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FREQUENCY MODULATION EQUIPMENT

Soon after short waves came into commercial use for long distance telegraphy, it was realised that selective fading took place, and that the effects could be minimised by radiating several frequencies instead of a single one. This was usually done by applying amplitude modulation to the transmitted wave, so producing the normal carrier and side bands. Frequency modulation was also used in a few cases, but in a rather haphazard fashion, as its nature and advantages were not clearly understood. Before describing the apparatus, some theoretical notes may be useful.

Theory of Frequency Modulation.

A GOOD account of the theory of frequency modulation is given in an article by H. Roder, published in the Proceedings of the Institute of Radio Engineers for December, 1931. The notes given below are mainly based on that article.

Fig. 1 represents graphically conditions in an amplitude modulated transmitter. The frequency F of the modulation is represented by $\frac{1}{T}$ and the depth of modulation by $\frac{a_1}{a_0}$. If the modulation envelope is sinusoidal, the emitted frequencies are f_0, the carrier frequency and two side band frequencies $f_0 \pm F$. If the envelope is not sinusoidal as usually happens on I.C.W. there will be a series of side band frequencies $f_0 \pm F, f_0 \pm 2F, f_0 \pm 3F$, etc.

In a similar way, Fig. 2 represents graphically the conditions in a frequency modulated transmitter, the amplitude of oscillation being constant. As before, the frequency F of the modulation is given by $\frac{1}{T}$.

At first sight it might be thought that the emitted radiation would consist of all frequencies between $f_0 + f_1$ and $f_0 - f_1$, but both mathematical analysis and experiment show that it consists of the carrier frequency f_0 and side frequencies $f_0 \pm F, f_0 \pm 2F, f_0 \pm 3F$, etc., the amplitude of these depending in a complicated way on f_1 and F, and on the form of the modulation. For the normal case of sinusoidal modulation where the instantaneous frequency is given by $f_0 + f_1 \sin 2\pi Ft$ these side frequencies have been calculated, and as purely theoretical examples are shown in Fig. 3 for the case of $f_1 = 500$ and various values of F the note frequency.

From this it will be seen that if the note frequency F is large compared with the frequency shift "f_1," the amount of energy in the side bands is small. For a note frequency of 2,000 the amplitude of the first side band is only 10 per cent. that of the carrier, and the energy in each, 1 per cent. of that in the carrier. When $F = 500$ ($\frac{f_1}{F} = 1$) conditions are very different, the amplitude of the first side bands is nearly 58 per cent., which is rather more than that obtained with 100 per cent. amplitude modulation. The higher side band components decrease rapidly in amplitude.

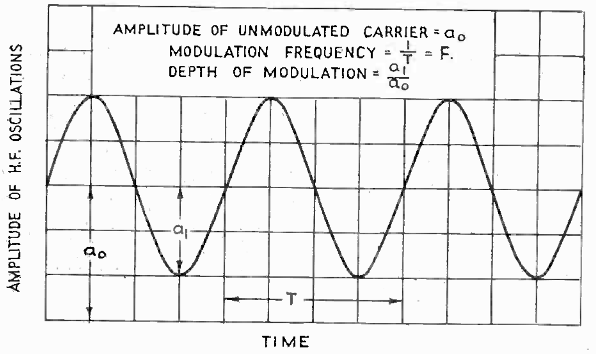

FIG. 1.

When F is much smaller than f_1 a whole series of side bands is produced as in the cases shown for 250 cycles, 100 cycles, and 50 cycles.

In Fig. 4, curves are given showing how the amplitudes of the first three side frequencies depend on the ratio $\frac{f_1}{F}$. From these it can be seen that the modulation ratio (corresponding to "depth of Modulation" in the case of amplitude modulation) can be measured by $\frac{f_1}{F}$ provided that it is not greater than 1 : for it will be seen that this ratio indicates approximately the relative amplitude of carrier and the two main side frequencies ($f_o \pm F$). Thus when $\frac{f_1}{F} = \frac{1}{2}$ the amplitude of each main side frequency is $\frac{1}{4}$. This is the value given by 50 per cent. amplitude modulation ($\frac{a_1}{a_o} = \frac{1}{2}$). As $\frac{f_1}{F}$ approaches 1 this analogy becomes less exact and when $\frac{f_1}{F}$ is greater than 1 complications ensue. Up to $\frac{f_1}{F} = \frac{1}{2}$, equivalent to 50 per cent. modulation only the fundamental side frequency $f_o \pm F$ is important. At $\frac{f_1}{F} = 1$ corresponding to 100 per cent. amplitude modulation, the second side frequencies $f_o \pm 2F$ have become appreciable. The curves indicate clearly that to avoid appreciable side band spread $\frac{f_1}{F}$ should not be much greater than 1.5. They also show that when $\frac{f_1}{F}$ approaches 2, the first side bands have a greater amplitude than the carrier so that more than $\frac{2}{3}$ of the transmitted energy is in the side bands ; whereas with

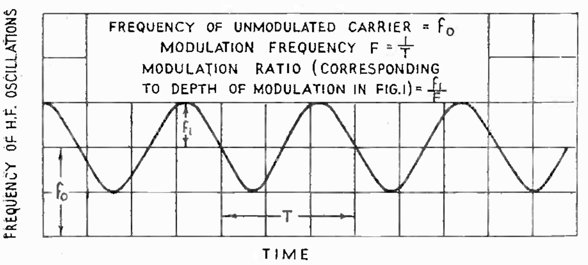

FIG. 2.

100 per cent. amplitude modulation, the amplitude of each side band is only half that of the carrier so that only $\frac{1}{3}$ of the energy is in the side bands. It has been found possible to realise such a condition in practice, the following result being typical :—

Carrier.	0 dB	
1st side band each	+ 2 dB	on carrier level
2nd ,, ,, ,,	— 8 dB	,, ,, ,,
3rd ,, ,, ,,	— 22 dB	,, ,, ,,
4th ,, ,, ,,	— 36 dB	,, ,, ,,

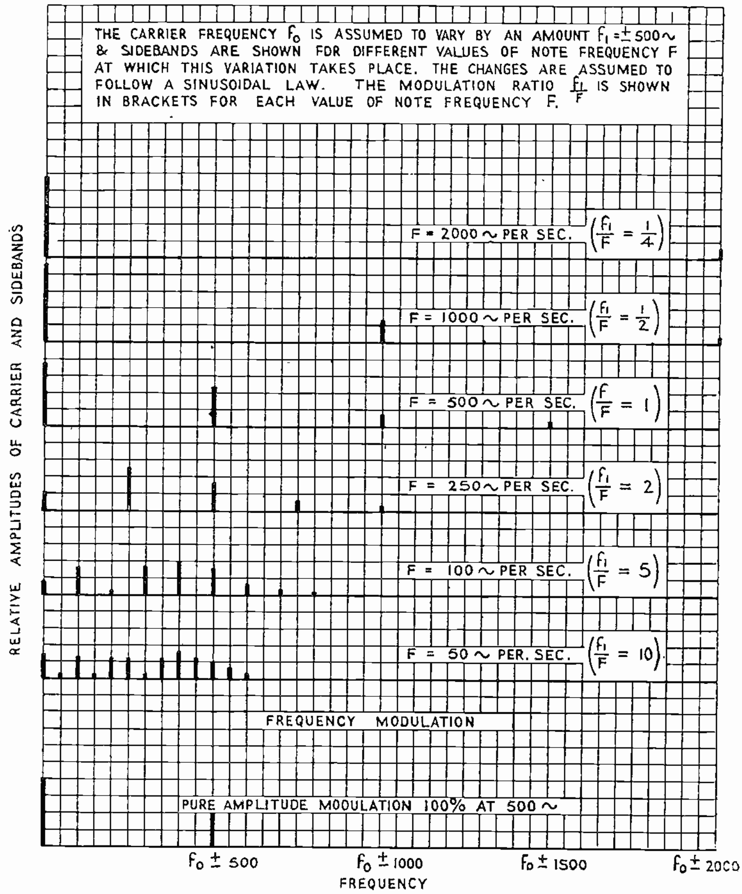

FIG. 3.

The rapid reduction of the higher side bands may be due to the fact that in an actual transmitter the modulation is produced on the master oscillator, and the chain of amplifiers attenuates the higher side bands.

It may seem strange that such large amplitudes of side bands should exist without the presence of amplitude modulation. The explanation lies in the relative phases of carrier and side bands. Fig. 5 "*a*" represents a high frequency wave amplitude modulated 100 per cent. This can be analysed into the unmodulated carrier Fig. 5 "*b*," and the two side frequencies $f_0 \pm F$, which are shown and added together in Fig. 5 "*c*."

Over the period "*b d*," the resultant phase of the modulation component is the same as that of the carrier, whilst over the portion "*d f*" the phase is reversed

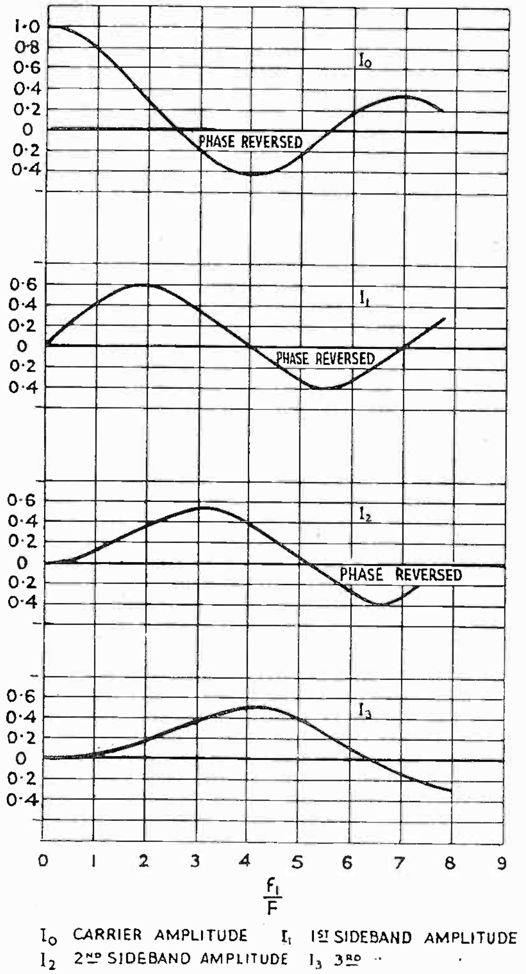

FIG. 4.

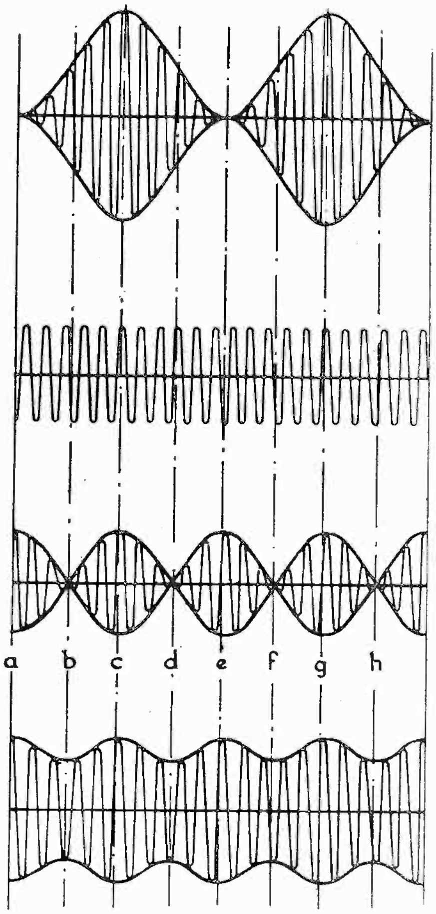

FIG. 5.

relative to the carrier. Hence in the resultant amplitude modulated wave the amplitude at "*c*" is double that of the carrier, while at "*e*" it is zero. If, however, the phase of the carrier is shifted 90 degrees relative to the side bands and then the two are combined, the result is very different. The amplitude at "*b*," "*d*," "*f*," etc., will be the carrier amplitude, while at "*a*," "*c*," "*e*," etc., it will be $\sqrt{2}$ (or 1.414) times the carrier amplitude. This is shown in Fig. 5*d*. The envelope is of double frequency and represents an amplitude modulation of only 21 per cent.

