TELEPHONY BY CARRIER AND ONE SIDE BAND.

By S. P. Chakravarti.

Introduction.

Up to the present time, commercial telephony has always been by one of the two following methods:—

(*a*) transmission on a single side band;

(*b*) transmission on carrier and both side bands.

Method (*a*) requires a supply of carrier current at the receiving end but has now been generally adopted because of the following advantages:—

(1) Smaller line currents are employed; (2) the reproduction of speech is better (since the amplitude of the speech currents in the demodulator output circuit is proportional to the product of the amplitudes of the carrier current and that of the corresponding side band component); and (3) a band pass filter of much smaller width is necessary.

A third method of transmission should be possible by the use of carrier and one side band only. This method would have the following advantages:—(1) it is not necessary to supply the carrier current at the receiving end, as in method (*a*); and (2) the width of the filter need not be so large as in method (*b*).

If f_c be the carrier frequency and f_1 and f_2 the limiting frequencies of the speech band (f_1 about 200 cycles/sec., and f_2 about 2700 cycles/sec.), then the upper side band extends from f_c+f_1 to f_c+f_2 and the lower side band from f_c-f_2 to f_c-f_1. Now a band pass filter passing alternating currents of frequencies f_c to f_c+f_2 cycles/sec. should pass the carrier and the upper side band. Again at the receiving end, it might be possible for the alternating currents of frequency f_c and frequencies from f_c+f_1 to f_c+f_2 to operate at any working point on the grid-voltage anode-current characteristic of the demodulator as if the carrier frequency and the side band existed separately. If such a filtration of the carrier and the upper side band from the lower side band and the separate existence of the carrier be possible, the third method of transmission could be obtained. This paper shows that a telephone system can be developed on the above lines.

Theory.

Consider, for simplicity, that a carrier frequency f_c modulated by a single frequency f_2 is to be transmitted. If $\omega_c=2\pi f_c$ and $\omega_2=2\pi f_2$, then, in the course of modulation by the anode choke method, frequencies f_c+f_2, f_c and f_c-f_2 are obtained. By means of a band pass filter, the frequencies f_c and f_c+f_2 are separated and passed over the line. At the receiver end, frequencies f_c and f_c+f_2 are applied to the grid of the demodulator valve which is adjusted to operate on the lower parabolic portion of its v_g-i_a characteristic.

Suppose

$$i_a = A + Bv_g + Cv_g^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

is the equation of the lower portion of the characteristic and the voltage v_g applied to the grid of the demodulator is represented by

$$v_g = V_c \sin \omega_c t + V \sin (\omega_c + \omega_2)t \ldots\ldots\ldots (2)$$

Substituting (2) in (1), we have

$$i_a = A + BV_c \sin \omega_c t + BV \sin (\omega_c + \omega_2)t + CV_c^2 \sin^2 \omega_c t + CV^2 \sin^2 (\omega_c + \omega_2)t$$
$$+ 2V_c VC \sin \omega_c t . \sin (\omega_c + \omega_2)t.$$
$$= A + BV_c \sin \omega_c t + BV \sin (\omega_c + \omega_2)t + \tfrac{1}{2}CV_c^2 (1 - \cos 2\omega_c t) +$$
$$\tfrac{1}{2}CV^2 [1 - \cos 2(\omega_c + \omega_2)t] - CV_c V[\cos \omega_2 t + \cos (2\omega_c + \omega_2)t].$$

Thus the plate current of the demodulator would have six frequencies

$$f_c;\ f_c + f_2;\ 2f_c;\ 2(f_c + f_2);\ f_2;\ 2f_c + f_2.$$

All frequencies higher than f_2 can be filtered off by a low pass filter leaving only f_2. This is the audible frequency signal current which can thus be isolated and further amplified if necessary.

If, instead of a single frequency f_2, a frequency band extending from f_1 to f_2 is transmitted, it is evident that at the transmitting end there will be the two side bands, from $f_c + f_1$ to $f_c + f_2$ and from $f_c - f_2$ to $f_c - f_1$, and the carrier frequency f_c. By means of a band pass filter passing frequencies from f_c to $f_c + f_2$, the carrier f_c and the upper side band $f_c + f_1$ to $f_c + f_2$ would be passed over the line.

