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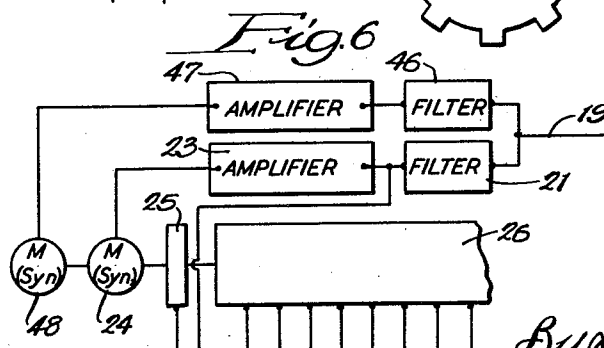
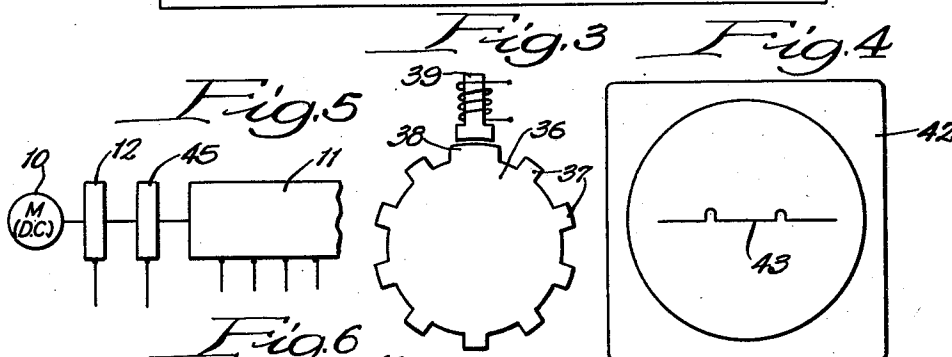
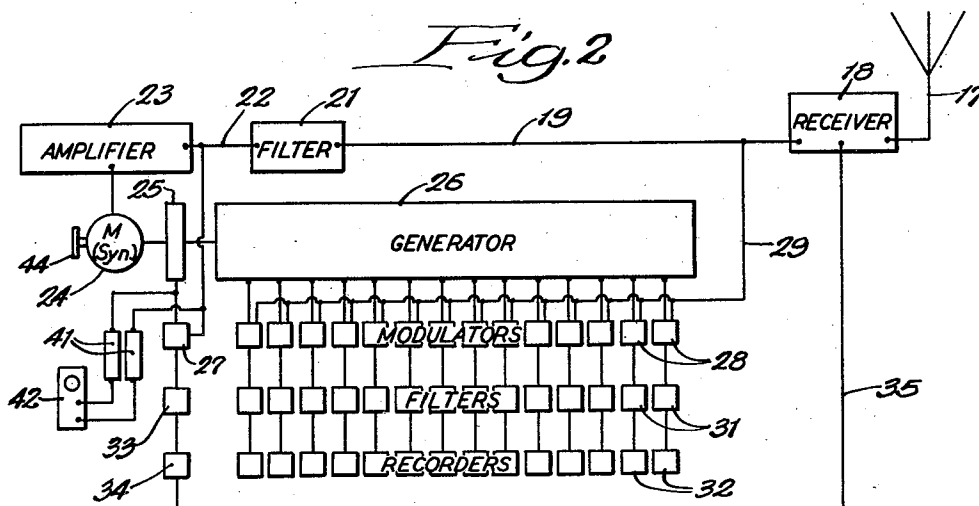
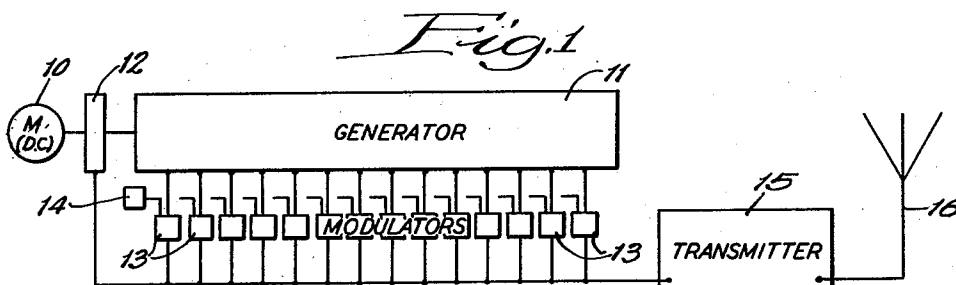
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MULTICHANNEL RADIO TELEMETERING SYSTEM

Filed Sept. 10, 1943

2 Sheets-Sheet 1



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MULTICHANNEL RADIO TELEMETERING SYSTEM

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2 Sheets-Sheet 2

Fig. 7.