In frequency modulation the carrier and first side frequencies are in quadrature as just described.

It is obvious that a pair of the side bands $f_0 \pm 2F$ of small amplitude and correct phase would fill in the greater portion of this residual amplitude modulation.

In the case of 50 per cent. amplitude modulation and the carrier phase shifted 90 degrees the resulting wave form will only have 5.5 per cent. amplitude modulation.

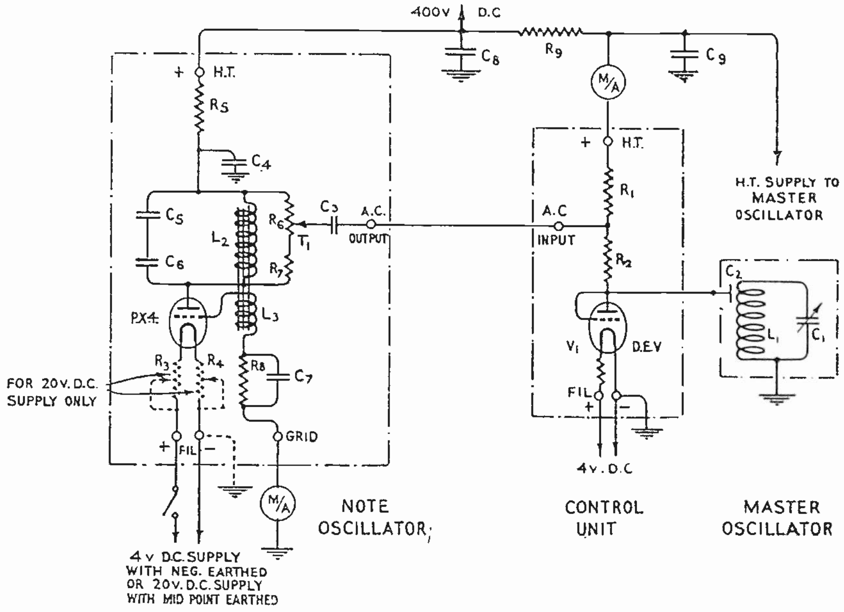

FIG. 6.

This analysis shows that if we start with a frequency modulated signal, any phase shift between carrier and side bands will result in the appearance of amplitude modulation. Any alteration in amplitude of the two side bands will also produce amplitude modulation. Such effects may be produced by selective fading in transmission. A sharply tuned receiver set on either side of resonance will also produce amplitude modulation by altering the relative amplitudes of the side bands. In these cases the transmission will produce an audible signal in a straight receiver. It should be noted however, that frequency modulation will not normally be audible without the use of a heterodyne.

From this theoretical discussion it will be seen that the advantages of frequency modulation over I.C.W. or amplitude modulation are as follows :—

(1) Simplicity of application.
(2) The transmitter is always working at full load instead of varying load, and therefore the power output is increased.
(3) The degree of modulation can be increased until the energy in the side bands is much greater than that remaining in the carrier without undue side band spread. This condition cannot be obtained with amplitude modulation.

Summary.

Let F = Modulating frequency in cycles per second
f_0 = Carrier ,, ,, ,, ,, ,,
f_1 = Maximum frequency swing of carrier in cycles when frequency modulation is applied.

The frequencies radiated comprise the following :—

Carrier $= f_0$
1st side band $= f_0 \pm F$
2nd ,, ,, $= f_0 \pm 2F$
3rd ,, ,, $= f_0 \pm 3F$ etc.

The frequency at any instant $= f_0 + f_1 \sin \omega t$ where $\omega = 2 \pi F$

Energy in side bands $\propto \frac{f_1}{F}$

Percentage modulation is approximately $= \frac{f_1}{F} \times 100$ provided $\frac{f_1}{F}$ is not greater than 1.

In order to avoid excessive side band spread, the modulation ratio $\frac{f_1}{F}$ should not be much greater than 1.5.

The carrier frequency, f_0, and the 1st side band frequencies $f_0 \pm F$ are in quadrature, and this fact together with the phase relationship of the carrier and the other side bands, eliminates amplitude modulation. In this case the received signal is inaudible until it is heterodyned. The effects of selective fading at a distance from the transmitter may, however, reintroduce amplitude modulation.

General Description.

The frequency modulation equipment consists essentially of two units as shown in Fig. 6.

(1) A Note Oscillator generating frequencies between 200 and 400 cycles per second.
(2) A Control Unit mounted close to the Master Oscillator using a diode as a variable resistance.

In Fig. 6, L_1 C_1 represents the tuned circuit of the master oscillator, the remainder of the circuit being omitted for simplicity. C_2 is a plate having a very small capacity to the high potential end of the winding L_1. This plate is arranged to screw in or out, and is normally set at 6 turns out from the position of contact with the winding L_1. The control valve V_1 is a type D.E.V. used as a diode by connecting anode and grid, and is connected between C_2 and earth. The resistances R_1 and R_2 control the D.C. feed, and in particular R_2 acts as a high frequency choke.

If the feed through V_1 is varied its resistance varies, and this in turn varies the capacity effect of C_2 on the tuned circuit of the master oscillator, and thus alters its frequency. Fig. 7 shows the relation between the control valve feed and master oscillator frequency shift with the plate C_2 set at 6 turns out.

It will be noticed that the change of frequency with control valve feed is approximately linear from 0.4 m.A to about 1.5 m.A. The resistances R_1 and R_2 are of such a value that the D.C. feed is about 0.95 milliamperes corresponding to point A near the centre of the linear portion of the frequency curve. The master oscillator is calibrated with the control unit in position and connected up and its feed adjusted to this value. The master oscillator frequency shift corresponding to point A on the curve is therefore zero. The alternating E.M.F. generated by the note oscillator is applied to the A.C. input terminal of the control unit via the potentiometer slider T_1 and the blocking condenser C_3. The resultant alternating feed supplied to the control valve sweeps its working point up and down the characteristic curve and imparts a sinusoidal frequency modulation to the master oscillator. The degree of modulation, or modulation ratio $\frac{f_1}{F}$, will be proportional to the A.C. component of current through the control unit. This depends on the A.C. voltage supplied by the

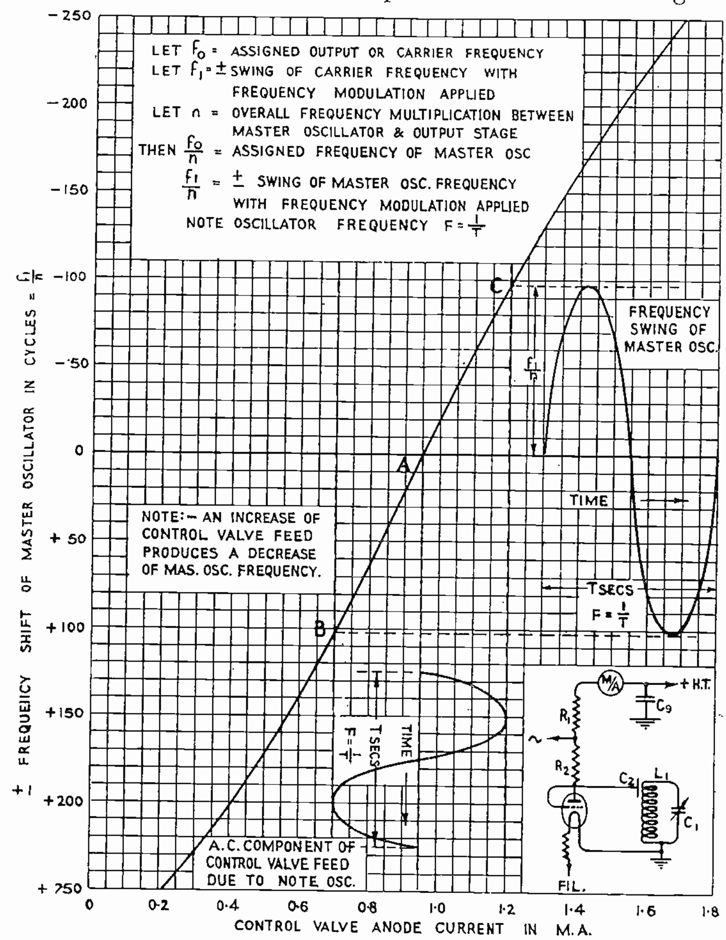

FIG. 7.

note oscillator and may easily be varied by altering the position of the potentiometer tapping T_1. This should be set so that the plus and minus variation of transmitter output frequency f_1 is about 50 per cent. greater than the note frequency F. Thus for a note frequency of 400 cycles per second the transmitter output frequency should vary ± 600 cycles. In Fig. 7 are also shown curves for the A.C. component of control valve feed and the corresponding master oscillator frequency swing, with respect to time. For the example shown the control valve feed is swinging between the limits 0.7 and 1.2 milliamperes, represented by the points B and C respectively.

Detailed Description.

A type P.X.4 valve is used for the note oscillator. Referring to Fig. 6, R_5 consists of the necessary anode breakdown resistance for the valve, and also in conjunction with C_4, provides resistance capacity smoothing. L_2 and L_3 are the anode and grid inductances, L_2 being tuned by the condensers C_5 and C_6. With both condensers connected in series the note frequency is approximately 400 cycles per second, but by changing the connections frequencies of approximately 270 and 215 cycles are obtainable.

Fig. 6 applies to circuits with cne master oscillator of which the S.W.B.8 type transmitter is a typical example. The output circuit comprises a potentiometer R_6, a fixed resistance R_7 and a blocking condenser C_3. Adjustment of R_6 provides control of the degree of modulation, and R_7 limits the modulation to the required maximum. A calibration chart is provided for the potentiometer R_6 which shows, for any output wavelength, the correct potentiometer scale reading for three alternative valves of the modulation ratio $\frac{f_1}{F}$ corresponding to frequency swings of $\pm$ 800 $\pm$ 600 and $\pm$ 400 cycles.

When frequency modulation is not required, the note oscillator may be switched off by means of the filament switch S_1. It should be noted that the control unit D.C. anode feed is always flowing, so that on switching off the note oscillator the master oscillator frequency settles at the pre-set figure represented by the point A, Fig. 7.

The H.T. supply for both note oscillator and control unit is obtained from the 400 volt D.C. H.T. supply used for the master ocillator and its amplifying stages. Milliammeters are provided for the grid circuit of the note oscillator and the control unit anode circuit.

On telephone-telegraph transmitters an interlock on the telephone-telegraph change-over switch prevents frequency modulation being applied when on telephony by opening the note oscillator filament supply.

Frequency Mcdulation on S.W. Transmitters employing two or more Master Oscillators.

On transmitters where frequent and rapid changes between spot wavelengths are required, it is common practice to employ one Marconi-Franklin master oscillator for each spot wave. Each oscillator is adjusted to give the required output wavelength, and the appropriate unit is switched into service from the control table as required. In such cases the output circuit and switching arrangements of the note oscillator are somewhat different from those already described but in other respects the unit is the same. A typical circuit arrangement for a transmitter employing four master oscillators is shown in Fig. 8. The four master oscillators with their associated control units and amplifying or frequency multiplying stages are mounted in one panel.

The output circuit consists of the blocking condensers C_{10} and C_{11} and a potentiometer comprising the fixed resistance R_7 and the externally mounted tapped resistances R_{10} and R_{11}. Tappings on the latter are selected and fixed to give the required A.C. voltage input to each of the four control units, via the four-way switch S_3 The appropriate voltage in each case for a given carrier frequency swing f_1 will depend on the overall frequency multiplication of the circuit in use between master oscillator and output stage. Coupled to S_3 is another switch S_2 which connects the anode circuit of the note oscillator to the H.T. supply of the master oscillator in use. It will be seen that the application of an unsuitable value of modulation swing through failure to adjust the output potentiometer when changing wave is automatically prevented by the coupling of the two switches and the pre-set potentiometer tappings. When unmodulated C.W. is required, the note oscillator is switched off by means of the filament switch S_1.

