m, which, since capacity involves a square of fundamental quantities, involves the square of " c," yielded a velocity 2.995×10^{10}. A more recent measurement with modern refinements gave 2.99781. Agreement with the various velocities we have quoted is so close that the identification of radio speed with ratio of units becomes sure.

Group Velocity, Phase Velocity and " c " as Limit to all Speeds.—We commented in the previous article on the wide significance of " c " as a velocity of all " free space " radiation, and as a limiting speed which the fastest " material bodies " (β-ray electrons from radium) can only approach but never exceed or even equal. This natural constant is so remarkable a feature of electrical phenomena that we make no apology for having stressed its derivation and measurement in greater detail than is customary among its daily utilisers in radio; it is, in some way not yet understood, a basic property of our ability to make any scientific or technical measurements at all, since all signals and information whatever are limited to this speed, including sight.

Our next problem is the diminution of this velocity when any material is substituted for the free space. We already met this in correcting velocity from air to vacuum standards. In the dielectrics of our condensers, or in the ionosphere, or in a RF coil exhibiting the " skin effect " the retardation of electromagnetic waves becomes of great practical importance.

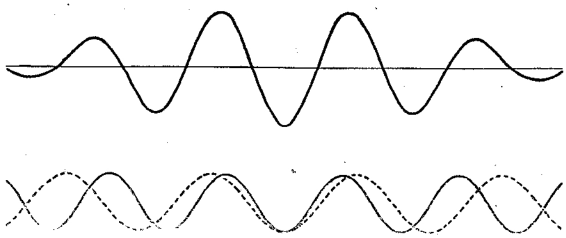


Fig. 3. Analysis of a wave group into two sine waves of slightly differing wavelength. If their speeds are not identical, the group centred at the point where the two reinforce each other will travel at a speed differing from that of either wave.

Before starting on this problem it will be worth mentioning briefly the source of various objections to " c " as limit, commonly raised by any enquiring mind faced with this apparently arbitrary barrier to indefinite speeds. Most of these objections refer only to our possibility of imagining higher speeds which would, however, not possess the property we associated with the Poynting vector, that of carrying energy. For example, imagine ourselves swinging a radio beam which reached from here to the stars—the distant end could swing as rapidly as we please if it were far enough away, since the linear velocity at the tip of a rotating radius is proportional to the length of that radius. But the Poynting flux of energy would still be only *along* the beam and limited to " c " in that direction.

Again, a " group " velocity may either exceed or be exceeded by a " phase " velocity, and it is only the former that carries the energy in radio and is what we actually measure in the velocity experiments. In any " dispersive " material, that is to say one where a mixture of wavelengths have differing speeds imposed on them by the material itself, the total disturbance may be regarded as made up of many superposed sine terms, and some phase velocity characterises each of those components. The group velocity gives the speed of the point at which all the waves reinforce each other, and the speed at which the characteristic shape of the resulting group must travel. In empty space, and very nearly so in air, all the velocities in electromagnetism are the same " c," but where mechanical or electrical waves move through denser material it is by no means impossible for a medium to impose conditions in which the phase velocity of the sine components may fall below that of the group. This happens in certain fluids and in some vibrating metal specimens. On the other hand, in watching ripple crests on a pond emerging behind and dying out in front of an advancing group we see the group velocity less than that of the individual waves.

Fig. 3 shows the simplest case of a group analysed into two sine waves only, of differing wavelength. If their speeds are not quite the same, the point of reinforcement will travel differently from either wave. For electromagnetic waves we have no means whatever of observing the separate waves, so the practical velocity is always that of the group, the reception of energy being in every case what we detect and measure in obtaining the constant " c " or its diminished magnitude in various materials.

" AMPLITUDE MODULATION UP TO DATE "

It has been pointed out that in the above article in our March issue the impression may have been given that extended positive-peak operation was one of the advantages given by cathode modulation. Actually, the remarks on extended positive-peak operation, starting p. 656, col. 2, " It is also claimed that by its use . . . ," apply to normal anode modulation, though the principle could be adapted to give a higher normal idling efficiency in a grid- or cathode-modulated stage.

The misunderstanding has arisen as the result of condensing the original text in preparing it for the printer.

WORLD OF WIRELESS

WHY "E" AND "F" LAYERS?

SIR EDWARD APPLETON'S lecture on the "Exploration of the Ionosphere" before the Wireless Section of the Institution of Electrical Engineers on April 7th was a masterly exposition of progress during the past eleven years in this particular field of research. As Sir Stanley Angwin remarked, "He made the language of the physicist understandable by the engineer."

Sir Edward stated that he had recently received a letter from Dr. Dellinger, the American physicist, asking what was the reason for labelling the layers of the ionosphere "E" and "F." To this he had replied that when he discovered the E layer he gave it this designation, as it left other letters below, as well as above, for the labelling of further discoveries!

RATIONALISED RADIO

REPRESENTATIVES of six of the leading radio manufacturers recently paid a three-day visit to a training centre of Royal Signals, with a view to rationalising the radio requirements of the Army. For manufacturers personally to investigate the Army's requirements is an innovation; previously the Army's needs have been investigated mainly by experts of the Ministry of Supply, and their findings conveyed to the manufacturers.

The long-term policy is to reduce the number of types of sets used in the Army, while covering the extended range of requirements. This will mean a considerable reduction in the number of spares carried by a unit.

It is learned from the Ministry of Supply that close co-operation exists between technicians in this country and in the United States and Canada "with a view ultimately to the rationalisation of production on an inter-Allied basis."

SETS AND COMPONENTS

OF the 125,000 receivers which were in process of manufacture in April, 1942, 65,000 had been made available by December 31st. This fact was recently made known by the President of the Board of Trade in reply to a question in the House of Commons.

He also stated that there were 125,000 sets in process of manufacture on January 1st this year, and he hoped these would be completed and released at the same rate as last year.

Asked whether he would make valves and spare parts for receivers more easily available, Mr. Dalton stated that in addition to the imports of valves from America the production of valves in this country for civilian sets was very considerable. As regards components, the principal difficulty had been with electrolytic condensers, but steps have already been taken to increase the production of these.

R.M.A. REPORT

PROVISIONAL specifications and circuit diagrams for a battery and a mains utility set have been prepared by the Radio Manufacturers' Association in consultation with the B.B.C. The sets call for the minimum of materials in short supply, and utilise valves and components in common production for the Services. These facts are revealed in the recently published annual report of the R.M.A., from which it is also learned that "it has been no part of the policy of the R.M.A. to press for civilian radio production. A decision as to the necessity and extent of manufacture for civilian purposes can only be made by the Government."