Also, the plate current of the demodulator would have two single frequencies and four frequency bands as follows:—

f_c; band $f_c + f_1$ to $f_c + f_2$; $2f_c$; band $2(f_c + f_1)$ to $2(f_c + f_2)$; band f_1 to f_2; band $2f_c + f_1$ to $2f_c + f_2$.

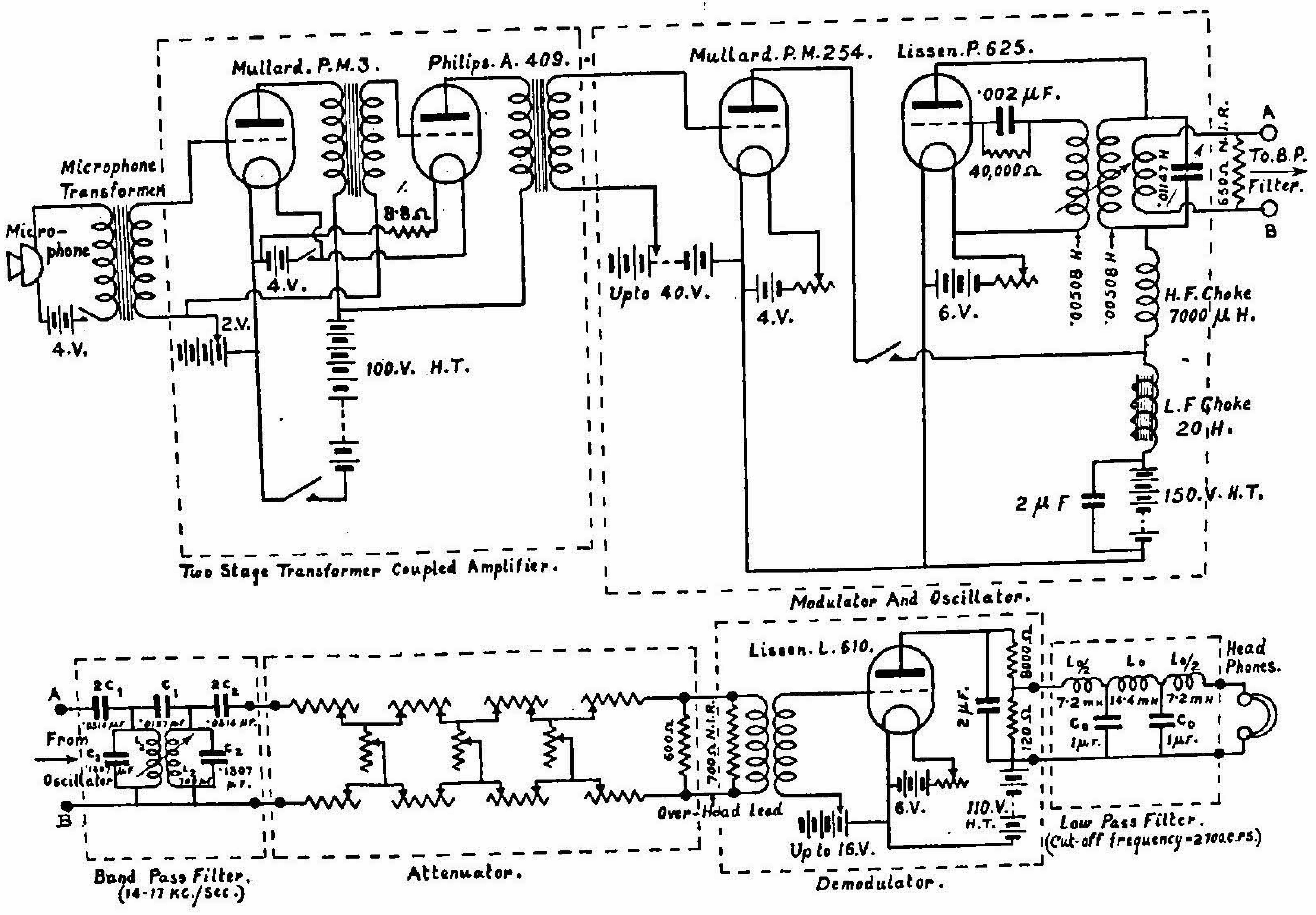
The higher frequencies and frequency bands would be filtered off by a low pass filter, giving the speech band f_1 to f_2.

