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MULTIPLEX PHASE DISCRIMINATION TRANSMISSION SYSTEM

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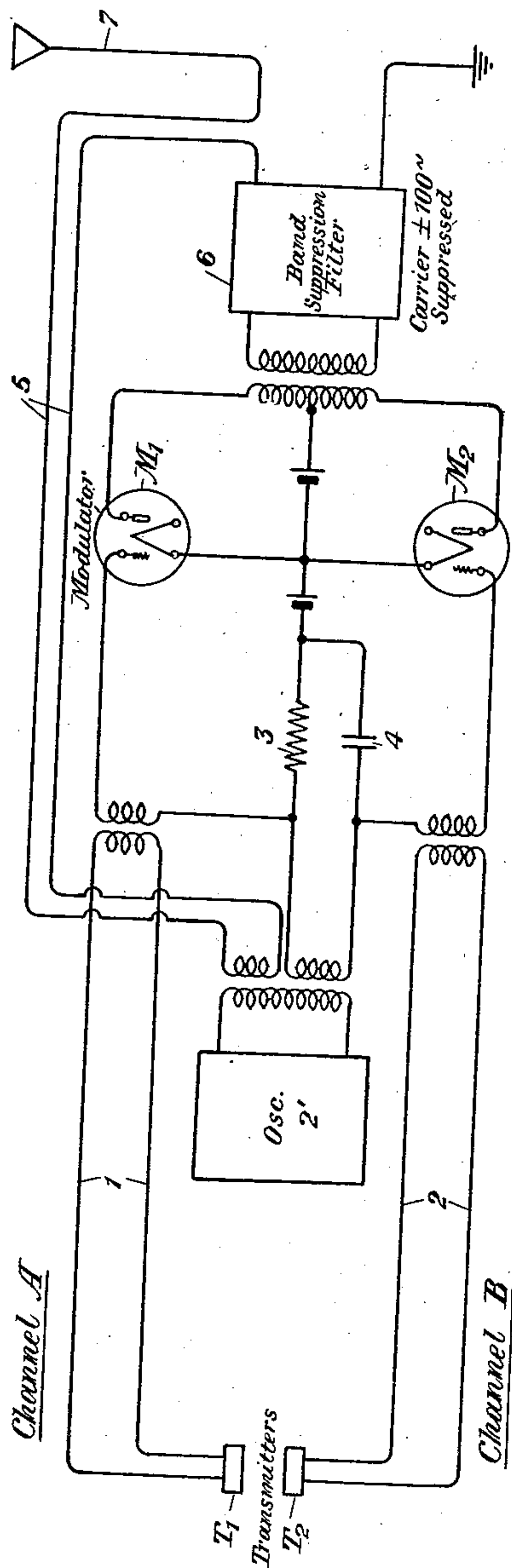