Civilian receiver sales for last year are reported to be 20,795 for export (value £178,598) and 107,317 for home use (value £1,226,887).

S. R. Mullard, M.B.E., M.I.E.E., the new president of the R.M.A.

The difficulties of the retail trade in handling receiver repairs is dealt with in the report. An enquiry in February, 1942, revealed that 10 per cent. of the country's 8,600,000 odd licensed receivers were not in use; half of these were awaiting repair, the other half being short of some part which was not likely to be available in the near future. Some 240,000 repairs were being accepted each month by the 4,000 retailers from whom these details were received. The repairs were being undertaken by 3,260 skilled and 2,160 semi-skilled employees.

The shortage of components and accessories is stated to have been a considerable impediment in the execution of repairs, but was not considered to be the major cause.

RADIO OFFICERS HONOURED

THE enterprise, skill, and perseverance of the First Radio Officer of a torpedoed merchant vessel in restoring to working order the lifeboat's oil-covered transmitter resulted in the securing of assistance and the rescue of forty-two persons.

For his outstanding resource and energy throughout, First Radio Officer Arthur M. Arthurs was made a Member of the Order of the British Empire.

Lloyd's War Medal for bravery at sea was recently awarded to Chief Radio Officer G. W. Jennings, who, when his ship was torpedoed and set on fire and so badly damaged that she was abandoned, remained in the wireless cabin to the last to make certain that his distress signals had been received.

Twenty-four hours after being landed Mr. Jennings heard that another ship needed a Chief Radio Officer and at once volunteered.

AIRCRAFT RADIO OFFICERS

AN agreement has recently been concluded between British Overseas Airways Corporation and the Radio Officers' Union regarding the terms and conditions of service of radio officers employed by the Corporation.

The standard annual rates of basic pay to Third Radio Officers is £300, for Second Radio Officers from £325 to £450, and for First Radio Officers from £450 to £550. Annual increments at the rate of £25 are payable to Second and First Radio Officers until the maximum salary appropriate to the grade is attained.

Officers employed in connection with flights or services operating between the United Kingdom and countries outside Europe, or whilst posted to a base outside the United Kingdom, receive additional oversea pay. If engaged on trans-oceanic routes between the Americas and Africa or Europe, additional trans-oceanic pay at the following annual rates will be received: Third Officer £150, Second Officer £175, First Officer £200.

Uniform is provided by the Corporation.

THE LATE R. W. PAUL

WE record, with regret, the death of Robert William Paul, the well-known electrical instrument maker, at the age of 73. He started business as an instrument maker in Hatton Garden, London, in 1891. His firm amalgamated with the Cambridge Scientific Instrument Company in 1919, under the title of the Cambridge and Paul Instrument Company, now the Cambridge Instrument Company. Mr. Paul was a member of the I.E.E., and a past vice-president of the Physical Society. In 1938 he was awarded the Duddell medal.

His name will always be associated with the unipivot galvanometer which he produced in 1903. Older readers of *Wireless World* will recall that Mr. Paul was also interested in the development of loud speakers and contributed to the pages of this journal on the subject. He was also one of the pioneers of cinematography, having developed in 1895 a method of projecting moving pictures.

Mr. Paul's versatility is further demonstrated by his production, in collaboration with the late Sir William Bragg, of the Bragg-Paul pulsator, to aid breathing in cases of respiratory paralysis.

DF PIONEER

NEWS has recently been received of the death in January of Dr. Ettore Bellini, who, in collaboration with Commandant A. Tosi, produced the Bellini-Tosi system of direction finding. The system, which employs fixed aerials in conjunction with a goniometer having a rotating search coil, was widely used in the Marconi Company's DF gear. Bellini, who was an electrical engineer in the Italian Navy, filed a patent as long ago as 1907 for "sense" finding, or the avoidance of 180-degree ambiguity.

"MUSIC WHILE YOU WORK"

THE Court of Appeal has upheld the recent decision of Mr. Justice Bennett that the relaying of music to factory workers is a public performance and constitutes an infringement of the rights of the Performing Right Society in any broadcast music of which the Society holds the copyright.

Licences for the relaying of music in factories, whether provided by gramophone records or the B.B.C.'s broadcast transmissions, must be obtained from the Society. The fee is calculated at the rate of 1d. per worker per annum for an hour's music a day.

The fact that the B.B.C. has a comprehensive fee for its transmissions of music does not alter the situation. Its licence is "for domestic and private use only."

BRIT. I.R.E. HOUSE-WARMING

THE new headquarters of the British Institution of Radio Engineers, 9, Bedford Square, London, W.C.1, were officially opened on March 30th. The guests, among whom were included many prominent personalities in the world of wireless, were received by the president, Sir Louis Sterling. After outlining the aims and objects of the Institution the general secretary, Graham D. Clifford, spoke of the possibilities of extending its activities to cover all English-speaking countries.

B.B.C. SHORT-WAVE NETWORKS

RECENT changes in the schedules of the B.B.C.'s short-wave transmissions makes this an opportune moment to give some details of the organisation of the various Services.

There are two main Divisions responsible for the transmissions radiated to countries oversea; these are the Overseas and Empire Services. Each of these Services is sub-divided, for programme purposes, into coloured "networks," which have been defined as "an association of a particular suite of studios, a variable group of transmitters, and the chain of equipment and telephone lines connecting the two."

Three networks carry the programmes of the Oversea Service to the Empire and to English-speaking peoples oversea. These are:—

Red Network: Broadcasts in English to the Empire and to the U.S.A.

Green Network: Broadcasts in English to the British Forces oversea and also broadcasts in Empire and Far-Eastern tongues.

Purple Network: At present limited to broadcasts in Afrikaans.

The European Service is divided into four networks—brown, blue, yellow, and grey—each of which is directed to a specified group of countries.

While the present issue of *Wireless World* is current, the following schedule of the times (BDST) of the B.B.C.'s short-wave transmissions of news in English and the wavelengths on which these are radiated will be operative.

0306: 25.68, 30.53, 31.32, 48.43, 49.10.
0445: 25.68, 30.53, 30.96, 31.32, 41.96, 42.13, 42.46, 48.43.
0630: 25.68, 30.53, 30.96, 31.32, 42.13, 48.43, 49.10.
0815: 19.82, 25.53, 25.68, 30.53, 31.25, 31.55, 42.13.
0930: 16.84, 19.50, 19.82, 25.53, 25.68, 30.53, 31.55, 42.13.
1000: 30.96, 31.25, 31.32, 31.75, 31.88, 41.01, 41.75, 41.96, 49.42, 49.59.
1300 & 1500: 13.97, 16.64, 16.79, 16.84, 19.42, 19.50, 19.82, 25.53, 25.68.
1700: 13.97, 16.64, 16.79, 16.84, 19.42, 19.82, 25.68, 31.55.
1800: 16.59, 16.64, 16.84, 19.50, 19.66, 25.53, 25.68.
2000: 16.84, 19.50, 19.66, 25.29, 25.53.
2245: 19.66, 25.53, 25.68, 30.96, 31.25, 31.88, 41.49, 49.92.
2345*: 25.53, 25.68, 30.53, 31.32.
* Sundays excepted.