Experimental.

The transmitting and receiving circuits were designed for an overhead line having a characteristic impedance of 650 ohms. The complete circuit diagram is given in Fig. 1. The characteristics of filters are given in Figs. 2 and 3. As far as possible all circuit impedances were matched on the input and output sides.

Speech Circuit:—This consists of a carbon microphone transmitter, a four-volt battery and a microphone transformer feeding into a two-stage transformer-coupled amplifier, having a uniform voltage amplification of about 120 in the voice range. The valves used were Mullard P.M. 3 ($R = 13{,}000\Omega$, $\mu = 14$) and Philips A. 409 ($R = 14{,}300\Omega$, $\mu = 9$).

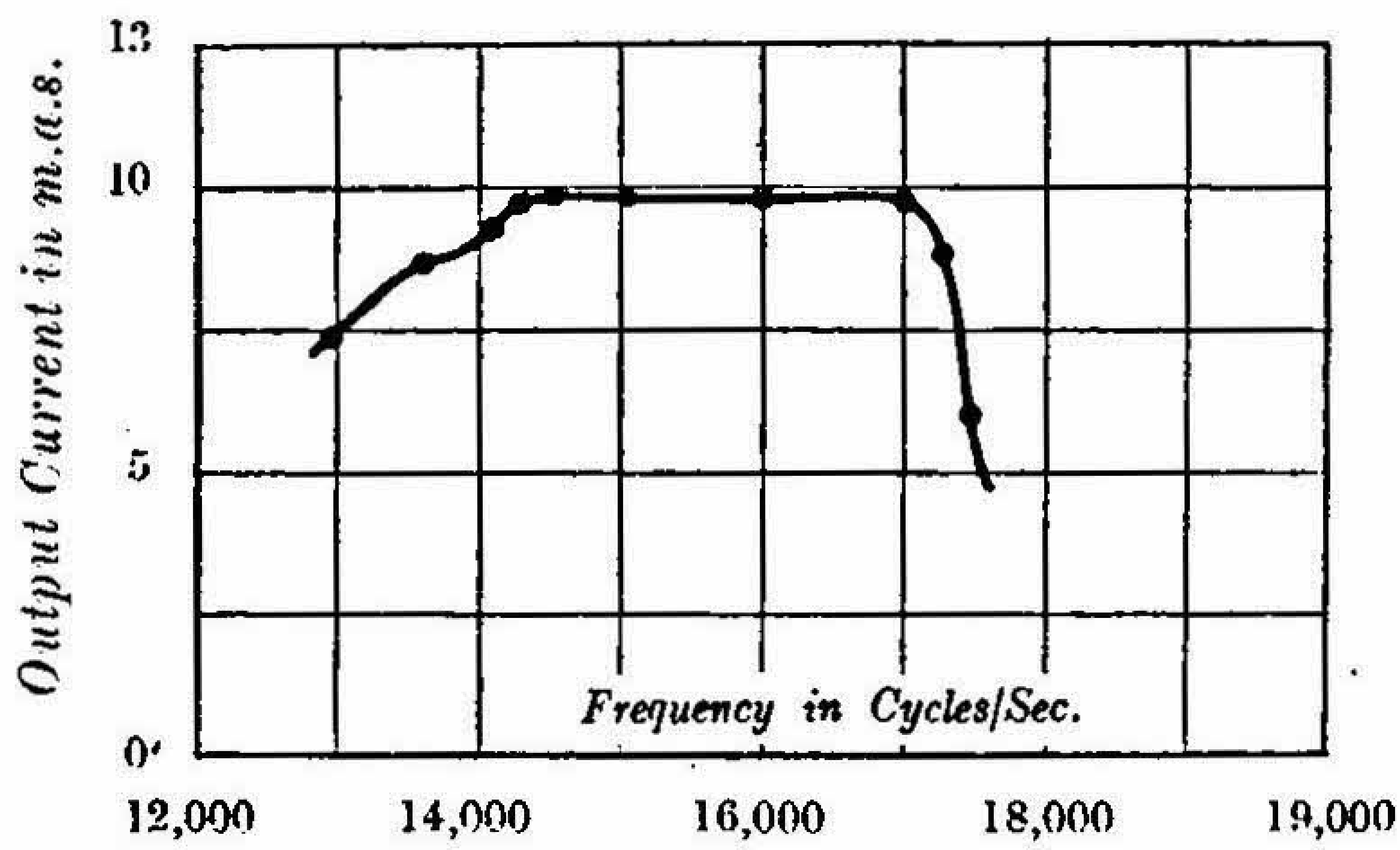
FIG. 1—*Circuit Diagram of Single One-Way Carrier Telephone Channel.*