Fig. 1

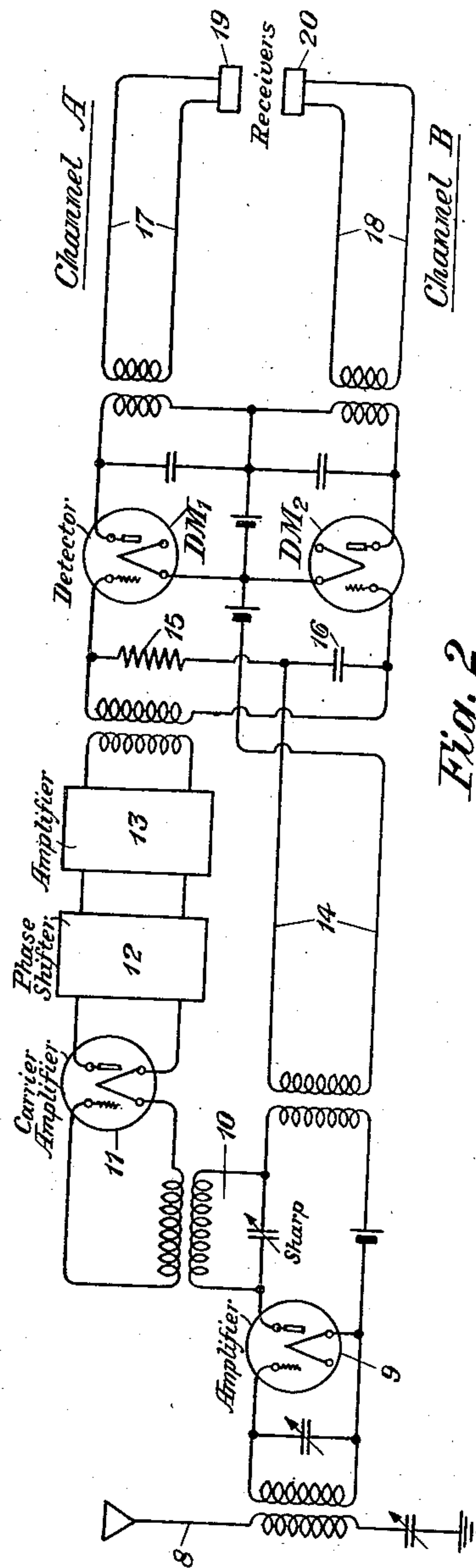


Fig. 2

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MULTIPLEX PHASE DISCRIMINATION TRANSMISSION SYSTEM

Application filed October 30, 1928. Serial No. 315,995.

This invention relates to high frequency signaling systems and more particularly to diplex transmission systems whereby two independent message channels may be obtained from one high frequency channel by means of phase discrimination.

In the prior art, there are to be found a number of different types of systems for obtaining a plurality of message channels from a single high frequency channel by means of phase discrimination. One of such types of systems is illustrated in a Patent No. 1,608,566 to R. K. Potter, November 30, 1926. In this patent, the diplex phase discrimination system disclosed is utilized for the binaural transmission of sounds. It is pointed out that this is but one of the many uses to which such a diplex transmission system as is disclosed therein could be put. It is pointed out that a system of the type disclosed in said patent is capable of diplex use in general. In other words, it might be utilized for the transmission of messages from two separate sources rather than from a single source. The above mentioned patent is referred to only as an illustration of a specific method of diplex transmission utilizing phase discrimination purposes and capable of other uses than for binaural transmission. Accordingly, the arrangements of the invention are applicable to multiplex phase discrimination systems in general, and in particular to systems for binaural transmission.

It is pointed out that in systems of the type illustrated in the above patent it is essential that the carrier currents used for detection in the receiving set, whether transmitted or generated locally, should have definite, constant phase relations with the carrier currents used at the transmitting station. One of the methods in the above mentioned types of systems has been to employ for this purpose the usual component of the carrier frequency in the transmitted output. This component will be the resultant of two similar components 90° apart in phase, one for each of the two independent message channels. However, it has been found that there are important limitations in the use of said carrier component in this connection. This is due to the

fact that at the receiving station the circuit used for selecting the carrier component cannot be made infinitely sharp, and will thus allow slow variation in the amplitude of the carrier component, corresponding to the modulation from the lower frequencies of the voice. Since the two channels are independent the components of the carrier frequency in these will vary in magnitude independently. This will vary the phase of the resultant with respect to either of the carrier components, thus violating the requirement that such phase angle be constant. This effect is more pronounced as the modulation is greater—the limitation therefore consists in the necessity of keeping the modulation small. Accordingly, the primary object of the arrangement of this invention is to provide a novel method for transmitting current to perform this function when amplified at the receiving station, which will avoid the limitations existing in former systems. Other features and objects of the invention will appear more fully from the detailed description hereinafter given.

In the method of this invention, a certain amount of entirely unmodulated carrier current is superimposed on the regular modulated current. To prevent confusion between the two, current of the carrier frequency itself and in a narrow band (of say 100 cycles) on each side of it is eliminated from the regular modulated current by a band suppression filter. The unmodulated carrier current will have unvarying phase relations with the modulating current drawn from the oscillator. At the receiving end this unmodulated carrier is separated from the rest of the current by a sharply tuned circuit and passed through a phase shifter and amplifier to the phase discrimination apparatus for purposes of detecting.

The invention may be more fully understood from the following description, together with the accompanying drawings, in the Figures 1 and 2 of which the invention is illustrated. Fig. 1 is a circuit diagram of a radio transmitting station, and Fig. 2 is a circuit diagram of a radio receiving station embodying principles of the invention.