The morse transmissions of news in English, German, and French are now radiated at 0230, 0300, and 0330 (BDST) respectively in the 49-metre band.

TEACHING RADIO

THE aim of the Convention of University Radio Teachers, opened by Sir Stafford Cripps, Chairman of the Radio Board, on April 10th, was to give those present, by direct contact with members of the Services, a better idea of the tasks their students will have to perform when their training is complete.

Sir Stafford stated that "We were met with a clear insufficiency of scientific personnel when this great expansion of the manufacture and use of wireless took place." He referred

The World of Wireless—

to the distinguished work in organising the recruiting and training of personnel done by the Wireless Personnel Committee of the Radio Board.

He paid tribute to the work of the technical colleges in training very large numbers of radio mechanics for the Services, and to the Universities for the training of the more highly skilled scientists, officers, research workers and development engineers.

In conclusion, Sir Stafford laid considerable stress on the need for the scientist and technician to be prepared to tackle post-war problems.

MAGNETIC MATERIALS

AN informal discussion on "Modern Magnetic Materials" was opened jointly by G. A. V. Sowter, B.Sc., M.I.E.E., and A. J. Tyrrell, A.M.I.E.E., at the meeting of the British Institution of Radio Engineers on March 26th. This discussion was in place of the previously announced paper on "Selective Methods in Radio Reception."

Mr. Sowter described a new alloy which, while possessing excellent magnetic properties, was composed entirely of non-magnetic materials. A permanent magnet "pot" just over an inch in diameter was exhibited, for which it was claimed that a speaker fitted with it would handle an output of two watts.

I.R.E. MEDAL OF HONOUR

"FOR his achievement in the development of modern electronics, including its application to radio-telephony, and for his contribution to the welfare and work of the [American] Institute of Radio Engineers," Dr. William Wilson has been awarded the I.R.E. Medal of Honour.

After periods of research in electronic physics at Manchester, Cambridge, Giessen and Toronto Universities, he undertook research work in industry, and since 1914 has been with the Western Electric Company and the Bell Telephone Laboratories.

Dr. Wilson was born in Preston in 1887 and received his D.Sc. degree from Manchester University in 1913.

CHANTING MORSE

A.T.S. trainees for the latest branch of Royal Signals to be opened to them—that of Operator Wireless and Line (OWLS)—are taught morse by a system of chanting—"dit dah, A." They do not see a printed morse symbol, their training being entirely oral.

To simulate actual working conditions, trainees are grouped in networks of three "stations" for practice handling of traffic. By means of a test board an overseer can listen to the operators' key work and can cut in on "phone" to correct any shortcomings. Their technical training is very elementary, as they are not expected to undertake more than external running repairs to sets in their charge.

HIRE PURCHASE

THE Hire Purchase (Control) Order, referred to in the March issue, by which the hire purchase of receivers was prohibited, has now been superseded. By a new Order, the Hire Purchase and Credit Sale Agreements (Control) Order, new receivers of the domestic or portable type and hearing aids are now obtainable by hire purchase.

PAUSING FOR BREATH

WHEN addressing the Radio Industries Club, C. O. Stanley, O.B.E., suggested that broadcast receiver manufacturers should, for a few months after the war, produce their pre-war models unchanged. This would give them an opportunity to take stock and plan new productions in the light of existing post-war conditions.

REPAIR AND MAINTENANCE of transmitters and receivers under Service conditions in the desert are simulated for the personnel of the Royal Armoured Corps on arrival in Egypt.

IN BRIEF

French Licence Fees.—Increased licence fees for wireless receivers were introduced in France early this year. The new fees are 25 francs for crystal sets and 175 francs for all other receivers intended for home use. Where sets are installed in halls or other public assembly places the fee is 350 francs. If a charge is made for admission to the hall the fee is doubled.

Rationing Receivers.—Vouchers are now required by Nazis for the purchase of receivers. It is learned from the *U.I.R. Bulletin* that purchase vouchers are granted only for the needs of the Army and civilians who are victims of the war or meet with accidents during their war work.

Radiolocation Pioneer Honoured.—The honorary degree of Doctor of Laws is to be conferred on Sir Robert Watson Watt, pioneer of radiolocation, by the University of St. Andrews.

Royal Engineers.—Although the tl wartime reunion of the Royal Engineei Wireless Association, 1914/1918, held at Newbury, Berkshire, on March 13th was only in "skeleton form" owing to the various restrictions, it was a considerable success. Capt. H. de A. Donisthorpe, the vice-president, was in the chair.

R.M.A.—At the first meeting of the newly elected Council of the Radio Manufacturers' Association, F. B. Duncan, joint general manager of Marconiphone, was appointed chairman, and E. J. Power, managing director of Murphy, vice-chairman.

Institution of Electrical Engineers.—The Wireless Section of the Institution of Electrical Engineers is holding its next meeting at 5.30 on Wednesday, May 5th, when a paper on "The Frequency Synthesiser" will be given by H. J. Finden. The last meeting of the Session will be on May 11th at 5.30, when an informal discussion on "Factors Determining the Choice of Carrier Frequencies for an Improved Television System" will be opened by B. J. Edwards.

Brit. I.R.E.—The date of the April meeting of the British Institution of Radio Engineers has been changed to Friday, April 30th, at 6.30. It is lear that the Institution has been electe full membership of the Parliament… and Scientific Committee.

Quartz Crystals.—The Minister of Supply has appointed a Controller of Quartz Crystals. All communications relating to the supply of quartz crystals should be addressed to the Controller, R. L. Prain, Portland House, Tothill Street, S.W.1. Telephone: Abbey 7788.

Resignation.—We are informed that L. J. Mold has resigned his directorship of Taylor Electrical Instruments.

In the advertisement of C.B. Engineering Company, X.L. Works, Robin Hood Gate, Kingston Vale, S.W.15, which appeared in our April issue, the district was incorrectly given as S.W.19.

The Minister of Supply recently stated that the public had responded magnificently to appeals for salvage in the past, but still more waste paper was needed for essential war purposes; otherwise the needs of everyday life would inevitably be still further curtailed.