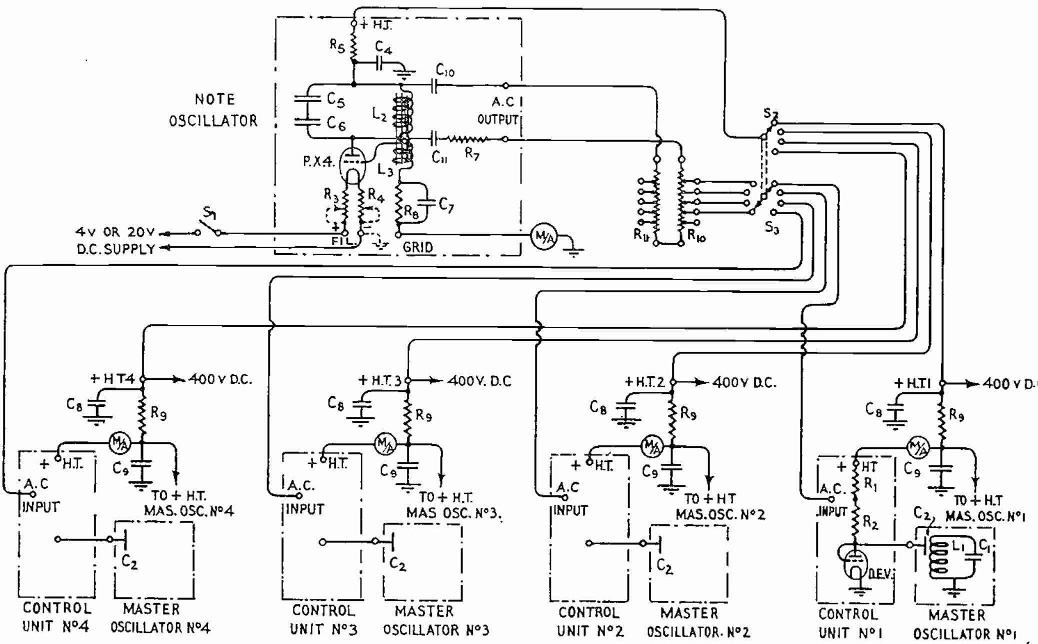

FIG. 8.

On a telephone-telegraph transmitter serious interference with the received speech would be caused if frequency modulation were applied when on telephony. This is automatically prevented by an interlock on the telephone-telegraph change-over switch which disconnects the note oscillator filament supply when the switch is in the telephone position.

The functions of the remaining components in Fig. 8 have already been described for the circuit shown in Fig. 6, and the same reference letters are used.

A typical set of readings for the units shown in Fig. 6 is given in the following table :—

NOTE OSCILLATOR.

H.T.V.	Anode Current m.A.	Grid Current m.A.	Anode Resistance ohms.	Grid Resistance ohms.	Actual Anode Volts.	Filament Volts.	Effective Load Resistance ohms.	A. C. Peak Volts. Across R6 and R7 in series.	From output terminal to earth with Pot. at Max.
400	5·5	0.9	50,000	50,000	125	4	50,000	93	62

CONTROL UNIT.

H.T.V.	Diode D.C. Feed m.A.	Anode Resistance R_1 ohms.	Anode Resistance R_2 ohms.	Filament Volts.
186	0.95	100,000	100,000	3

Privacy Modulation Equipment for S.W. Telephone Transmitters.

General Description.

Another useful application of the principle of frequency modulation is in the use of a privacy modulator or " wobbler " on a S.W. telephone transmitter, in addition to the use of an inverter, as a means of preventing unauthorised reception of speech. It will be seen from the following considerations that the use of inverted speech alone does not provide an absolute guarantee of secrecy.

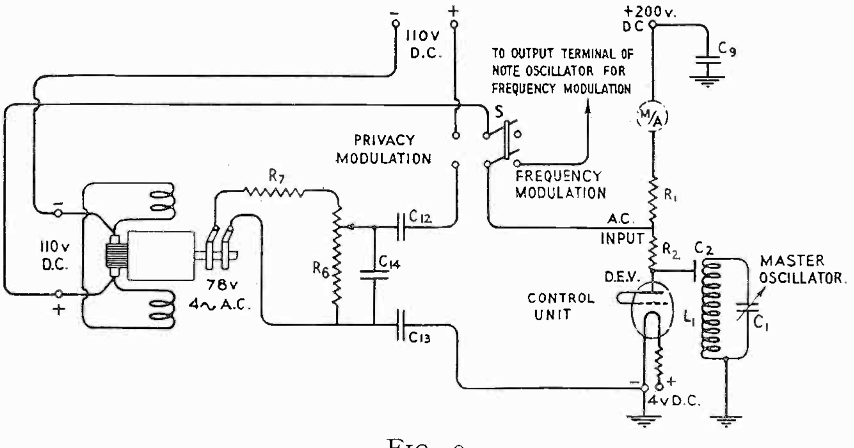

FIG. 9.

The audio frequency components of a carrier modulated with inverted speech consist of the frequencies resulting from the subtraction of the original speech frequencies from a frequency of 3,000 cycles per second. By the use of a receiver having a heterodyne oscillator capable of adjustment to a frequency difference of 3,000 cycles from that of the carrier, such a transmission is rendered intelligible by the restoration of the original speech frequencies. Under favourable conditions, such a process is also possible on a receiver having an autodyne detector, and one or other of these two types is usually in the possession of the amateur. The prevention of such unauthorised reception is easily effected by the simple addition to the transmitter of a privacy modulator or " wobbler." This is a device which imparts a very low periodicity swing to the carrier frequency, above and below its mean value. In order to detect plain speech from such a transmission without elaborate inverter equipment it would be necessary for the unauthorised listener to vary his heterodyne oscillator frequency in synchronism with the swing of the carrier frequency. The accomplishment of such a process would be extremely difficult, and beyond the scope of the amateur. The effect produced by such a transmission in the authorised receiver, which is of the superheterodyne type, is to swing the signal band to and fro within the limits of the band width of the intermediate frequency stage. The signal then passes on to the inverter for restoration to plain speech.

It should be noted that a commercial receiver in conjunction with an inverter may be used without modification, for either plain, inverted, or inverted and wobbled transmission, provided the modulation swing imparted to the carrier does not exceed the band width of the receiver.

The frequency swing of the carrier f_1 should be of the order of $\pm$ 200 cycles minimum, up to a maximum value of $\pm$ 400 cycles. The latter figure should be maintained at the lower carrier frequencies. The modulation or wobble frequency should be from two to three cycles per second. With master oscillators of the Marconi-Franklin valve type any required degree of carrier frequency swing is obtainable without any sacrifice of constancy of the mean or assigned frequency.

Two types of privacy modulator have been developed, one depending on a cyclic variation of capacity produced by a motor driven variable condenser, and the other employing a miniature rotary converter. The description which follows is confined to the latter type.

Rotary Converter type Privacy Modulator.

The basic principles underlying the action of this type of privacy modulator are similar to those already described in the case of frequency modulation for telegraphy.

In this case, however, the low frequency A.C. voltage applied to the control unit is obtained from a miniature rotary converter instead of from a note oscillator. Fig. 9 shows the circuit used for a telephone-telegraph transmitter. The control unit, which has already been described, serves for both frequency modulation on telegraphy and for privacy modulation on telephony. The lower blade of the D.P. D.T. switch S, changes over the A.C. input lead of the control unit from the output of the note oscillator to the output of the rotary converter, as required. The upper blade of this switch controls the 110 volt D.C. supply to the input side of the converter. The output rating of the converter in the case of the first model produced was 78 volts, 10 milliamps, at 4 cycles per second, but recent experience shows that a lower wobble frequency is preferable, and a frequency of 2 cycles per second will probably be adopted in future.

Referring to Fig. 9, the A.C. output of the converter is taken to a potentiometer consisting of a tapped resistance R_6 and a fixed resistance R_7. The position of the tapping on R_6 determines the extent of the frequency shift, f_1, applied to the carrier. The potentiometer is fitted with a control knob and scale, and a chart is provided which shows the correct potentiometer setting for any wavelength, for carrier frequency swings of $\pm$400, $\pm$ 300 and $\pm$ 200 cycles. Any harmonics which are present in the converter output are smoothed out by the condenser C_{14} in order to avoid degradation of the received speech. The A.C. output of the converter is coupled to the control unit via the blocking condensers C_{12} and C_{13} which isolate the control unit H.T. supply and the filament earthing point from the converter circuit.

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AN IMPROVED PULSE TRANSMITTER

THE investigation of the ionosphere by the method of Breit and Tuve requires, as a first essential, a transmitter capable of emitting short pulses of radiation at regular intervals. As a pulse frequency of about 50 per second proves to be the most useful experimentally, it is usual to take advantage of the possibility of locking the pulse to the frequency of an A.C. mains supply. The arrangement generally used is based on that described by Ratcliffe and White,* and a brief description must be given here by way of introduction.

The circuit is given in Fig. 1. V_1 is a mercury thyratron, to the anode of which is applied an alternating potential of 300 volts through the resistance R_4 of 10,000 ohms. To the grid is applied a voltage nearly in quadrature and lagging on the anode voltage, obtained from the network L_1 R_1. As a result, V_1 does not strike until the anode voltage is nearly a maximum. When it strikes, the anode voltage drops instantaneously to about 15 volts, the steady ionization potential, and almost the whole of the 300 volts is thrown across R_4. As R_4 is relatively small, the thyratron remains conducting almost until the A.C. volts have dropped to the ionizing potential, when it goes out and is ready again for the next cycle. Across R_4 is put a circuit R_2 C_2 arranged to have a small time constant, and R_2 is joined across the grid and cathode of a valve V_2 which has a short grid base (e.g., an MH4 valve). When the thyratron flashes, the volts thrown across R_4 all appear initially across R_2 as negative bias on V_2 which falls exponentially to zero as C_2 charges up. Thus, at each positive peak of the A.C. mains, when the thyratron flashes the Valve V_2 is rendered non-conducting for a short time depending on the time constant of C_2 R_2. As this time constant is small compared with the period of the mains, the voltage across C_2 drops as the A.C. volts drop to zero, and during the negative half-cycle while the thyratron is out there are no volts across R_4 or C_2 R_2. The circuit can therefore only give one pulse per cycle of the mains. There is no possibility of V_2 being backed off during any other part of the cycle, and perfect synchronism is obtained.

The valve V_2 is fed from a D.C. supply of about 600 volts through an anode resistance R_3 of 50,000 ohms which is also in the grid circuit of a valve V_3, which itself is in series with the self-oscillating transmitter valve V_4 across the main high-tension supply of, say, 4,000 volts. V_3 is thus a series modulator, and must be chosen so that it is completely non-conducting when backed off by the volts across R_3 while V_2 is passing its normal anode current, and at the same time when at zero bias it must be able to pass the feed current required for V_4 when oscillating while itself only taking a small fraction of the main supply volts, e.g., 400 volts, on its anode. If the transmitter valve V_4 is an MT.12, then a DET.2 forms a suitable modulator.

The action of the whole circuit is as follows :—

Normally when there is zero grid-bias on V_2 and it is conducting the volts developed across R_3 keep V_3 completely backed off and non-conducting. The transmitter valve V_4 therefore cannot oscillate. When the thyratron flashes and V_2 is rendered non-conducting the bias is removed from V_3, and V_4 oscillates until

* J. A. Ratcliffe and E. L. C. White An Automatic Recording Method for Wireless Investigations of the Ionosphere. Proc. Phys. Soc. Vol. 45, Part 3, p. 401, 1 May, 1933.

V_3 cuts off as V_2 becomes conducting once more. The transmitter therefore sends out a series of H.F. pulses, and the relation of these pulses to the pulses applied to the grid of V_2 can be seen diagrammatically from Fig. 2.