In Fig. 1 are shown two transmitters T₁

and T_2 connected to circuits 1 and 2, whereby the separate channels A and B may be transmitted to the tubes M_1 and M_2 of a modulator of the well known duplex type. Associated with the modulator is an oscillator 2'. Current from this oscillator of carrier frequencies is passed through a resistance 3 and a condenser 4 in series. The potential differences across these will be 90 degrees out of phase with each other. On one and the other of these, respectively, are superimposed the modulating currents from channels A and B. After modulation the currents from the two channels will be transmitted through the band suppression filter 6 and thence to the sending antenna 7 or any other desirable type of transmitting circuit. The band suppression filter 6 will eliminate current of the car-

$$\frac{i_2}{k} = V^2 \sin^2 \omega t + 2V \sin \omega t [f(t)] + [f(t)]^2 + 2Vc_2 \sin \omega t + 2f(t)c_2 + c_2^2 \quad 85$$

rier frequency itself, and in a narrow band on each side of it. A circuit 5 will superimpose on the regular modulated current in the output circuit a certain amount of entirely unmodulated carrier current from the oscillator 2'. At the receiving station the signals will be received by a suitable device such as the antenna 8 and amplified by the tube 9. The unmodulated carrier current will be separated from the rest of the current by a sharply tuned circuit 10. The width of the band suppressed by filter 6 should be greater than that of the band transmitted by the tuned circuit 10 so that no current of frequencies in the side-bands resulting from the modulation in tubes M_1 and M_2 will pass through the tuned circuit 10. The unmodulated carrier current will then be passed through the amplifier 11, phase shifter 12, and amplifier 13 to the phase discrimination apparatus comprising the detector tubes DM_1 , DM_2 , and the input circuits associated therewith which have the resistance 15 and condenser 16 connected in series. The rest of the signaling currents will be transmitted over the circuit 14 to the detector apparatus. These currents will be detected by the phase discrimination apparatus in a well known manner, and channels A and B will be transmitted over the circuits 17 and 18, respectively, to the receivers 19 and 20.

The theory of operation of the principles of a phase discrimination system is explained briefly below.

The general principles of operation of a two-channel radio telephone system using phase discrimination are as follows:

Let the voice current from channel A impress on its appropriate grid a voltage

$$v_1 = f(t).$$

The carrier current

$$i_1 = I \sin \omega t$$

where

$$\omega = 2\pi \times \text{carrier frequency}$$

will impress on the same grid a voltage

$$v_2 = V \sin \omega t \quad 70$$

so that the total grid voltage for channel A, including the "C" battery voltage, will be

$$v_3 = V \sin \omega t + f(t) + c_1.$$

The plate current of a vacuum tube is, in terms of the grid voltage,

$$i_2 = k (v_3 - c)^2$$

where k and c are constants characteristic of the tube. In the present case, then

$$i_2 = k [V \sin \omega t + f(t) + c_1]^2$$

The voltage output at the plate will be substantially proportional to this current, and can be indicated by simply changing the numerical value of k .

The voltage on the output side of the output transformer will be similar, except that the high frequency term, $V^2 \sin^2 \omega t$ and the low frequency and constant terms $[f(t)]^2$, $f(t)c_2$, and c_2^2 are likely to be much reduced if the operating range of the transformer is for frequencies of the order of magnitude of

$$\frac{\omega}{2} \quad 100$$

Assuming these very high and very low frequency terms to be negligible, either due to the inefficiency of the transformer or to appropriate filters

$$\frac{V_4}{k} = [Vc_2 + Vf(t)] \sin \omega t \quad 105$$

This may be written

$$v_5 = [a + f(t)] \sin \omega t \quad 110$$

where v_5 is now simply proportional to the voltage instead of equal to it.

Considering channel B, the voice current will impress on the grid a voltage

$$v_6 = g(t) \quad 115$$

The same carrier current as before, but in the opposite direction

$$i_2 = -I \sin \omega t \quad 120$$

will impress on the grid a voltage

$$v_7 = -V \cos \omega t$$

giving a total grid voltage of

$$v_8 = -V \cos \omega t + g(t) + c_1. \quad 125$$

The plate voltage will be proportional to

$$v_9 = V^2 \cos^2 \omega t - 2V \cos \omega t [g(t)] + [g(t)]^2 - 2Vc_2 \cos \omega t + 2g(t)c_2 + c_2^2 \quad 130$$

The output transformer voltage will be proportional to

$$v_{10} = -[b + g(t)] \cos \omega t.$$

5 The total voltage from channels A and B superimposed will be

$$v_{11} = [a + f(t)] \sin \omega t + [b + g(t)] \cos \omega t.$$

10 In the antenna, if the carrier frequency itself is not suppressed, the voltage will be proportional to this (the case where the carrier frequency is suppressed corresponds to the special case $a=b=0$).