Letters to the Editor

Expansion and Distortion • Future of Broadcasting • Transitron Modifications

Contrast Expansion

I HAVE read with considerable interest the correspondence in your columns on contrast expansion and, while heartily supporting the plea for automatic compression at the transmitting or recording end, I must agree with Mr. J. Moir (your March issue) that contrast expansion used with manually controlled orchestral broadcasts and recording is a really worth-while measure, if only for the marked reduction in background noise.

I cannot, however, agree with Messrs. Hughes (January issue) and Moir that contrast expansion must either degrade transient response or increase amplitude distortion of low audio-frequencies. This conclusion is based on the assumption that the "pick-up" and "decline" delays are equal, as is the case with the majority of contrast expansion units, and in my opinion is at the root of the unsatisfactory results experienced by so many people. With this type of equipment the time delays cannot be reduced below about 0.1 second without introducing amplitude distortion, and with this delay transient response is poor, and a reduction in realism results from the loss of the echo at the end of loud passages due to the rapid fall in gain, giving a flat, lifeless performance.

In my own equipment the pick-up and decline delays are adjusted about 0.02 second and 2 seconds respectively, by shunting the resistance in the resistance-capacitance delay circuit with a diode. The delay times are controllable within quite wide limits by suitable choice of component values. It might be thought that a decline delay of 2 seconds would be excessive, but it gives the advantages that "flutter" does not occur during loud staccato passages, and that reverberations are faithfully reproduced. I have not yet heard any musical performance which was adversely affected by this delay.

The results are much superior to those which I obtained with the more normal type of contrast expansion unit, no deterioration in transients or increase in amplitude distortion being audible. Care must be taken to ensure that the low-frequency "thump" generated by the rapid change in gain of the expansion unit is reduced below audibility, but this is not difficult, and should not cause trouble unless a large amount of bass boost is used in the amplifier. It is preferable on this account to arrange that the tone controls precede the expansion unit, the amplifier having a falling characteristic below 100 c/s, this being equalised by the tone control.

In my experience an expansion of only 15-20 db. is required to transform a performance lacking in vigour into one which has all the punch of Toscanini, but an adequate reserve of output must be available for best results.

DAVID T. N. WILLIAMSON.
Edinburgh.

Post-war Broadcasting

AT the British Association conference on "Science and the Citizen" (March 20th-21st), the session on "Radio and the Cinema," which was nominally concerned with the distribution of scientific knowledge through these two media, did in fact cover the whole field of the future of broadcasting. Perhaps this is not surprising when Sir Allen Powell (Chairman of the B.B.C. Board of Governors) was presiding, and Sir Robert Watson Watt was the first speaker, but it would be a pity if, because it was not a technical meeting, technicians overlooked the suggestions made there on technical as well as general policy.

Sir Robert Watson Watt said the listener needed four freedoms: (1) Freedom from interference, (2) freedom from distortion, (3) freedom of choice, (4) freedom from distraction. The first depends on design of equipment; on atmospherics, which can be combated by choice of wavelength; and on man-made static which is a social rather than a technical problem. The second depends on band-width and circuit design. The third requires a large increase in the number of channels, which would be a reversal of the present policy of sacrificing æsthetic values to the economic coverage of wide areas. Coupled with

Letters to the Editor—

the need for a large number of channels, the avoidance of transmission *via* the ionosphere points to the use of much higher frequencies for broadcasting, and a further advantage of this would be the elimination of international difficulties, since these stations would all be of strictly limited range.

Here Sir Robert went farther than most of us would wish, and said that, on the principle that you should never use radio if you can do the job without it, all urban areas (towns of population 5,000 upwards) should have their programmes distributed by wire.

Dr. McClean, in the course of a statement on behalf of the Association of Scientific Workers, suggested that the B.B.C. ought to undertake fundamental scientific research, because it is a very wealthy Corporation; later in the meeting Sir Allen Powell countered this by saying that far from being wealthy, the B.B.C. would be "broke" if it did not receive from the Government an annual grant several times greater than the licence revenue. (The ordinary listener will surely comment on this that if the B.B.C. is spending £10 millions a year on the present "Home" and "Forces" programmes, it's time someone else took over the job; but if most of the money is going on the Overseas propaganda services, it is only right that it should be paid for out of general Government resources, not out of the licence fees.

The idea of having specialist B.B.C. Governors (including one scientist) was opposed by the chairman, and the B.B.C. was criticised for its failure to broadcast talks on scientific subjects.

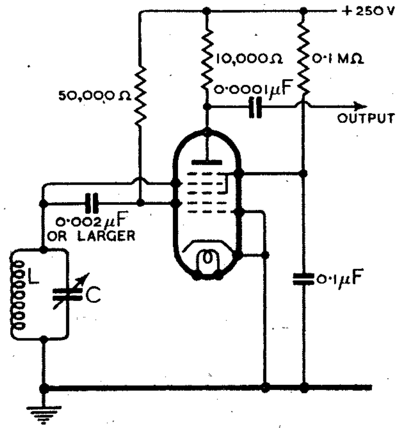
Radio will undoubtedly be important in the post-war world, and I recommend all who are interested in it, whether as an industry, as a social force, or just as entertainment, to look out for any hints such as these from those who are at the head of technical development and B.B.C. policy; otherwise they may lose the chance of putting forward their views before the plans for the future of broadcasting are fixed. D. A. BELL.

London, N.21.

Transitron Oscillators

I WAS very interested in recent *Wireless World* articles on the Transitron Oscillator, as I have been using a similar circuit for some years. However, two important improvements are embodied in my own circuit, shown in the accompanying diagram, which is used for heterodyne frequency meter work.

First, all who have had practical experience of any form of RF oscillator will appreciate the advantages obtained by having one end of the LC circuit at earth potential to both DC and RF. Secondly, one very important feature of the Dow or ECO circuit, as it is commonly employed, is that the output is usually obtained from the anode circuit load, the coupling between this and the frequency determining circuit being *via* the electron stream of the valve. These two important advantages can be embodied in the Transitron oscillator if a heptode valve is substituted for the RF pentode shown by Mr. Chambers. In general, the upper frequency limit of oscillation of the Transitron and similar circuits is limited by the electron transit time, and in the case of the X63 and similar heptodes this limit lies between 30 and 40 megacycles. I have no experience of the limits



Transitron oscillator circuit with heptode valve (Osram X63, American 6A7, etc.)

that may be reached with heptodes especially designed for UHF work.