Modulator and Oscillator Unit:—A Mullard valve P.M. 254 ($R=2{,}000\Omega$, $\mu=4.2$) was used as the modulator. A negative bias of 24 V. was necessary for working it on the straight portion of the characteristic. The anode choke method of modulation was adopted. The oscillator valve was a Lissen P. 625 ($R=2{,}500\Omega$, $\mu=7.5$). The output of the oscillator was nearly constant over the frequency range used.

Band Pass Filter:—The values of the elements were as follows:— $C_1=.0157\ \mu F$; $C_2=.1307\ \mu F$; and $L_2=700\ \mu H$. The total d.c. resistance of the coils was 3.8 ohms and the filter was designed to work between terminal impedances of 650 ohms. The output current frequency characteristic of the filter was nearly flat from 14 to 17 KC/sec. with an output impedance of about 678 ohms.

FIG. 2—*Output Current–Frequency Characteristic of the Band Pass Filter*

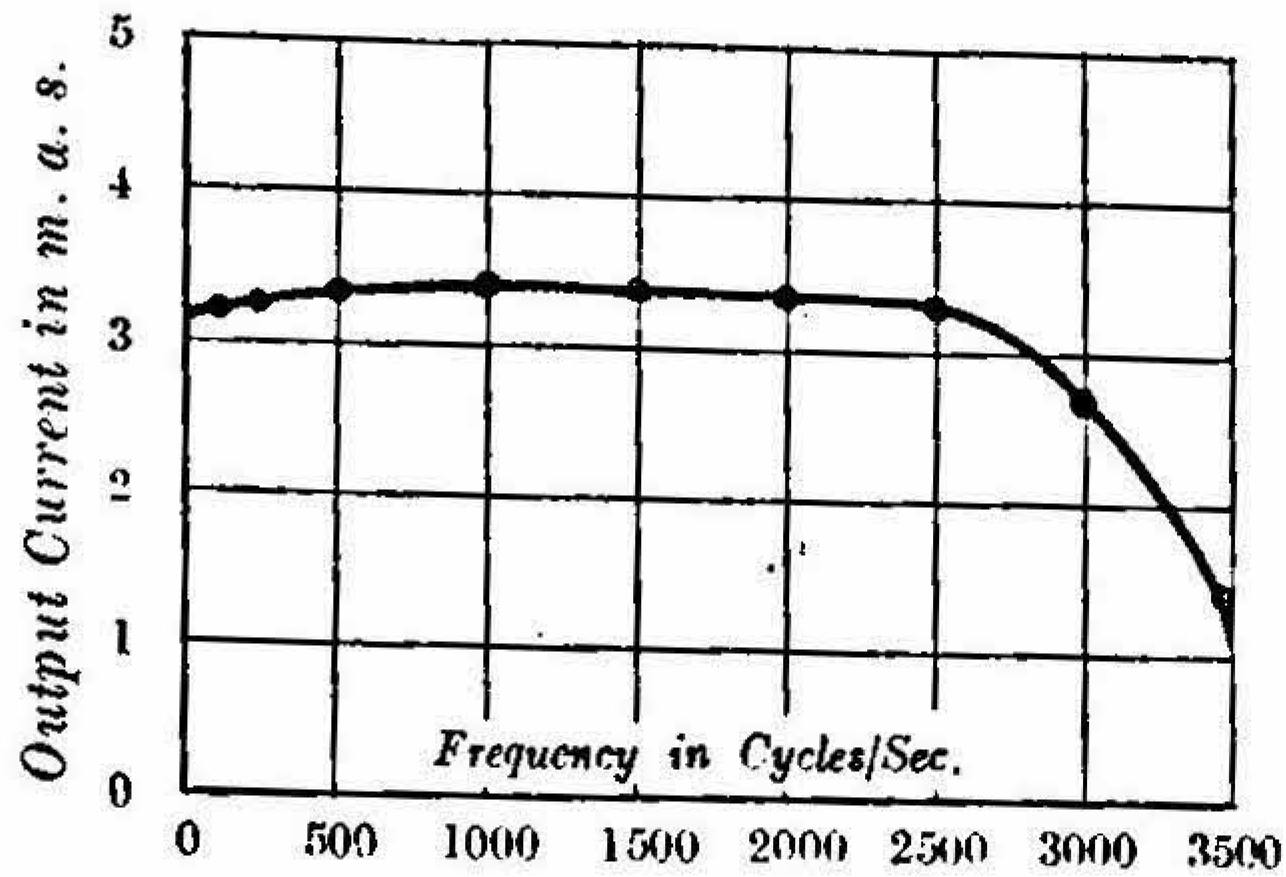


Attenuator:—As the experiments were carried out in the laboratory, the transmitting and receiving station being in different rooms, a pure resistance attenuator graduated in decibels and having a characteristic impedance of 600 ohms when terminated by a non-inductive resistance of 600 ohms was used instead of the overhead line. An overhead lead, about 30 yards long, was taken to the receiver end from the attenuator. On the receiving side, the non-inductive shunt to the primary of the input transformer was adjusted to 700 ohms to bring down the terminal impedance to about 600 ohms, to match the line impedance.

Demodulator:—A Lissen valve L. 610 ($R=8{,}000\Omega$, $\mu=16$) was used as the demodulator. A bias of about —6.0 V. was applied to the grid to bring the working point down to the parabolic portion. The low pass filter was connected across a 120 ohm tap on the anode resistance of this valve.