(A) represents the A.C. potential across the reservoir condenser C_1 as a function of time.

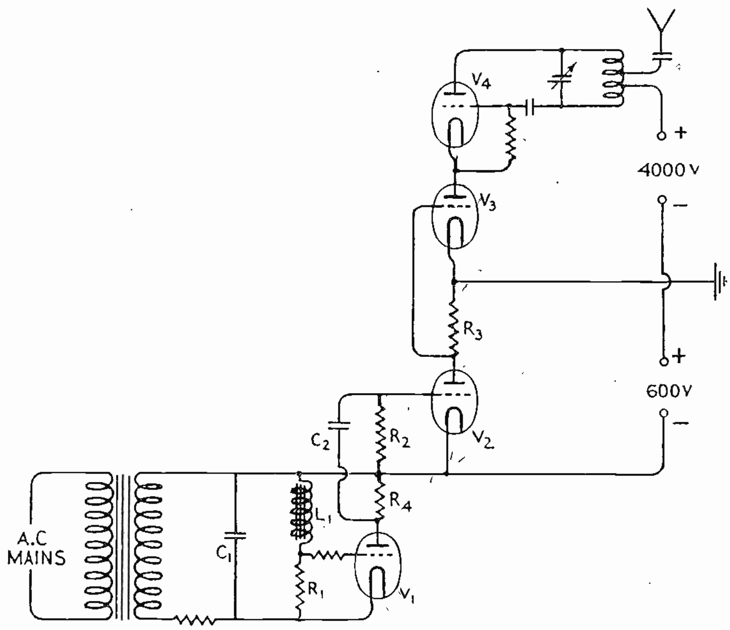


FIG. 1.

(B) represents the potential across R_4, the sharp up stroke representing the moment when the thyratron V_1 flashes.

(C) represents the negative potential thrown on to the grid of V_2 across R_2.

(D) represents the anode voltage on V_2 measured negative with respect to the H.T. positive of the 600 volt supply, i.e., it also represents the grid bias on V_3.

In (D) the dotted line x^1 represents the grid voltage at which V_3 begins to conduct, allowing V_4 to oscillate, and x in (C) represents the corresponding voltage on the grid of V_2. In (C) the line y represents the voltage at which V_2 becomes completely non-conducting, and corresponds to zero grid bias on V_3 and full oscillation of V_4. The enclosed portion of the curve in (D) thus determines the shape of the H.F. pulse, the envelope of which is shown in (E).

The H.F. output remains at maximum for a short time and then falls rapidly *but not instantaneously* to zero. Now since the effective width of the pulse is determined by the maximum width at the base, it follows that if we attempt to obtain a very narrow pulse by reducing the time constant of the C_2 R_2 circuit, we will reach a point where the top of the pulse is so narrow that the transmitter will not have

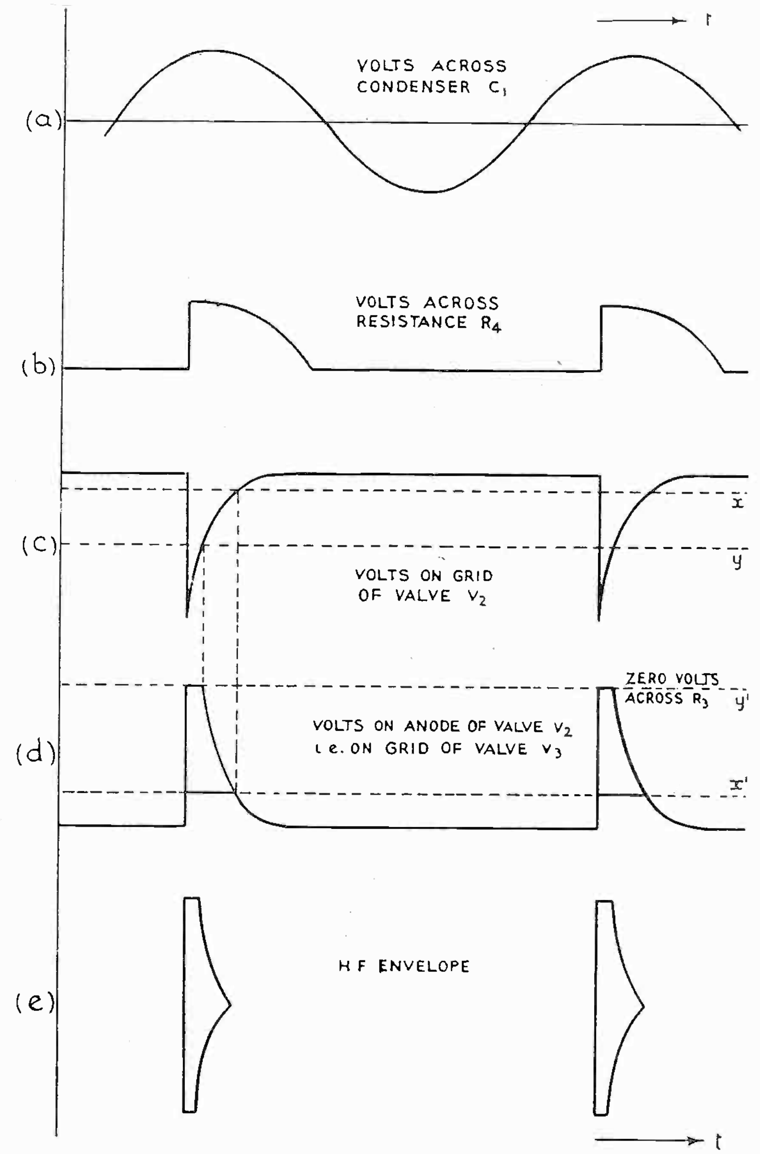


FIG. 2.

Vertical scales arbitrary. Pulse width greatly exaggerated for sake of clearness.

time to build up to the true peak value of oscillation. With this type of circuit there is thus a practical limit to the width obtainable, below which the amplitude of the H.F. pulse will be seriously reduced or the transmitter will refuse to respond at all (cf. Appendix).

Since a very narrow pulse would be of value in the investigation of certain points in connection with the E layer of the ionosphere, a modified pulse generator was built to give a pulse which was truly square topped with an instantaneous cut-off. Referring to Fig. 2 (c), if we could make this curve of the form shown in Fig. 3, the resulting H.F. pulse would be square topped with maximum output over the whole width of the pulse (down to times comparable with the build-up time of the oscillator). Now since the initial sharp rise is produced by the sudden flashing of a thyratron, this suggests that the desired sharp cut-off may be obtained by the sudden flashing of a second thyratron which is controlled by a delay circuit from the first thyratron. By altering the constants of the delay circuit the width of the pulse should be controllable.

This has been achieved in a circuit shown in Fig. 4. It will be seen that R_4 has been replaced by R_5+R_4 where R_5 is made 1,000 ohms and R_4 is 10,000 ohms as before. R_2 is also replaced by R_6+R_7, where R_6 and R_7 are both equal to 5,000 ohms and C_2 is made 0.1 μF. The time constant of C_2 (R_6+R_7) is thus of the order of 10^{-3} seconds, which, while small compared with the period of the mains, is large compared with the width of the widest pulse we are likely to require. Across R_6 is connected another circuit C_3 R_8 and a second thyratron V_5 inverted as shown. C_3 is made 0.01 μF. and R_8 is a variable 0—250,000 ohm resistance. The grid of V_5 is connected via a grid bias battery B to the common point of C_3 and R_8. The common point of R_6 and R_7 is now joined to the grid of the valve V_2 and the cathode of V_2 is taken to the common point of R_4 and R_5. Now, as before, when V_1 is non-conducting there is no voltage across the grid resistance of V_2 which is now R_5+R_6. When V_1 flashes, half the peak volts appear across R_6 as negative bias on V_2 and a small fraction appear across R_5 as positive bias. The net result is that the grid of V_2 is thrown heavily negative, and V_2 becomes non-conducting as before, giving the beginning of the H.F. pulse. Initially also, the volts across R_6 appear across R_8 and zero volts across C_3, and the negative bias from B is made large enough to prevent V_5 from flashing when the voltage thrown across R_6 becomes its anode voltage. As C_3 charges up a point is reached when the voltage across it overcomes the bias B, and V_5 will flash at a time after V_1 determined by the time constant of C_3 R_8 and the characteristics of V_5. When V_5 flashes, the volts across R_6 are transferred to R_7 with the exception of the ionization potential required to keep V_5 conducting, which remains as negative bias on V_2. This residual bias, however, is overcome by the positive bias already developed across R_5 when V_1 flashed, since this bias can be made large enough to do this while remaining a small fraction of the peak volts thrown across R_4+R_5. Thus, when V_5 flashes, the grid of V_2 is made zero (or even positive) as rapidly as it was backed off when V_1 flashed. As C_2 is made 0.1 μF. and R_7 is 5,000 ohms, the charging current for C_2 through V_5 and R_7 is ample to provide the necessary ionization current for the efficient operation of V_5.

We have thus obtained the desired result of Fig. 3. where *a b* represents the exponential decay of the volts across R_6 as C_2 charges up through R_6+R_7 in the interval between the flashing of the two thyratrons, and as the time constant of C_2 (R_6+R_7) is relatively large *a b* will lie wholly below the cut-off line *y* for any pulse we are likely to require. It is found that with the values given for C_3 and R_8 and with B = —40 volts it is possible to obtain a pulse up to about one-third millisecond, while by reducing R_8 the pulse can be narrowed down to something less than 20 microseconds before one begins to lose H.F. amplitude. The limit of goodness of the H.F. pulse then becomes the oscillatory circuit, but it has been found that a sharply terminated pulse down to the above limit can be obtained by loading the tuned circuit adequately either by a correctly coupled aerial or by some form of resistance.

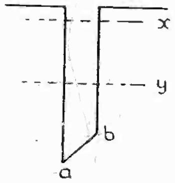


FIG. 3.

This circuit is found to work excellently, and there is no trouble from H.F. getting back on to the thyratron gear provided that an H.F. stopping resistance (e.g., a Dubilier metallised resistance of about 50,000 ohms) is placed in the grid lead to the modulator valve V_3 and the lead itself is run in screened cable. If the thyratron gear is to be placed very near to the oscillatory circuit it is best to put it in a screened box to shield the thyratrons from the direct influence of the H.F. field. It is advisable, however, to allow adequate ventilation, as mercury thyratrons have such a large temperature coefficient for their control ratio that the pulse width would be considerably narrowed if the second thyratron should get unduly hot. This trouble can be overcome by replacing it by one of the new argon filled thyratrons which have a very small coefficient.

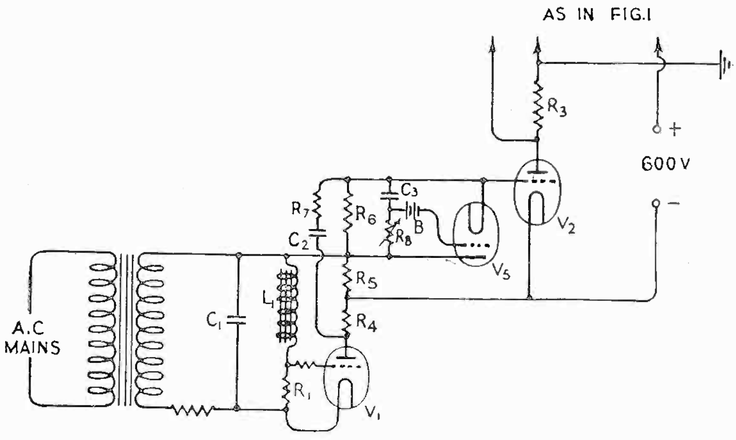


FIG. 4.

It may be noted that as far as the modulator and oscillator valves are concerned the limiting factor is their break-down voltages. As the integrated current on pulse is so small they can be heavily overrun to give a momentary peak power far in excess of their normal C.W. rating. Thus the MT.12 and DET.2 appear to stand up quite all right to anode voltages of nearly 5,000 volts on pulse, but care must be taken to see that the modulator bias does not fail while running.

Appendix No. 1.