It may be added that if a resistance is substituted for the LC circuit, it then becomes a current controlled relaxation oscillator, that will oscillate at an audio frequency continuously variable by varying the resistance. If such use is intended it will be advisable to increase the value of the screen-suppressor coupling condenser to, say, 0.1 mfd. in order that the reactance may be small compared to the grid leak resistance to transmit satisfactorily the lowest frequency to be used. The circuit will then work satisfactorily down to a few c/s

E. A. DEDMAN, G2NH

New Malden, Surrey.

"P.M.G. Examinations": Reply to Criticisms

THE principal objection raised by critics of my article is that the pay and prospects of Radio Officers do not justify any increase in the standards of training and examinations. My views are:—

(1) As the equipment on ships becomes more specialised and the fitting of modern equipment becomes general employers will, in their own interests, be obliged to staff the ships with men capable not only of operating, but maintaining such gear.

(2) The present conditions of pay and prospects of Radio

Officers are, in part, due to the ease with which students may be trained and the short time required to reach the P.M.G. examination standard. This results in a permanent surplus of operators in training except in exceptional times, such as the present war.

(3) After the war is over there will be a very large number of men holding special certificates who will wish to continue as Radio Officers and who will need a higher qualification. It is probable that only a small proportion of these men will be required permanently. An immediate increase in the standard would ensure the selection of those best fitted for the work.

(4) Since the war began the pay of Radio Officers has materially increased—exclusive of war risk bonus—and an increase of examination standards may help in retaining this increase.

Mr. Lamb, who writes on behalf of the Radio Officers' Union, does not agree that the present P.M.G. examinations are stereotyped.

He goes on to say that any increase in the technical standard now in force would not materially assist the Radio Officer, since he is first and foremost a telegraphist.

After making the surprising admission—for the R.O.U.—that the chance the Radio Officer has of obtaining a position commensurate with the financial outlay and mental effort entailed in obtaining a certificate of increased standard is doubtful, Mr. Lamb then contradicts his previous criticisms.

He briefly outlines a scheme which in its implications goes much farther than that I suggested.

Mr. Lamb suggests a fourth or extra first-class certificate. This certificate covers advanced radio practice both for marine and shore purposes. It will demand, therefore, a greatly increased standard of basic training apart from the study a Radio Officer will need to do while at sea and at school preparing for the examinations for the various grades of certificates.

No doubt, as Mr. Lamb suggests, some such scheme as that I have suggested will be adopted, and I would like to emphasise the great importance of the basic training courses to men at sea studying alone, and whose time at school is necessarily limited.

WM. M. MOORE.
The Marine School,
South Shields.

ELECTRICAL INDUSTRIES RED CROSS FUND

Wireless Section's Contributions

"HOPE and the Red Cross make life worth living to us here; they are our salvation of mind and body." So writes a sergeant major who is a prisoner of war, and sergeant majors are not notorious as sentimentalists. This sentence not only summarises the efforts made by the Red Cross and St. John Joint War Organisation for prisoners of war, but the word "salvation" crystallises both the urgent need for such efforts and the success that is attending them.

By the provision of regular food parcels to supplement deficiencies of diet, by the despatch of books, games and sports equipment to combat boredom, by arrangements for educational facilities, by its special care for prisoners who are ill or blinded or deaf, the Red Cross has done much to earn such high praise and deep gratitude.

The services to prisoners of war have tended to overshadow the other great responsibilities which rest on the Red Cross and St. John, but as the war develops first one and then another aspect is thrown into relief.

During the heavy air raids in the past the Red Cross amplified the work done by official relief services in every conceivable way, and was instrumental in saving hundreds of lives, bringing thousands back to health, and restoring the faith of hundreds of thousands by little acts of comfort throughout the country. There is still a *Luftwaffe*. The Red Cross must stand prepared.

As for the future, who dare hope for final victory without a heavy increase in Service casualties? The Red Cross must be, and is, ready to supplement basic medical treatment provided by the Forces with comforts for the sick and wounded.

Care for the children, assistance on a vast scale to our allies, particularly Russia, comfort for those who, safe themselves, have husbands or sons missing, prisoners or wounded—how impossible it is briefly to summarise the great task of the Red Cross.

At the time of going to press over £14,000 has been contributed to the Electrical Industries Red Cross Fund. Among recent subscriptions from wireless firms and those with wireless interests are the following:—

COVENANTED SUBSCRIPTIONS

	£	s.
Bush Radio, Chiswick	200	0
Micanite and Insulators Co., London	100	0
Creed and Co., Croydon	100	0
Sun Electrical Co., London	50	0
Radio Gramophone Development Co., Bridgnorth	21	0
Michael Black, Glasgow	10	10

DONATION

	£	s.
Ward and Goldstone, Manchester	50	0

UNBIASED

By

FREE GRID

Remember Southampton

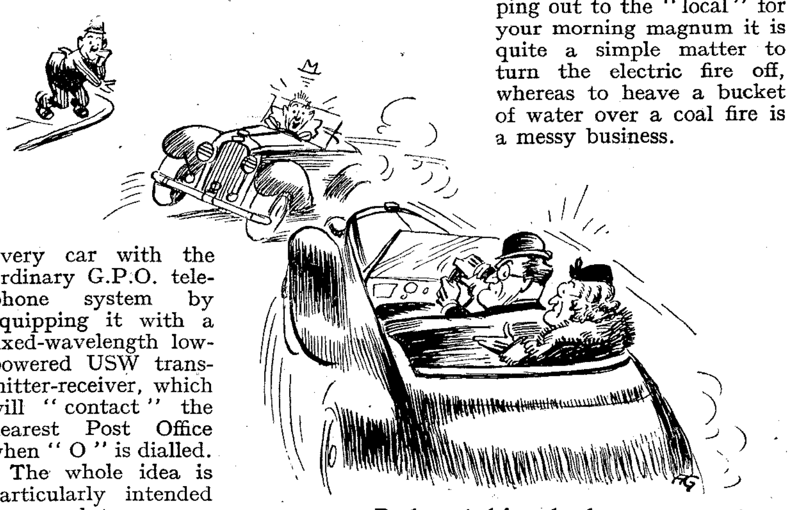
EVEN those of you who confine your reading to the Editorial and Recent Inventions pages of this journal, counting the rest as so much dross, will be aware that proposals have been put forward that the B.B.C. programmes should, after the war, be distributed over the electric mains.

These proposals, which were well ventilated in this journal early in 1942, leave me quite cold, but I must offer a warning to the B.B.C., the P.M.G., and any other would-be Hitlers of the ether. If any attempt is made to force this system on us, and thus compel us to listen to whatever is pumped along the mains, instead of being able to roam the ether at will, the result will be the establishment of highly mobile "bootleg" wireless transmitters in stratospheric aircraft, in order to give the people "freedom programmes."