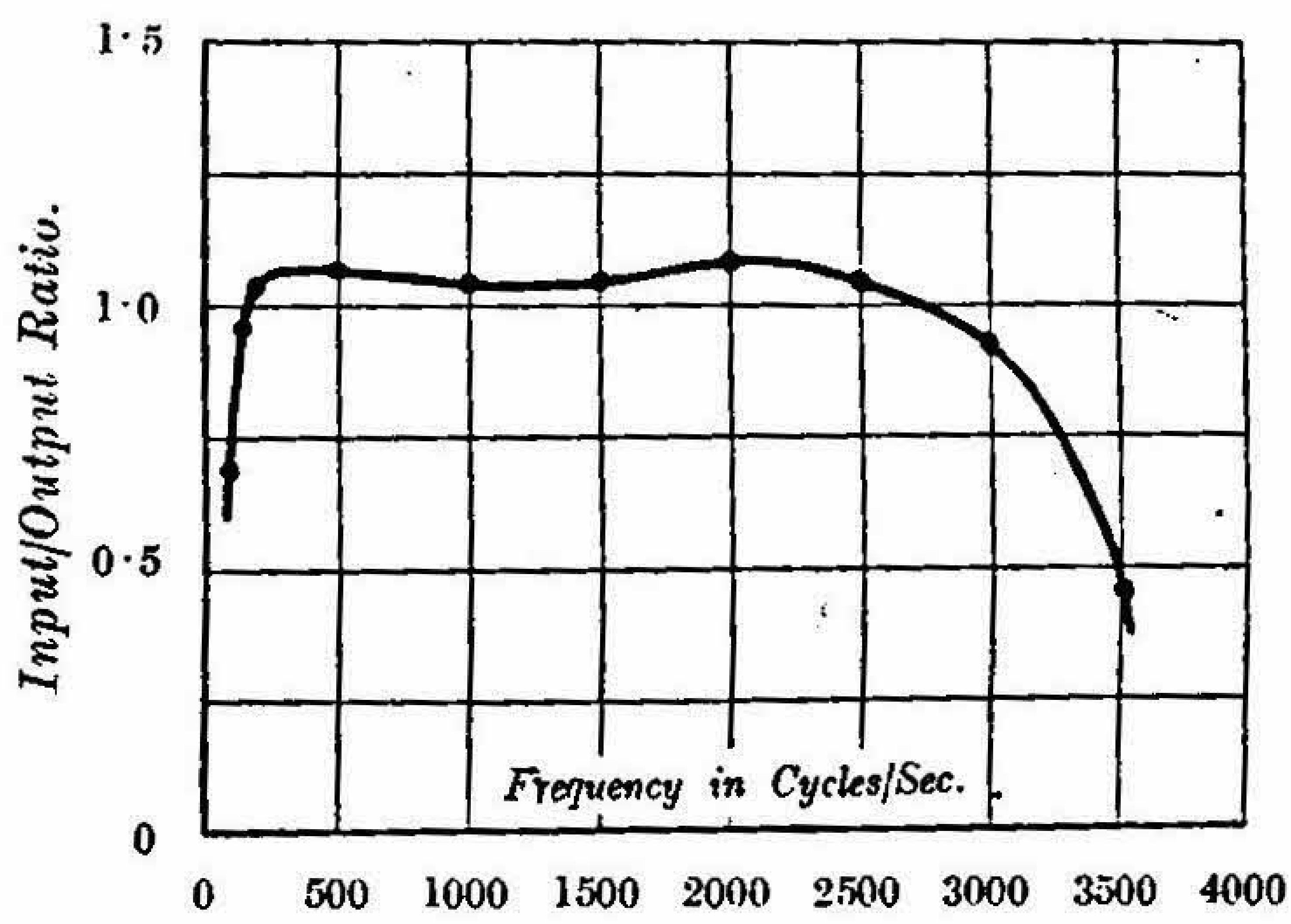
Low Pass Filter:—The values of the elements were as follows:— $L_0=14.4$ mH, $C_0=1.0\mu F$, and the filter was designed to have a surge impedance of 120 ohms. The total d.c. resistance of the coils was about 21 ohms, and the cut-off frequency was about 2700 cycles/sec.

FIG. 3 *Output Current–Frequency Characteristic of the Low Pass Filter.*



The ratio of amplifier input to low pass filter output was measured at different frequencies, with a carrier of 14.3 KC/sec., filter input impedance of 650 ohms and an artificial line of 3 decibels. The results are shown in Fig. 4. Speech transmission over the same circuit gave clear reproduction.

FIG. 4—*Overall Transmission Characteristic of the System.*



Conclusion.

The experiments indicate that the carrier behaves in the demodulator as if it had a separate existence from the side band. The band pass filter passed the carrier frequency and the upper side band, and these two operated on the parabolic part of the demodulator grid-voltage anode-current characteristic to give the frequencies and frequency bands from which the speech band was isolated. No carrier was supplied at the receiving end, as none was necessary.

The possibility of a third method of telephonic transmission, namely by carrier and one side band, is thus established. The advantages claimed may be summed up as follows:—

(1) A supply of the carrier current at the receiving station is unnecessary.

(2) The frequency band occupied is only half that required by the usual system with two side bands.

(3) The carrier and the side band undergo the same amount of phase change in passing through the filters, line apparatus, etc., so that the reproduced speech does not suffer from phase distortion as in the suppressed carrier method. This is of importance if transmission is to be over long distances.

A disadvantage is that the speech band cannot be amplified by supplying a carrier of large amplitude at the receiving station as in the suppressed carrier method, but has to be amplified by voice frequency amplifiers.

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Department of Electrical Technology,
Indian Institute of Science,
Bangalore.

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