In Fig. 2 if the grid bias on V_2 represented by the line x is E_2 and the line y is E_1 while the peak bias is E_0, then the width of the top of the H.F. peak is t_1 where

$$E_1 = E_0 \, e^{-\frac{t_1}{CR}} \text{ i.e., } t_1 = CR \log \frac{E_0}{E_1}$$

and the width at the base is t_2 where

$$E_2 = E_0 \, e^{-\frac{t_2}{CR}} \text{ i.e., } t_2 = CR \log \frac{E_0}{E_2}$$

where CR now represents the time constant $C_2 R_2$ of Fig. 2.

$$\therefore \frac{E_1}{E_2} = e^{\frac{t_2 - t_1}{CR}}$$

and $t_2 - t_1 = CR \log_e \frac{E_1}{E_2}$

Thus the spread of the pulse depends upon CR and on $\frac{E_1}{E_2}$ (the value of which depends on the characteristics of V_2 and V_3). It is independent of E_0.

It is usual to make E_0 considerably greater than E_1, but with

$$\frac{E_0}{E_1} = \frac{E_1}{E_2} \qquad t_2 - t_1 = t_1$$

i.e., the spread is equal to the pulse width at the top. Under practical conditions $\frac{E_0}{E_1}$ may be less than $\frac{E_1}{E_2}$ and $t_2 - t_1$ may be greater than t_1. t_2 can thus only be made very small (by decreasing CR) by making t_1 very small indeed.

G. MILLINGTON.
S. W. H. W. FALLOON.

THE VARIATION OF INTER-ELECTRODE CAPACITY IN THERMIONIC VALVES

In the course of a general investigation of the frequency stability of valve oscillators, the author found that under certain conditions it was possible to construct an oscillator in which the change of frequency for a chosen change of anode voltage corresponded to an almost constant change of capacity, regardless of the operating frequency. Since all "circuit" factors influencing the frequency (e.g. harmonics, or valve amplification factor and circuit resistance) result in a fractional *frequency change, the corresponding capacity change would be proportional to the tuning capacity in circuit; it seemed probable, therefore, that this frequency variation corresponding to a constant capacity change was in fact an actual change of inter-electrode capacity of the valve. The influence of space-charge on the effective capacity between electrodes has been the subject of mathematical papers by Benham* (1) *and Hartshorn* (2), *but practical electrode systems are not as simple as is required for theoretical investigation; experimental measurements are therefore desirable in actual valves.*

Valve capacity changes have been reported by several previous investigators (3); *the results described below are in general agreement with previous measurements, but show that the change of capacity between any two electrodes of a valve is not solely a function of the magnitude of the current flowing. The importance of avoiding grid-current when measuring input capacities is emphasised; and it is suggested that for oscillators of stable frequency the proper procedure is to arrange that an increase of grid-cathode capacity shall balance a decrease in anode-cathode capacity, a result which can be attained by control of the grid coupling.*

SOME measurements on capacity variation in a valve operating under dynatron conditions have been made by Baker (3), who found that, for the particular part of the characteristic at which he was observing, the capacity change was directly proportional to the anode current, which in turn is a constant fraction of the total current emitted from the cathode. On the theory of the effect papers have been published by Benham (1), Llewellyn (4) and Hartshorn (2). Briefly there are two effects to consider :—

(A) In the presence of space-charge the electric field at the anode is greater than it would otherwise be; the density of charge is therefore greater, i.e., the capacity appears to be increased, according to calculation in the ratio 4 : 3.

(B) The apparent capacity between two electrodes between which an electronic current is flowing is affected by the time of transit of the electrons; although this time is very small even compared with the period of the applied voltage at normal frequencies, it is finite, and results in the current lagging behind the voltage which is producing it. Instead of being shunted by a pure resistance therefore, the electrostatic capacity is shunted by what is virtually an inductive resistance; expressed in terms of apparent capacity change, this means a decrease of capacity.

Effect (B) appears in a diode or in the anode-cathode capacity of a triode, while (A) appears in the input capacity of a triode when the grid is negative. The measured

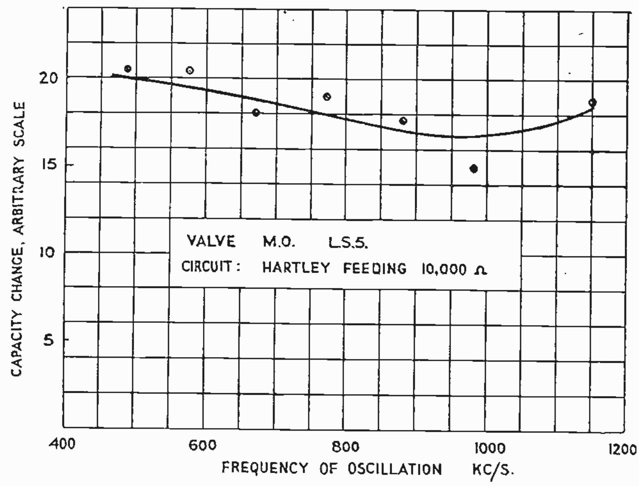
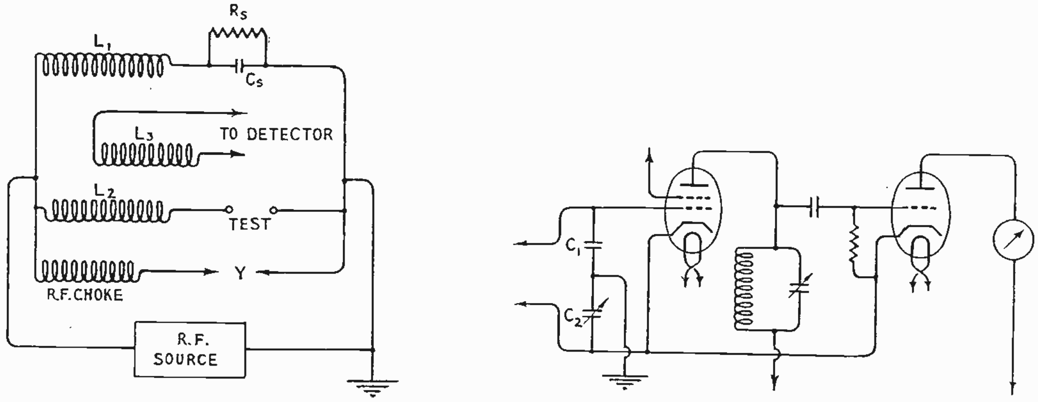


FIG. I.

changes are of the correct sign, but larger than predicted by the theory, particularly for (B), the decrease of capacity.

A practical demonstration of the existence of these capacity change effects in valve oscillators is as follows. It was found that with an L.S.5 valve in a Hartley



Bridge. *Detector.*

FIG. 2.

circuit at frequencies from 475 to 1,150 kcs., a change of anode voltage from 220 to 100 volts produced a frequency change, at all working frequencies, which can be corrected by a practically constant capacity change (actually of the order of 0.13 $\mu\mu$F). Further experiment showed, however, that the magnitude and sign of the capacity change involved in any change of a specific operating condition, such as change of anode potential, depended upon all the initial operating conditions; for example, the change of frequency with anode voltage may be completely changed by an alteration in filament current. (The graph of capacity change against working

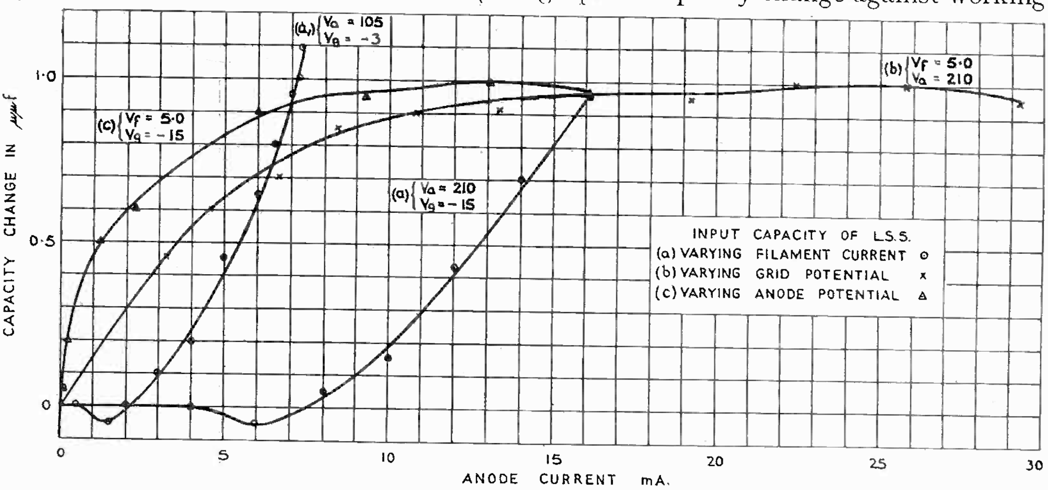


FIG. 3 (*a*) (*b*) *and* (*c*).

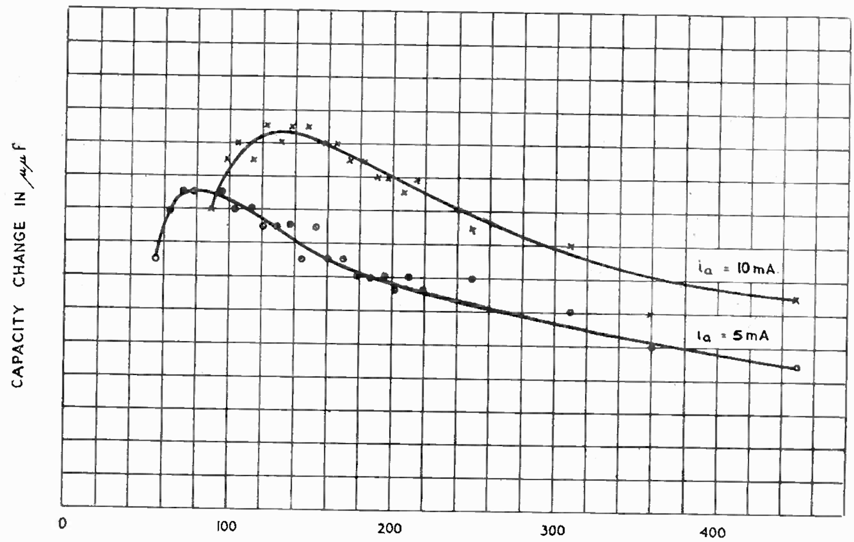


FIG. 3 (*d*).

frequency from this experiment is given in Fig. 1.) Observations of this type, however, are an unsatisfactory method of investigation for the following reasons :—

(A) It is impossible to separate the effects of grid and anode capacities, which, as will be seen below, follow quite different laws.

(B) Change of operating potentials may affect the frequency through some mechanism other than change of inter-electrode capacity.

(C) The alternating voltages involved are likely to be so great that results can refer only to an average over the whole sweep of the valve characteristic.

Resonance methods are also unsatisfactory, since the resistance accompanying the valve capacity will appear as a large correction to any frequency change. We are therefore forced to employ some form of bridge method of measurement, and at a fairly high frequency in order that the capacitive current flowing between the electrodes may not be too small compared with the conductive current.

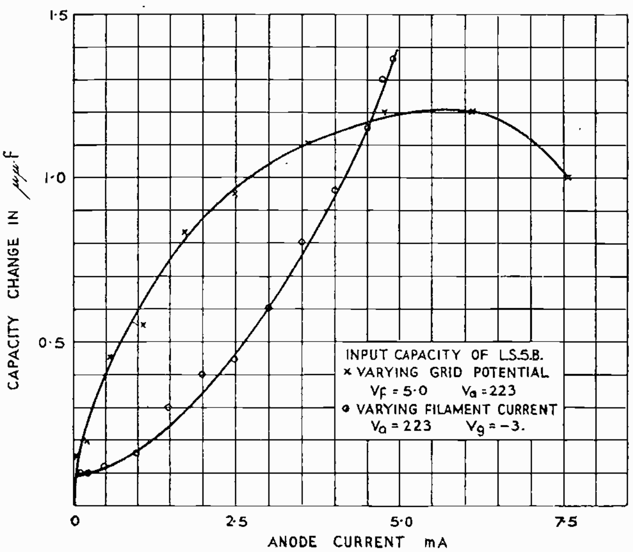


FIG. 4.