I raise this matter now as it has come to my ears that a very subtle scheme is being prepared by the panjandrums of Portland Place and the moguls of St. Martins-le-Grand to swing a large proportion of the population over to acceptance of the idea of non-wireless broadcasting. The scheme, which is magnificent in its daring, and Machiavellian in its subtlety, consists of nothing less than the establishment of a multi-wavelength USW station on the roof of every Post Office, and the linking of every car with the ordinary G.P.O. telephone system by equipping it with a fixed-wavelength low-powered USW transmitter-receiver, which will "contact" the nearest Post Office when "O" is dialled.

The whole idea is particularly intended to appeal to women, with their love of ceaseless and senseless chatter, and it would at any rate relieve us unfortunate motorists of the bugbear of back-seat women drivers. They would be far too busy on the 'phone to bother about whether we were driving on the wrong side of the road or cutting in. Since each car would have a channel permanently allotted to it, even the USW part of the spectrum would become uncomfortably crowded with the great increase in cheap motoring after the war, and thus some force would be lent to the argument of the wired wireless protagonists that wireless must be reserved for services where it is impossible to use the "carrier" system.

If the scheme does come into being my first act will be to try to bring the whole thing to a *reductio ad absurdum* by agitating for every pedestrian who desires it to be allocated a personal USW channel and to be supplied with lightweight apparatus in order to link him with the nearest G.P.O. exchange. In any case, the scheme will be defeated as decisively as was the great G.P.O. Southampton conspiracy in 1939.



Back-seat driver bugbear.

A DC Dilemma

ACCORDING to reports which reach me from a confidential source near Whitehall, it appears that users of electrical energy are well to the fore in the matter of fuel saving. There is nothing very extraordinary about this, for, after all, when slipping out to the "local" for your morning magnum it is quite a simple matter to turn the electric fire off, whereas to heave a bucket of water over a coal fire is a messy business.

However, in spite of the fact that electricity users set a good example to the nation, I was greatly puzzled when examining some statistics to find that in certain districts where the supply is DC the consumption of electricity was going up instead of down, and I determined to get at the cause by making a house-to-house call.

After experiencing one or two un-

"On the scent."

fortunate contretemps in which, owing to mistaken identity, old clothes and other salvage were thrust into my arms, so that the scent got on me rather than I on the scent, I retired to the local hostelry in a very low state. By one of those strokes of good fortune which do happen sometimes, I stumbled simultaneously on the explanation of the mystery and some pre-war beer, the latter being served to me by a sympathetic barmaid who said that my appearance reminded her of a favourite uncle, a gravedigger by profession, who had overstrained himself while digging for victory on his allotment.

With such an excellent conversational opening, it was not long before I was on terms of intimacy with the whole bar, which included several *Wireless World* readers, and I soon learned that the cause of the great increase in current consumption this and other DC districts was terrible dearth of DC mains valves. AC valves were, as I knew from personal experience, considerably easier to obtain, with the result that people were simply substituting them in their DC sets and running them in series with an external resistance of large ohmage and amperage, if I may be permitted so to express myself. Certain other adjustments have to be made, of course, but the salient fact is that the heater consumption of each set is increased no less than five times, since AC valves take a full amp. at 4 volts instead of 0.2 amps. at a higher voltage, as do their DC counterparts. Possibly, Major Lloyd George may be interested in this startling fuel leakage and be able to dam it by exerting strong pressure in the right quarter to get a few more DC valves made available.

Wireless World Brains Trust

Radio's Jubilee Year?

Question No. 11.—Who first conceived the idea of using electromagnetic waves as a means of communication? It seems strange that Clerk Maxwell and Hertz who, respectively, postulated mathematically and experimentally proved the existence of the waves, should apparently have had no thoughts on the practical uses—to our generation so obvious—to which their discoveries might be put. J. HARMON.

This seems to be best dealt with as an "open question," as we doubt any of our regular "Brains Trustees" would claim any special knowledge on the dawn of wireless history. Replies for publication are therefore invited from anyone having information on the subject. In the meanwhile, a few notes may be of interest, if only because the question is opportune. Whatever the precise answer may prove to be, it seems highly probable that the practical conception of electro-magnetic wave communication is now almost exactly 50 years old.

WE can find no record that Clerk Maxwell ever expressed any views on the practical uses of electro-magnetic waves. The outlook of Hertz was apparently equally academic; but when a German engineer named Huber suggested in 1889 the use of the waves for telephonic communication, Hertz discouraged the idea on the ground that the telephone would not respond to RF oscillations.

The first prediction of a practical communications application mentioned in G. G. Blake's "History of Radio Telegraphy and Telephony" is credited to Sir William Crookes, the physicist. "In 1892 he wrote an article in the *Fortnightly Review* in which he foreshadowed telegraphic communication from one place to another across free space by means of electro-magnetic waves, and he suggested the possibility of tuning, so that many stations might signal simultaneously. . . ."

Though the name of Nikola Tesla, who died early this year, is primarily linked with projects for the wireless transmission of power, his claims to priority in the field of signalling must also be considered. The American journal *Communications* for January, 1943, in an obituary notice, says of Tesla: "As early as February, 1893, he described a wireless transmitter, in general but nevertheless correct terms, and further stated that 'a properly adjusted self-induction and capacity device could be set in action by resonance at any point within a certain radius of the source.' This, he said, would lead to 'transmitting intelligence, or perhaps power, to any distance through the earth.'" The use of the word "through" may suggest earth-current signalling, but it seems certain that wave telegraphy was intended. In a book published in Belgrade in 1936 to commemorate Tesla's 80th birthday it is stated that he made similar public statements in 1892.

Another claimant to the honour of having early appreciated the practical possibilities of the work of Clerk Maxwell and Hertz is the Russian physicist, Popov. In fact, it is possible (though, according to Ellison Hawks' "Pioneers of Wireless," not conclusively proved) that, in 1895, he was the first to demonstrate true radio-telegraphy. In the same book it is established that in December, 1895, Popov wrote: "I entertain the hope that when my apparatus is perfected it will be applicable to the transmission of signals to a distance."

Just as Tesla's main interest laid in the transmission of power, so Popov was chiefly concerned with the investigation of atmospheric disturbances by means of the coherer with which his name is linked. It is strange that both these pioneers should have followed relatively unprofitable paths when the technique of a much more valuable application of electro-magnetic waves was opening up to them. It is certain that, when Popov's recorded prediction was made, Marconi had for some time been actively engaged in harnessing Hertzian waves to communication. Possibly his aims and aspirations were already on record, but we can trace no published statement. The first Marconi patent application, specifically covering signalling, was filed only some seven months after Popov's statement was made.