15 The receiving modulated carrier voltage will also be proportional to this. For channel A there is superimposed upon this voltage

$$v_{12} = A \sin \omega t$$

giving a total voltage

$$20 \quad v_{13} = [A + a + f(t)] \sin \omega t + [b + g(t)] \cos \omega t.$$

This is equivalent to

$$v_{13} = \sqrt{[A + a + f(t)]^2 + [b + g(t)]^2} \sin [\omega t + \phi(t)]$$

25 Expanding the radical by Taylor's series

$$v_{13} = [A + a + f(t)] \left[1 + \frac{1}{2} \left(\frac{b + g(t)}{A + a + f(t)} \right)^2 + \dots \right] \sin [\omega t + \phi(t)].$$

30 The second factor above, in so far as it is different from 1, represents interference from channel B. It will be noted that the first order term is missing, and that the second order term may be reduced by making A large in comparison with the other quantities, and by making a and b small. The amplitude A may be made large by the use of amplifiers, as shown in the drawings.

40 The voltage after rectification will be the envelope of the above, or

$$v_{14} = A + a + f(t)$$

if the interference is negligible. Upon removing the constant component, there remains

$$v_{15} = f(t)$$

which is impressed upon the telephone receiver. A similar demonstration would follow for the B channel.

50 The component of carrier frequency in the transmitted output, when not suppressed, can be used for securing the necessary phase relations at the receiving end, only with limitations, as shown below.

55 The output voltage from the transmitting antenna is

$$v_{11} = [a + f(t)] \sin \omega t + [b + g(t)] \cos \omega t$$

or

$$60 \quad v_{11} = \sqrt{[a + f(t)]^2 + [b + g(t)]^2} \sin \left[\omega t + \tan^{-1} \left(\frac{b + g(t)}{a + f(t)} \right) \right]$$

The received voltage will be the above which will furnish the detecting current by

passing through a device arranged to give a constant amplitude (say an overloaded amplifier), or giving

$$70 \quad v_{16} = K \sin \left[\omega t + \tan^{-1} \left(\frac{b + g(t)}{a + f(t)} \right) \right]$$

The phase of this voltage will vary with time. The range of variation of this phase will depend upon a , b , and the range of variation of $f(t)$ and $g(t)$. The usual and interesting case is when both channels A and B are substantially similar, so that $a=b$ and $f(t)$ and $g(t)$ vary between the same limits, say between m and $-m$. Then the range of phase variation will be

$$\Psi = \tan^{-1} \frac{a+m}{a-m} - \tan^{-1} \frac{a-m}{a+m}$$

or approximately

$$\Psi = \tan^{-1} \left(1 + \frac{2m}{a} \right) - \tan^{-1} \left(1 - \frac{2m}{a} \right).$$

The Taylor series for the arc tangent ex-

panded about the value 1 is

$$\tan^{-1}(1+h) = \frac{\pi}{4} + \frac{h}{2} - \frac{h^2}{4} + \frac{h^3}{12} \dots$$

hence

$$\Psi = \frac{\pi}{4} + \frac{m}{2} - \frac{\pi}{4} + \frac{m}{a}$$

$$\Psi = \frac{2m}{a} \text{ radians.}$$

Thus it is necessary under these circumstances to keep the modulation small, i. e., m small compared with a . Assuming that the range of phase variation should be kept with $+5^\circ$, then a must be made more than about 24 times as large as m (since only first order terms have been kept the expression is not very accurate unless Ψ is small).

This invention is in part a continuation of application Serial No. 230,877, filed November 3, 1927, in the name of Smart Brand and Pierre Mertz.

While the invention has been disclosed as embodied in certain specific arrangements which are deemed desirable, it is understood that it is capable of embodiment in many and other widely varied forms without departing from the spirit of the invention as defined by the appended claims.