A number of capacity measurements were made at a frequency of the order of 1 Mc/s on a simple 1 : 1 differential bridge, whose circuit is shown in Fig. 2. The two coils L_1 and L_2 are wound together, turn for turn, on a single former, but connected in circuit in opposite sense, so that when equal currents flow through them there is no resultant flux to induce an E.M.F. in the detector coil L_3. The condensers C_1 and C_2 at the detector input are used to balance out the capacity coupling between L_3 and L_1 L_2 ; this necessitates the cathodes of the valves in the amplifier-detector being above earth potential at radio frequency, but with indirectly heated valves and local dry batteries for high tension this causes no difficulty. The circuit used for the detector-amplifier proved a great convenience ; the screen grid amplifying stage ensures adequate sensitivity, while the grid detector can be overloaded without damage to the anode current meter, which of course shows maximum current for balance. The steepness of the I_a/V_g curve of the rectifying valve at $V_g = 0$ compensates for the loss of sensitivity due to the large standing current. The accuracy of balance, as regards freedom from stray couplings to the detector, can of course be checked by switching off the oscillator ; there was complete freedom from pick-up within the limits of the detector sensitivity.

Since it is necessary to apply a steady potential to each electrode of the valve under test, a high frequency choke was connected as shown between the "live" input terminal of the bridge and the terminals γ. Since this choke merely forms a shunt across the oscillator driving the bridge, it can have no influence on the balance, and accuracy of measurement does not depend upon the efficiency of the choke.

It is interesting to note that at balance the radio-frequency voltage applied to the capacity under test is equal to the input voltage supplied to the bridge (neglecting resistance and leakage reactance in the differential transformer); in practice this was normally some 3 volts R.M.S. The accuracy on pure capacity measurements was verified by calibrating the bridge variable condenser against a standard in situ; the calibration so obtained agreed with that obtained by a substitution method in

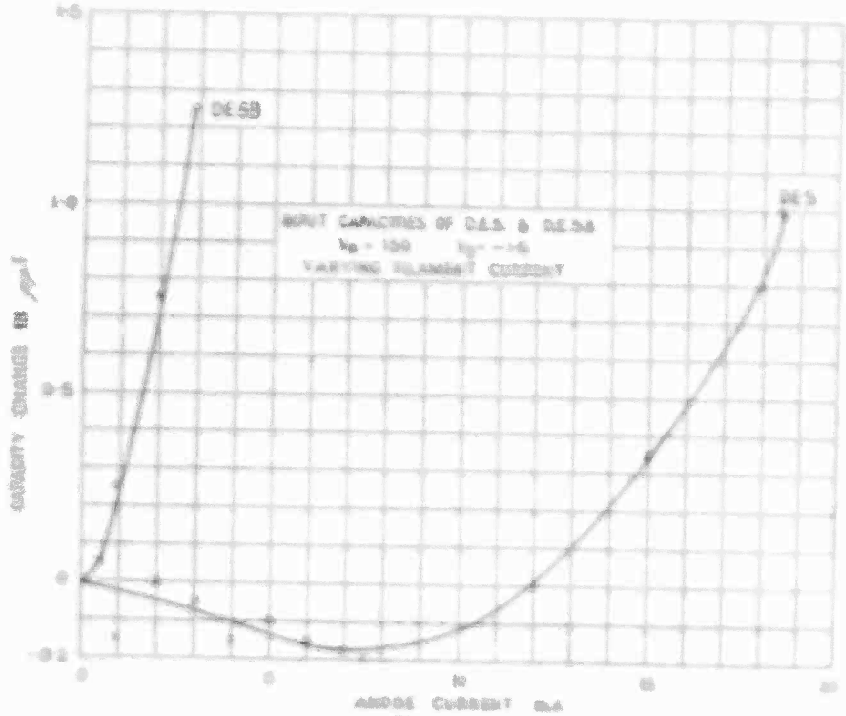


Fig. 5

an oscillator. If power-factor correction is provided by resistances in *parallel* with the variable capacity, as shown in the diagram, the resistive and reactive currents are independent, and the two balances correspondingly independent; even if the resistance cannot be exactly balanced, the minimum which is obtained in the detector in place of zero indicates the true capacity balance. This was found to hold good in practice when a capacity reading was taken both before and after an adjustment to the resistance balance. It is of course essential that variation of resistance should not be accompanied by any change of reactance; small metallised resistors (grid-leak type) were therefore used, and the nearest value chosen for each balance. Here again the independence of capacity and resistance balances gives reassurance that these resistors have all a substantially identical reactance.

Input Capacities of Triodes.

It is well known that if there is an impedance between anode and cathode of a triode, the apparent input capacity (and resistance) will be modified by the action of the coupling through the anode-grid capacity ("Miller effect").* It is therefore …

* It is quite practicable to measure Miller effect on this bridge.

essential that the anode be connected to cathode for radio-frequencies when measuring the input capacity with the filament and anode potentials on. The capacity measured on the bridge was therefore the total input capacity $C_{gf}+C_{ga}$. All capacities have been plotted in the curves as changes from the cold value, and,

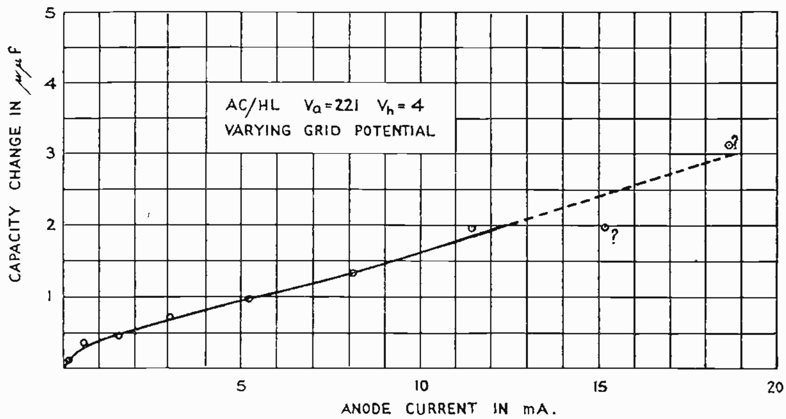


FIG. 6.

unless otherwise specified, whatever the actual variable parameter may be the capacity changes are plotted against the corresponding values of anode current. In considering the curves for variation of capacity with change of filament current, it must be remembered that the curve of anode current against filament current reaches a limiting value (owing to space-charge limitation); hence the curve for

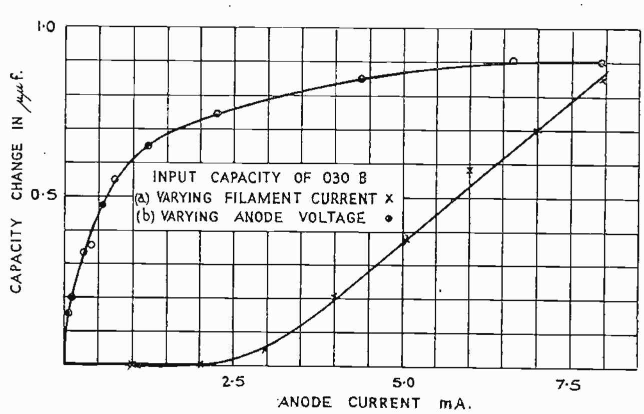


FIG. 7.

capacity change against filament current also is asymptotic to a particular value, though this does not appear from the curve plotted in terms of anode current. The objections to plotting the capacity changes against filament current are that it is the emission current, not the heating current, which is really a valve parameter, and that the variation with heating current is very rapid and dependent upon the type of filament (bright- or dull-emitter).

The valves measured are as follows :—

Fig. 3, Marconi-Osram L.S.5, variation of input capacity with (A) filament current ; (B) grid bias ; (C) anode potential ; (D) different combinations of grid bias and anode potential to give a particular value of anode current (plotted in terms of anode potential).

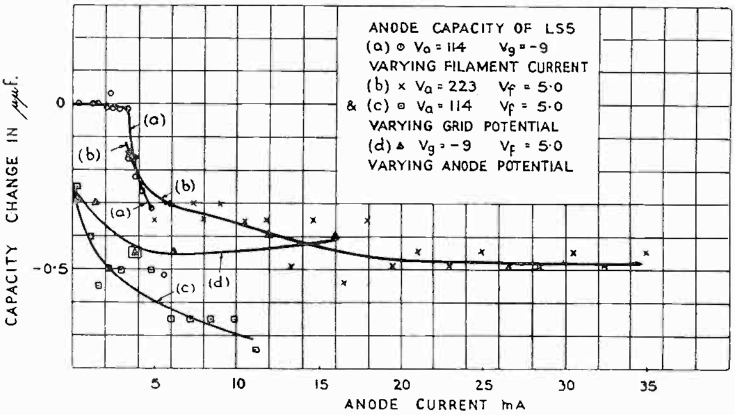


FIG. 8.

Fig. 4, Marconi-Osram L.S.5B, variation of input capacity with (A) filament current ; (B) grid bias.

Fig. 5, Marconi-Osram D.E.5 and D.E.5B, variation of input capacity with filament current.

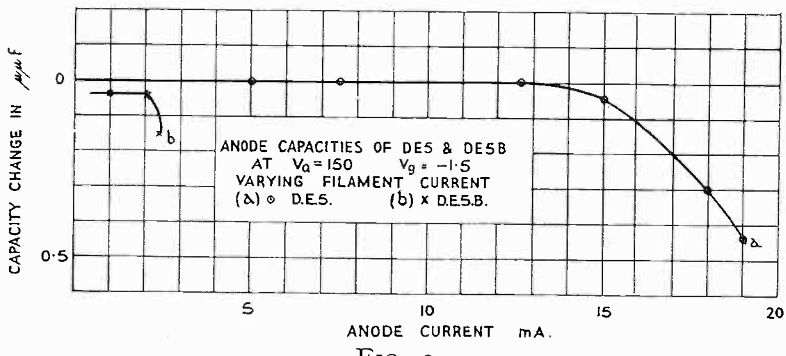


FIG. 9.

Fig. 6, Mazda AC/HL, variation of input capacity with grid potential.

Fig. 7, Philips 030.B, variation of input capacity with (A) filament current ; (B) anode potential.

The general impression given by these curves is that there is an increase of input capacity proportional to the quantity of space-charge which is actually distributed between grid and cathode, and not merely a change dependent upon the attainment of complete space-charge limitation, as might be expected from the theory. For although there is a limiting value with increase of filament current, corresponding presumably to full space-charge limitation for the particular values of grid and anode potentials employed, the capacity change can be reduced by cutting down the anode current by means of these potentials while leaving the filament current at its maximum value (Fig. 3d). It is interesting to compare the capacity changes in valves which are similar except for the grid mesh, such as L.S.5 and L.S.5B, D.E.5 and D.E.5B ; the valve with the higher amplification factor has the greater change of capacity, although its anode current is very much less. In the

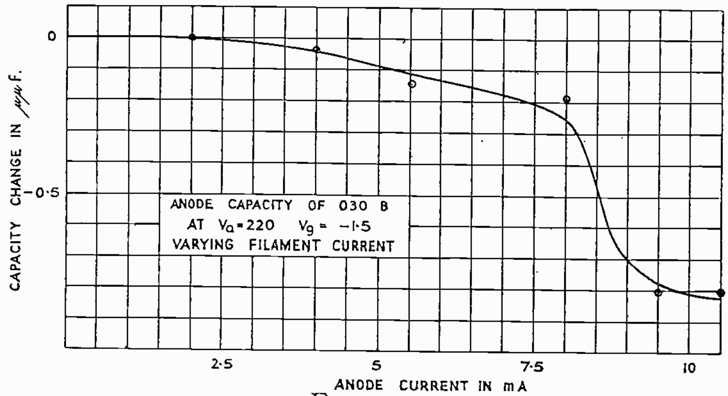


FIG. 10.

absence of figures for the " net " cold capacity (i.e. the capacity between the working parts of the electrodes, without supports and pinch) it is impossible to say whether the increase of capacity change is simply proportional to the increased cold capacity.