RANDOM RADIATIONS

By "DIALLIST"

Radio Waves

THE delightfully simple account of the adventures of radio waves in the ionosphere which T. W. Bennington gave us last month must have appealed to a wide circle of readers. I hope that he will be able later to give his ideas on two very interesting subjects for which he then had no space. The first of these concerns echoes, particularly those of long delay. There must be few short-wave enthusiasts who have not heard radio echoes; perhaps the best known instance before the war was that of the B.B.C.'s 13-metre service, which was a beamed transmission. In many localities in this country this transmission was accompanied by what is known as the "tunnel effect"; the announcer sounded just as though he were speaking in a reverberating tunnel; every syllable had its echo. This echo was undoubtedly due to double reception of the transmission. One heard it first at the end of its short journey from Daventry to one's aerial. Then, having gone round the world, it arrived again about one-seventh of a second later. But the most curious of radio echoes are those of long delay, about which a considerable amount of data was obtained by observers a year or two before the war. I forget now the longest delay that can be vouched for, though I recall that the observation of delays of 25 seconds and more was claimed. Various explanations were put forward, some of them highly improbable. It was, for instance, suggested that waves which had penetrated the reflecting layers and made their way out into space might be turned back to earth by the moon, the sun or some other heavenly body. Echoes of about 2½ seconds' delay were certainly recorded; this fits in with the time needed for the double journey to the moon and back, and the temptation to conclude that the moon was the reflector proved irresistible to some.

Between the Layers?

Attractive as the idea might be at first sight, it would not hold water, for there were far too many echoes whose delay did not fit the time for the return journey to any heavenly body. My own belief is that the waves responsible for these echoes never leave the ionosphere at all. I imagine one part of a transmission reaching the F_1 layer at such an angle that it penetrates it and continues up to the lower surface at F_2. Turned back from there, it arrives at the upper surface of F_1 at such an angle that it bounces upwards again. And so its journey continues, round and round the world between the two F layers, until finally it manages to re-penetrate the lower and come back to earth once more. A longer wave might conceivably make a similar voyage of great length in the space between the upper surface of the Heaviside Layer and the lower of the first Appleton. Or, again, the circling of the globe might take place by a short-wave transmission between the top of F_2 and the bottom of F_3—if there is such a layer. If these processes are possible—and I don't see why they should not be in certain states of ionisation of the reflecting layers—echoes with enormous delays may occur without there being any need for the waves to travel out into space and back again.

Differential Fading

Another interesting problem of wave propagation is that of differential fading. Every short-wave man knows this curious and not very pleasant form of distortion, which is often pronounced in long-distance reception. The proper balance of the audio-frequencies is continually being upset. At one moment certain frequencies are over-emphasised, whilst others practically disappear. At the next these frequencies may be more or less normal, but others are affected. The phenomenon is closely bound up with the fact that when the reflecting surfaces are in a state of disturbance transmissions of different frequencies have different adventures on meeting them. Diversity reception depends on this fact. The receiving apparatus is so designed that it passes to the audio stages only the best received signal at any moment. Various schemes (that of our own G.P.O. will be recalled) were afoot when the war broke out to counteract the fading of carriers by complex kinds of diversity reception; but how we're ever going to devise anything to straighten out differentially fading sidebands, I do not know. I have no doubt that it could be done, but the apparatus required would be of staggering complexity and size.

□ □ □

Those Prophets

THERE must be few articles more enjoyable for the lay journalist to write than the ever-recurring "Science After the War," "Science in Ten Years' Time," and the like. He can let imagination and pen run riot, and the wilder his predictions the more the man-in-the-street will enjoy what he has to say. In the many articles of the kind that I have come across in the last twelve months there are one or two predictions by the seers into the future of applied science that crop up again and again. In fact, they have been made so often now that the public must be coming to regard them almost as certainties. One of them concerns the pocket "personal" wireless set—a kind of midget combination of transmitter and receiver which will enable its owner to call up and communicate with his friends wherever he or they may be. There is nothing improbable about the small transmitter-receiver; it was in existence long before the war. But, "pocket"? Well, that is an elastic term, and, of course, pockets can be of any size, from the little one ought to contain the ticket you n… can find to the variety favoured by poachers and gamekeepers, which can accommodate a hare and a brace of pheasants without being unduly strained. "Vest pocket" should be a more rigid definition of size, but I have known it applied by enthusiastic designers to gadgets that would have needed something more like a haversack to contain them! Anyhow, I do not see any likelihood of genuine pocket transmitter-receivers arriving in the near future—unless some revolutionary invention in radio methods is made.

Exit the Telephone?

Still less do I agree with the possibility of the set which would enable anyone provided with it to call other users or to be called by them. There are certain little problems involved connected with channels. So far as we can see at present it is difficult enough to make the available channels go round amongst broadcasting and commercial stations, whose number is minute compared with that of the potential users of personal sets. I do not think that the telephone's existence is threatened just yet. Incidentally, what would be the equivalent of "number engaged" with the personal set? Can you imagine the state of mind of a personal wireless enthusiast who is being called by half a dozen people at the same time? And there would be no soothing "Sorry you've been trrrroubled."

Not Just Yet

And there is the other old stager about television in every home when peace is with us again. I do not doubt that there will be a huge increase in the number of privately owned television receivers, especially if television programmes become such that everybody wants to enjoy them. But frankly I cannot see the television set being taken, in the near future, out of the luxury class, as was possible with the wireless set at quite an early stage in its development. By the time that broadcasting had begun in this country it was possible to make a crystal receiving set for a very modest outlay. But there is no equivalent for the crystal set in television, whose receiving equipment, so long, at any rate, as we work on present lines, must always require a cathode-ray tube and a comparatively large number of valves. Our manufacturers must have learnt a lot about the mass production of tubes and valves during the war, and no doubt all kinds of new machinery have been installed for the purpose, but I do not see prices coming down all that much. I would be inclined to put the lowest price for a sound-and-vision receiver with a small tube at about £25, and the public showed years ago that it ...s not attracted by small viewing ...ens. On the whole, we can feel fairly safe in prophesying that it will be some little time before the number of television sets in use is as great as the present number of wireless receivers—and the day of television in every home is still farther off than that.

□ □ □

Metres and Yards

HAVE you ever come across one very useful and simple rule of thumb for converting metres into yards? The metre is a yard, plus ten per cent. It works out surprisingly well if you do not need extreme accuracy. For instance, a yard is 36 inches; ten per cent. of 36 is 3.6; 36+3.6 is 39.6 inches. Try it against the other rule for converting kilometres to miles; a kilometre is five-eighths of a mile, or 8 kilometres equal 5 miles. (This, by the way, is a very close approximation, as you can see by comparing the mile and kilometre scales of, say, an inch-to-the-mile map.) Well, according to ...mula No. 1, 8 km=8,000 m.= ...o yards. Working the rest in your head, 5 miles=10 half-miles. Half a mile is 880 yards; 880 x 10= 8,800. Some day, I suppose we will adopt the metric system officially in this country and save ourselves much work and many headaches.