What is claimed is:

1. In a system for the binaural transmission of signals, the method which consists in

the modulation of a carrier by signal variations resulting from sound waves to produce side bands and a modulation component of carrier frequency, separately modulating by another set of signal variations resulting from sound waves from the same source carrier oscillations of the same frequency as employed in the first mentioned modulation operation but differing in phase by 90° therefrom to produce side bands and a modulation component of carrier frequency, eliminating the resultant of both modulation components of carrier frequency, and transmitting both sets of side bands and a monophase current of carrier frequency.

2. In a system for the binaural transmission of signals, the method which consists in the modulation of a carrier by signal variations resulting from sound waves to produce side bands and a modulation component of carrier frequency, separately modulating by another set of signal variations resulting from sound waves from the same source carrier oscillations of the same frequency as employed in the first mentioned modulation operation but differing in phase by 90° therefrom to produce side bands and a modulation component of carrier frequency, eliminating the resultant of both modulation components of carrier frequency, transmitting both sets of side bands and a monophase current of carrier frequency to a receiving station, selecting said monophase current of carrier frequency from said side bands at said receiving station, and utilizing said current of carrier frequency for phase discrimination detection of said side bands.

3. In a system for the binaural transmission of signals a transmitting station having means to separately modulate carrier oscillations by the signal variations resulting from sound from the same source, the carrier oscillations being of the same frequency but differing in phase by degrees, thereby producing side bands and two modulation components of carrier frequency, means to eliminate from the transmitted output the resultant of the two modulation components of carrier frequency, and means to apply to the transmitted output a monophase current of carrier frequency for purposes of phase discrimination detection.

4. In a system for the binaural transmission of signals the combination with a transmitting station having means to separately modulate carrier oscillations by the signal variations resulting from sound from the same source, the carrier oscillations being of the same frequency but differing in phase by 90° degrees, thereby producing side bands and two modulation components of carrier frequency, means to eliminate from the transmitted output the resultant of the two modulation components of carrier frequency, means to apply to the transmitted output a mono-

phase current of carrier frequency, of a receiving station including a phase discrimination detecting device, a circuit for selectively applying to said detecting device the received side bands, and a circuit for selectively applying to said detecting device the received monophase current of carrier frequency.

5. In a system for the multiplex transmission of signals, the method which consists in the modulation of a carrier by signal variations to produce side bands and a modulation component of carrier frequency, separately modulating by another set of signal variations carrier oscillations of the same frequency as employed in the first mentioned modulation operation but differing in phase by 90° therefrom to produce side bands and a modulation component of carrier frequency, eliminating the resultant of both modulation components of carrier frequency, and transmitting both sets of side bands and a monophase current of carrier frequency.

6. In a system for the multiplex transmission of signals, the method which consists in the modulation of a carrier by signal variations to produce side bands and a modulation component of carrier frequency, separately modulating by another set of signal variations carrier oscillations of the same frequency as employed in the first mentioned modulation operation but differing in phase by 90° therefrom to produce side bands and a modulation component of carrier frequency, eliminating the resultant of both modulation components of carrier frequency, transmitting both sets of side bands and a monophase current of carrier frequency to a receiving station, selecting said carrier frequency from said side bands at said receiving station, and utilizing said carrier frequency for phase discrimination detection of said side bands.

7. In a system for the multiplex transmission of signals a transmitting station having means to separately modulate carrier oscillations by signal variations, the carrier oscillations being of the same frequency but differing in phase by 90° degrees, thereby producing side bands and two modulation components of carrier frequency, means to eliminate from the transmitted output the resultant of the two modulation outputs of carrier frequency, and means to apply to the transmitted output a monophase current of carrier frequency oscillations for purposes of phase discrimination detection.

8. In a system for the multiplex transmission of signals the combination with a transmitting station having means to separately modulate carrier oscillations by signal variations, the carrier oscillations being of the same frequency but differing in phase by 90° degrees, thereby producing side bands and two modulation components of carrier frequency, means to eliminate from the trans-

mitted output the resultant of the two modulation components of carrier frequency, means to apply to the transmitted output a monophase current of carrier frequency, of
5 a receiving station including a phase discrimination detecting device, a circuit for selectively applying to said detecting device the received side bands, and a circuit for selectively applying to said detecting device the
10 received monophase current of carrier frequency.

In testimony whereof, we have signed our names to this specification this 29th day of October, 1928.

15 SMART BRAND.
PIERRE MERTZ.

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