The curves for variation with grid bias all show a tendency to fall at the highest values of anode current ; this is due to the fact that the grid bias was here insufficient to prevent the flow of grid current at the peak of the radio-frequency voltage. (When grid current flows there is a reduction of capacity due to effect (B) of page 18).

The effect on the frequency of an oscillator of the variation of input capacity depends partly on the closeness of coupling required between the grid of the valve and the tuned circuit ; and for a given frequency variation the valve which gives the greatest power output is clearly to be preferred. It can be shown that from this point of view the valve " figure of merit " is $\mu^4 V_g^2/(\rho \triangle C_g)$ where V_g is the largest input voltage which the valve will accept at the anode voltage for which the figure of merit is to be specified, and $\triangle C_g$ the maximum change of input capacity. There is also an optimum loading condition, with the impedance of the anode load three times the internal resistance of the valve. The measurements show that an increase of voltage will not cause a proportionate increase in the maximum capacity change, though it will increase the permissible input voltage ; consequently the figure of merit of a valve is likely to be improved by working it at the highest permissible anode voltage. As will appear below, however, the anode capacity of a valve is liable to a decrease in operation ; the most promising method of improving oscillator stability, therefore, is to arrange that the reduction of anode capacity balances the increase of grid capacity. For this reason the grid capacity figure of merit given above is not considered to be of much practical importance.

Triode Anode Capacities.

The capacity between anode and grid plus cathode of a triode decreases under working conditions. As in the case of the grid capacity, there is no change until the emission from the cathode is sufficient to produce some approach to space-charge limitation, but with maximum emission from the cathode the capacity change is a function of the current flowing to the anode, as varied by changing anode and grid potentials. With a pair of valves differing only in the grid mesh, the valve of

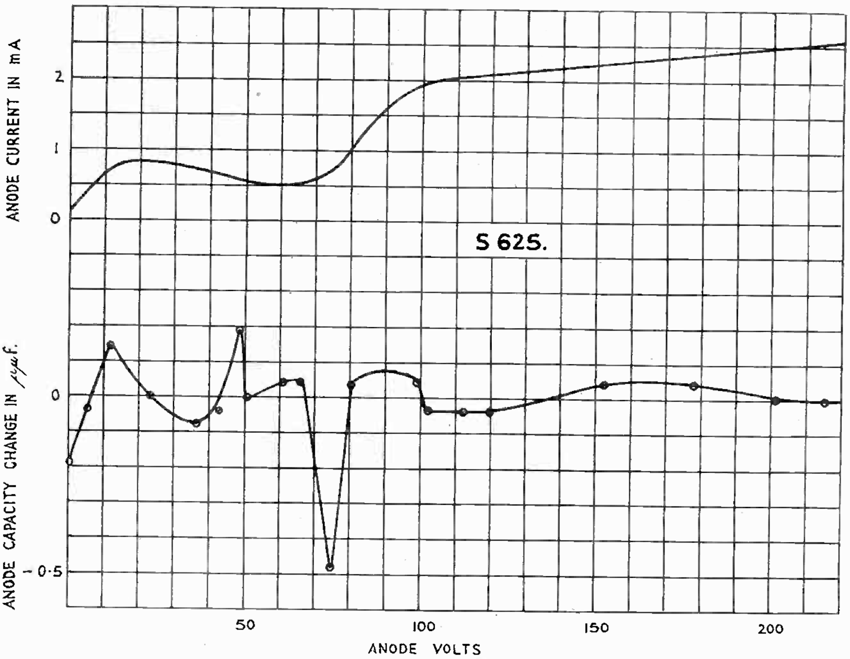


FIG. 11.

higher amplification factor has a much smaller change of anode capacity. The curves reproduced are :—

Fig. 8, Marconi-Osram L.S.5, change of anode capacity with (A) filament current ; (B) and (C) grid bias ; (D) anode potential.

Figure 9, Marconi-Osram D.E.5 and D.E.5B, change of anode capacity with filament current.

Fig. 10, Philips 030.B, change of anode capacity with filament current.

For use as stable frequency oscillators, it is probably desirable to arrange the grid coupling so that the proportion of the grid capacity change which is transferred to the tuned circuit is just sufficient to balance the anode capacity change. With valves of the L.S.5 class this is possible, but for valves of very high amplification factor this would imply very loose coupling of the grid, which might be unsatisfactory from the point of view of power output. It must also be remembered that the grid capacity tends to fall off when the grid is positive, and appreciable flow of grid-current may be essential to good efficiency, particularly if the anode circuit is of low impedance. On the whole valves of low amplification factor are likely to be more stable oscillators from the point of view of inter-electrode capacity change.

Tetrode Anode-Screen Capacities.

As long as the anode of a tetrode is at a potential appreciably greater than that of the screen, the anode to screen space is practically saturated (i.e. there is negligible space-charge limitation in this region) and the capacity is practically unchanged from the "cold" value (i.e. the value with the filament not heated). But with the anode potential below that of the screen there are large variations of capacity, which seem to be partly associated with secondary emission. A specimen

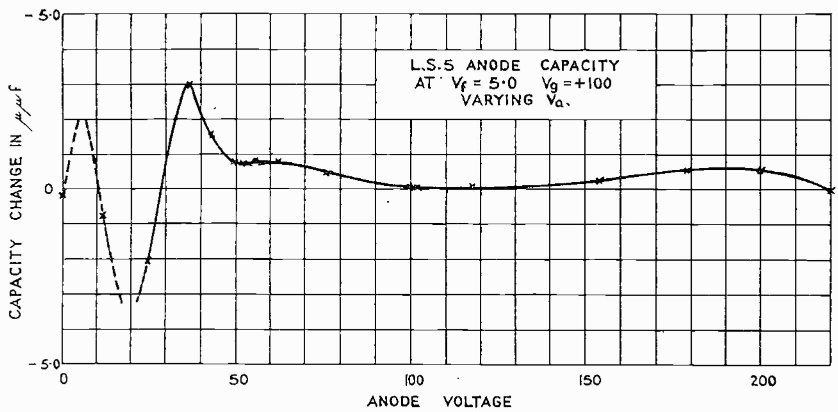


FIG. 12.

curve is given in Fig. 11. For the sake of comparison, on the score of secondary emission, a curve is also given in Fig. 12 for the capacity from anode to grid plus cathode of an L.S.5 under dynatron conditions (grid potential 100 volts, anode potential varied from 0 to 220 volts). The changes here are much larger than for the same valve under normal operating conditions with the grid at a small negative potential. This would appear to constitute a definite objection to the use of the dynatron oscillator, though of course there is no grid input capacity to consider.

ACKNOWLEDGMENTS.

The work described in this paper was carried out in the Engineering Laboratory, Oxford University, and the author wishes to thank Mr. E. B. Moullin for his many helpful suggestions and continued interest throughout.

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D. A. BELL.

MARCONI NEWS AND NOTES

MARCONI VETERANS' REUNION, 1935

THE Marconi Veterans held their Seventh Annual Reunion and Dinner on Saturday, the 9th November, at the Howard Hotel, Norfolk Street, London, under the Chairmanship of Mr. M. Travailleur, Director of the S.A.I.T., Brussels, who was supported by Mr. A. Hubert, Mr. F. S. Hayburn, Mr. H. W. Allen, Mr. Andrew Gray, Mr. C. E. Rickard and Mr. H. M. Dowsett.

At the Annual Meeting, which immediately preceded the Reunion, Mr. G. H. Green was unanimously elected Chairman for the ensuing year in place of Mr. Travailleur (retiring); with Mr. G. Pells as Deputy-Chairman, the remainder of the Standing Committee were re-elected "en bloc," and Mr. W. J. Collop signified his willingness to continue to act as Hon. Treasurer. The Chairman then informed the Meeting that, owing to the demands upon his time, the present Hon. Secretary (Mr. F. K. May) had asked to be relieved of that position. With regret, his resignation had been provisionally accepted. Mr. C. C. Howe had kindly offered to take over the work as Secretary, and he recommended that the thanks of the Meeting should be accorded to Mr. May for his services, and that Mr. Howe should be appointed Secretary in his stead. This course was agreed to by the Meeting.

It was proposed and agreed that the Annual Reunion and Dinner should take place in future on the last Saturday in October.

The meeting then terminated, and the members foregathered with the later arrivals at the Reunion. After a cheery, and by no means silent exchange of reminiscence and banter, the Veterans (83 in number) sat down to dinner.

The Secretary read telegrams and letters of good wishes and regrets for absence from H.E. The Marchese Marconi, Mr. A. H. Ginman, Marquis Solari, Mr. H. Jameson Davis, Mr. Gaston Perier, Mr. G. J. Boome at Peshawar, Mr. G. E. Turnbull at Gothenburg, and Messrs. Kroes, Mayer, Magnee, Stroink, Ten Hacken, Morel and Steverink of "Radio-Holland."

Following the Toast of The King, the Chairman proposed that of H.E. Marchese Marconi, which was accorded musical honours. Mr. Travailleur said: "I should first of all like to say how much we all regret the absence of our great leader, His Excellency the Marchese Marconi, who is prevented by circumstances from being with us this evening, and to propose that we send him from this room a message which might be couched in the following terms:—

> "'Marconi Veterans celebrating seventh annual reunion request me send you respectful greetings and assurance of whole-hearted devotion. I have much pleasure in sending this message in their name together with my own personal regards.
>
> TRAVAILLEUR.'

"Our last meeting was such a successful one that I feel sure that no one will mind if I make a short reference to it, to that part when our President that evening, Mr. H. M. Dowsett, sketched an extremely interesting picture concerning the evolution of wireless technique and theories and the early experiments carried out by Marconi which showed that the phenomena produced related not to an illimitable ether as previously thought, but to ether limited in some way to the space near the earth's surface.

"It may not be unfitting if this evening I make a few remarks on the evolution of the practical, commercial and industrial aspects of the utilisation of wireless.

"After having, with some difficulty, overcome the early and perhaps natural prejudices of scientists, telegraph administrations and eventually of shipowners, wireless has progressed by leaps and bounds. In every country of the old world its flag has been planted, vast enterprises employing countless engineers, staff and workpeople have sprung up, offering a new field of employment for thousands of people.

"Ever since civilisation began, space and the time taken to span it have been the great barriers between nations. Wireless has contributed in a large measure to break down these barriers, and citizens at the outposts of our more civilised world no longer find themselves isolated.

1895

His Excellency Marchese Marconi.