"RADIO WAVES IN THE IONOSPHERE"

THE word "curve," in the 5th line of the 1st paragraph on p. 99 of our April issue, should read "wave."

GOODS FOR EXPORT

The fact that goods made of raw materials in short supply owing to war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export

RECENT INVENTIONS

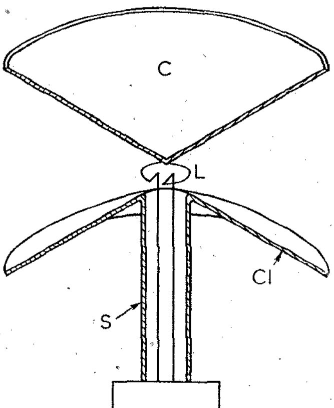
A Selection of the More Interesting Radio Developments

DIRECTIVE AERIALS

Two conical conducting surfaces C, C1 are arranged coaxially with their apices close together. The cones are coupled to a small loop L which is fed from a two-wire transmission line passing up through a tubular screen S connected to the lower cone. The size of the loop L is considerably less than half a wavelength, so that the amplitude and phase of the current it carries are substantially the same at all points.

Under these conditions the waves are guided outwards, as from an "electromagnetic horn," and form a vertically polarised beam which extends uniformly in all directions in the horizontal plane.

Standard Telephones and Cables, Ltd. (Assignees of W. L. Barrow). Convention date (U.S.A.) December 9th, 1939. No. 548,193.



Flat beam radiator.

TUNING BY VOLTAGE CONTROL

The tuning of an oscillatory circuit is varied by the application of a control voltage to the grid of a valve shunted across it, the arrangement being applicable either for phase or frequency modulation, or for the automatic tuning of a superheterodyne receiver.

The control valve includes a screening grid which carries a high positive bias, and an anode at cathode potential.

The anode and cathode are shunted across the circuit to be controlled, whilst the control grid is coupled to it. The input oscillations serve to produce a space-charge, or virtual cathode, between the screening grid and the anode, and this, in turn, induces in the anode a current which is in quadrature with the input and of a magnitude which is determined by a potentiometer adjustment of a DC biasing voltage applied to the control grid.

One branch of the anode circuit is earthed through an impedance, while a parallel branch is coupled to the circuit under control. For frequency modulation the control grid is coupled to the output from a microphone, while for automatic frequency control it is coupled to the output from a discriminator valve.

Sir L. Sterling. Convention date (U.S.A.) April 27th, 1940. No. 548948.

TELEVISION FROM FILMS

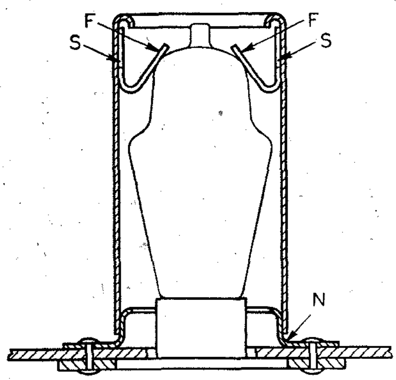
In a television transmitter of the dissector type, the picture is first focused on to a photo-electric cathode, and the resulting electron stream is then moved across a scanning aperture to allow each elementary area to pass in turn on to an electron-multiplier. When such a tube is used for developing television signals from a cinema film, it is found that any irregularity of emission from the surface of the photo-electric cathode becomes very noticeable.

According to the invention this defect is compensated by using a cylindrical lens to distort the image projected from the moving film on to the photo-electric cathode. The resulting electron stream is then scanned through a vertical slit, instead of through the usual square aperture, so that the defective point is "averaged" with all the other points on a transverse elementary strip of the cathode. The effect of the original bad point is therefore toned down or glossed over.

Standard Telephones and Cables, Ltd. (Assignees of H. E. Ives). Convention date (U.S.A.) September 24th, 1940. No. 549890

SCREENING CANS

A screening can is provided with an internal fitting which automatically presses the valve firmly on to its base. The fitting is made from a single strip of metal with, say, four projecting lugs F. The strip is first bent into a circle, and the lugs are horned up to form V-springs as shown. As the can is forced home over the flange N, the fitting slides up against the top lip, and the V-springs hold the valve from vibration.



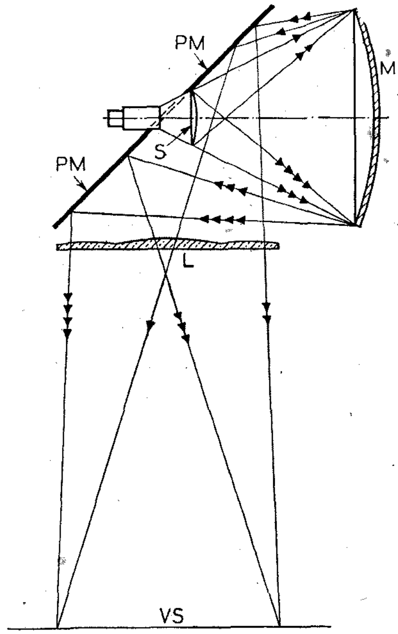
Valve location.

If necessary, the can can be made high enough to screen more completely the top connection of the valve, the holding spring then being anchored against an inside flange formed some distance from the open end. The device is compact, cheap and easy to manufacture.

Standard Telephones and Cables, Ltd.; L. W. Houghton; and S. J. Holdstock. Application date June 11th, 1941. No. 549970.

TELEVISION PROJECTORS

In order to make the most effective use of the light available from the fluorescent screens of a cathode-ray television receiver, it is collected by a concave mirror M which projects it back on to a plane mirror PM having a central aperture in which the fluorescent screen is located. The plane mirror is arranged at such an angle, say 45 deg., that none of the light reflected by it can reach the concave mirror, but passes, as shown by the arrows, directly on to the viewing screen VS.



Large-screen television.

In order to minimise spherical aberration and similar optical troubles, a "correcting" lens L is interposed between the mirror PM and the viewing screen. Various positions of the mirror PM are possible, but an analysis shows that the one in which it is tangential to the upper periphery of the fluorescent screen, as indicated in the drawing, is the most effective.

Philips Lamps, Ltd. (Communicated by N. V. Philips' Gloeilampenfabrieken). Application date January 12th, 1942. No. 548750.

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