1897

Col. H. Jameson Davis, H.W. Allen,

1898

P.W. Paget, C.E. Rickard

1899

W. Densham, Andrew Gray, H.M. Dowsett, R.T. Munson, F.S. Stacey

F. Woodhouse, C.S. Franklin, P.J. Woodward, A.B. Blinkhorn, M. Travailleur, G. Perier

1900

W.H. Corby, R.N. Vyvyan, A.J. Clark, F. Archer, J. Harvie Clark, Sir Ambrose Fleming, A.H. Atkinson, E.E. Triggs,

1901

W.S. Entwistle, G.H. Green, A. Eve, Capt. C.V. Daly, G. Pell, E.G. Tyler,

F.E.D. Periera, F.K. May, A.H. Ginman, A. Vanderpooten, R. Houpart, H.E. Dunn, F. Huff,

1902

E. Berry, W.F. Thomas, R.D. Bangay, F.E. Burrowes, W. Davies, Capt. H.J. Round, R.G. Kindersley

H.A. Ewen, E.C. Richardson, A.A. Kift, J. Lewis, H.E. Watterson, R.G. Newman, W.M. Sampson, G.E. Turnbull,

1903

D.W. Tulloch, J.R. Stapleton, F. Jones, J. Harvey, A.J. Huff, H.T. Worrall, E.T. Hills, L. Verbrugghen,

1904

H.J. Tattersall, A.J. Irvine, T. Iddon, W.A. Taylor, W.T. McGhee, J.R. Robinson, W. Platt, W.J. Collop,

W.N. Ball, F.S. Hayburn, A. Cappelaere, H. Cornwall, F. Delasse, W.J. Gray, G. Ludwig,

1905

S.C. Parish, J.N. Johnson, J.P.G. Aylett, W.B. Cole, E.J. Wagstaff, C.A. Manson, C.A. Mason, H.M. Burrowes,

C. James, F.W.M. Herring, P. Treacy, A.C. Lewis, D. Macdonald, F.K. Fells, E. Horton,

1906

C.J. Ketteridge, Marquis L. Solari, F. Beatson, A.J. Chesterton, E. Hill, A.M. Young, D. Sutherland,

S. Stansbridge, Seton Smith, A. Ashley, W. Rogers, F. Baker, S.C. Hills, C.C. Howe, H.D. Humphries, T.E. Hobbs,

J.C. Hawkhead, S. Kent, A. Fournier, A. Maernoudt, Annie König, M.J. Tasteney, R.C.A. Kroes,

1907

H. Caswall, C.G. Rattray, T. Cox, J.H.T. Leggett, J. Connell, J.T. Marler, R. Cox, T.H. Stubbs,

E.J. Moore, C. Newar, H. Nicholls, A. Hubert, E.C. Montague, A. Cobham, S.T. Dockray,

1908

A.E. Merritt, W.J. Baden, J.F. Mencar, W.D. Lacey, W. Shore, L. Atkinson, P.L. Outred, J. Campion, J. Hance, E. Dyer,

1909

J. Torry, N. Palmer, E. Praill, T. Cox, S.A. Cumberland, P. Dumenil, A.E. Martin, E.W. Hynes, P.B. May, G.G. Chapman,

C.T. Sanders, B. Wheeler, C.H. Norris, R.C. Quick, R.K. Rice, R.H. White, G.J. Boome, R.H. Strickland, R.S. Calder,

H.E. Hardy, H.E. Shaw, T. Webb, G.S. Whitmore, G.H. Magnee, L.F. Meijer, R. Stroink, C. Cammaerts, J.M. Van Embden,

1910

E. Anthistle, W.J. Reeve, L.G. Hazell, G.H. Entwistle, L.G. Lucas, B.St.J. Sadler, P.E. Privett, G. Watling, D.H. Jones,

P.G. Beckerson, V.M. King, B. Gale, A.C. Caldwell, E.E. Frankis, A.J.P. Dalgairns, A.R. Bullemthorpe, C. Littaur, J.L. Gowers,

F. Haynes, S.D. Sloggett, L.A. Dods, C.W. Bailey, W.H. Venn, B.J. Witt, A.R. Harding, J. Mather, J.E. Auroche,

J.S. Smith, W.M. Brock, E. Blake, G. Meyer, C.J.M. Simpson, S.R. Groser, F. Garwood, C. Horton, F. Jefferies

M.J.W. Hicks, W. Sparkes, J.W. ten Hacken, E.J. Kemp, W. Pettengill, J. Hefford, W. Stiles, W. Vernon, A.G. Hills,

H.W. Hall, F. Noakes, J. Rogers, G. Mason, B.P. Morel, G.Th.J. Steverink, C.A. McKay, H. Fisher, F. Post, W. Young,

J. Jordan, F. Riches, J. Richmond, P. Partington, J.H. Golding, A.A. Hockley, F. Finch, F. Setuain, S. Asensio, "Only some fifteen years have elapsed since broadcasting began, and now 200 million listeners throughout the world receive broadcast programmes covering all fields of human endeavour.

"Radio broadcasting performs a unique function in relation to public opinion: it supplies a system of communication which places within easy reach of the public information, opinion, entertainment, and, not perhaps the least in importance, Education, to which the new infant Television will soon add its benefits and far-reaching effects.

"From hesitant beginnings, international radio communication circuits have been brought during past years to a high state of efficiency. The recent demonstration at the Alberteum—Brussels Exhibition—whence a radio message was sent twice round the world in 100 seconds, was a striking illustration of this.

"The development in the marine wireless service has been such that it is difficult nowadays to imagine a vessel of any importance without wireless equipment, and by way of illustrating the extent of this development it will suffice to mention that our inter-company organisation, the C.I.R.M., has to-day under its control no less than 8,000 wireless fitted ships.

"From the point of view of service it has rendered to Humanity, I say without fear of contradiction that the wireless marine service as organised to-day throughout the oceans of the world as a Telegraph Administration, and the contribution it has made to the problem of Saving Life at Sea, is hardly surpassed by any of the numerous radio applications of to-day.

"The tragic disaster of the 'Titanic' in April, 1912, demonstrated in sad but stirring manner the need for and use of wireless at sea, and the debt that Humanity owes to Marconi.

"The destruction of the 'Volturno' by fire in mid-Atlantic in October, 1913, when, thanks to wireless, aid was summoned in time to save over 500 lives, is another memorable instance still vivid in my mind.

"It was following upon these two accidents that one of your famous journals, 'Punch,' published a cartoon showing Marconi standing in the wireless room of a ship, with Mr. Punch in front of him holding a newspaper with a heading '"Volturno" Disaster.' The caption of the cartoon—I have it here—was :—

> "'S.O.S.—Mr. Punch (to Marconi): Many hearts bless you to-day, Sir. The world's debt to you grows fast.'

"Since then, thousands of lives have been saved: it would be difficult to estimate the actual number, but it is this aspect of the many applications of wireless that it pleases me to recall this evening.

"May we hope that the increased application of the other radio developments I have referred to, which provide the nations of this world with a quicker way of learning about each other, will be the means of creating better unity and more peaceful relations between them, for does not misunderstanding thrive on ignorance?

"Gentlemen, I ask you to raise your glasses and drink to the health of His Excellency The Marchese Marconi."

The following message was later received from H.E. Marchese Marconi :—

> "Sincerest thanks for kind affectionate greetings most heartily reciprocated. Extremely sorry not have been able attend Reunion which always warms my heart. Hope have better luck next year. MARCONI."

Proposing the Toast of the "New Members," Mr. H. A. Ewen said it was self-evident that the importance and interest in the Marconi Veterans' annual reunion would increase year by year, and the function might even, in course of time, become one of international importance. To become a Marconi Veteran was no mean honour. To be elected, one had to serve a probationary period of 25 years in one or other of the Marconi organisations, either at home or overseas. The present year had been exceptionally prolific in the production of new Veterans, for there had been an addition of 66 to the Roll, and amongst those new Veterans they had the pleasure of welcoming Messrs. J. Asensio and F. Setuain of the Spanish Company, Mr. L. G. Lucas of the Belgian Company, and Messrs. W. M. Broek, J. W. ten Hacken, B. P. Morel and G. Th. J. Steverink of Radio-Holland. He felt it would be agreed that we ought to give a special welcome to these Veterans from overseas, for the object of the Reunion was to bring together old comrades, all of whom had spent the best part of their lives in the building up of the vast wireless organisations, the personnel of which labour under the Marconi flag in every country throughout the world.

Responding for the New Members, Mr. B. St. J. Sadler said he understood that the Hon. Secretary was grateful to him for consenting to reply to the toast of the " New Members." He also understood, from the same source, that there were something like 28 of the 66 New Members present, and by the same token, he felt there were 28 other gentlemen equally grateful to him. It was a law of nature that we must grow old, but to grow old in congenial company was a privilege which one enjoyed in this society, and looking back on his 25 years of service, he appreciated that membership was also a guarantee of a very fine constitution. On behalf of the New Members, he thanked Mr. Ewen and all others present for the hearty welcome extended to him and the other " this year " Veterans.

The Toast of " Absent Members " was proposed by Mr. H. E. Watterson, who, after touching upon the greatly regretted absence of H.E. The Marchese Marconi, referred specially to the inability of three colleagues—Mr. J. Asensio and Mr. F. Setuain of the Spanish Company, and Mr. L. G. Lucas of the S.A.I.T.—to be present that evening owing to the demands of duty and the lengthy travel which attendance would have entailed. It seemed hardly credible, he said, that it was 23 years ago that Mr. Lucas and he were climbing mountains in Brazil together. There were other Veterans who, because of distance and other obstacles, could not be with them that evening. There were also those, like Messrs. Blinkhorn and Stacey, who, but for ill health, would have been with them. But wherever those absent friends might be, the thoughts of all present went out to them.

The Toast of " The Chairman " was proposed by Mr. F. S. Hayburn, who said that he first had the honour and pleasure of meeting Mr. Travailleur in the days of the old Compagnie de Télégraphie sans Fil. For fifteen years Mr. Travailleur was his supreme chief, and he could assure those present that when, as a subordinate, he was in that gentleman's presence, he felt that here was, indeed, a great mind. Mr. Travailleur had been identified with wireless since 1900, and many of those present, permeated with the British idea of isolation, were unaware of the great part Mr. Travailleur had played in the furtherance of the great ideals of their illustrious chief, the Marchese Marconi. It was Mr. Travailleur who was principally responsible for the early development and extension of marine wireless among all the Continental nations, and there was not the slightest doubt that directly and indirectly all Veterans had profited to a great extent by Mr. Travailleur's far-sighted diplomatic business methods.

Responding, Mr. Travailleur said that he appreciated very highly Mr. Hayburn's remarks, and thanked him for his reference to the role which he and his Belgian friends had played in the early days of wireless. He referred in laudatory terms to the loyal and fruitful co-operation he and his colleagues had enjoyed with the Marconi organisation and to the fine spirit of international collaboration which had existed from the outset and still continued. They had amongst them, that evening, several who had taken a very intimate part in the work of development on the Continent. Mr. Hayburn, himself, had spent many years of his life in Brussels, and he recalled, with the greatest pleasure, his valuable collaboration. He could not conclude his remarks without saying how much he admired the high spirit of unity and comradeship which prevailed amongst the Marconi Veterans—a spirit which enabled men of all nationalities and all ranks to meet, as they were doing that evening, in true friendship and brotherhood.

Between the speeches Veterans listened to an enjoyable concert programme under the capable management of Mr. Harry Heap, the artists being Mr. Reginald Johnson, baritone, and Mr. Charles Plantaganet Hayes, comedian.

Altogether it was a very happy gathering which broke up reluctantly, at 10.30 p.m., the credit for its success being largely due to the efforts of the indefatigable Hon. Sec., Mr. F. K. May.

Police Wireless.

WIRELESS is now fully established as an invaluable aid to the Police. The Marconi Company has made a special study of apparatus suitable for this purpose and has been responsible for the supply of wireless equipment to police organisations in many parts of the world.

A demonstration of Marconi police wireless apparatus was recently given in Scotland before high officials of the Scottish Office at Glasgow. In spite of difficult conditions such as driving alongside trams, stopping under bridges, etc., reception on the police van carrying out the demonstration was consistently good throughout a six hours' test in the City of Glasgow. This was followed by a demonstration in the country districts, when messages were received without difficulty when the demonstration car was travelling at 60 miles per hour along country roads.

The complete success of the demonstration and the efficiency of the Marconi apparatus used are indicated by the remark of one of the principal police officials, who said: "In my opinion this apparatus is far ahead of any other equipment in use at the present time."

Marconi Aircraft Service Department.

THE rapid expansion of air services from England to the continent of Europe as well as within Great Britain has occasioned a corresponding increase in the activities of the Marconi Aircraft Service Department, in view of the large number of commercial machines fitted with Marconi wireless apparatus.

Marconi Aircraft Service Section at work at Croydon Aerodrome.

The Main Service Depot is located at the Croydon Aerodrome, near London, where well-equipped repair shops and stores, approved by the British Air Ministry, containing spare aircraft installations, as well as all kinds of accessories, are available, so that repairs and replacements can be effected expeditiously.

The accompanying photograph illustrates the delivery of a Marconi aircraft set to an Imperial Airways machine for fitting.