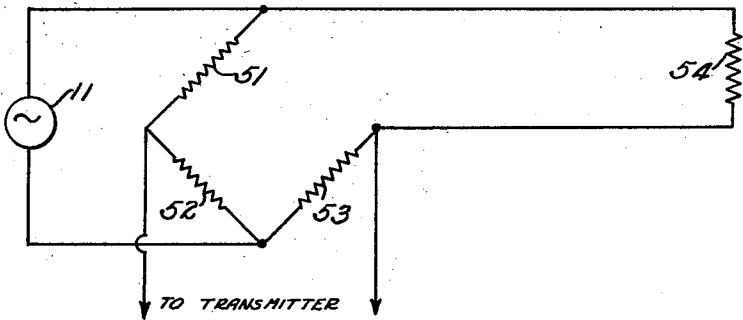
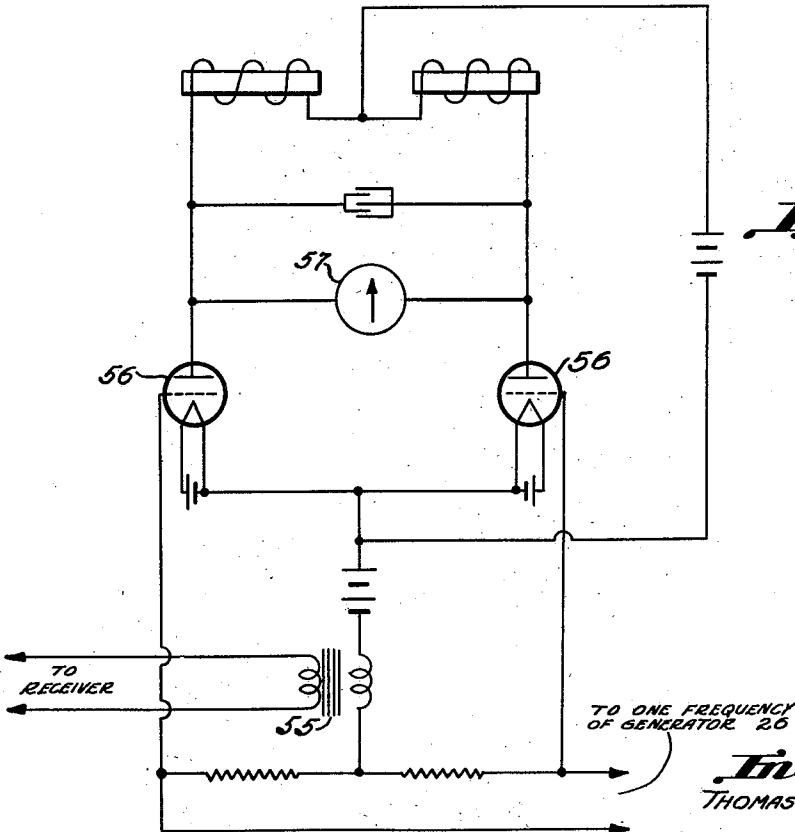


Fig. 8.



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MULTICHANNEL RADIO TELEMETERING
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This invention relates to telemetering apparatus and more particularly to the simultaneous transmission and reception of a plurality of information signals.

One of the objects of the invention is to provide an apparatus for transmitting and receiving a plurality of information signals through a single transmission channel.

Another object of the invention is to provide a telemetering apparatus in which the sending and receiving apparatus are automatically synchronized and may be kept in phase and in which the volume of the received signal is automatically controlled. According to one feature of the invention all of these functions are performed by one or more unmodulated control frequencies.

The above and other objects and advantages of the invention will be more readily apparent from the following description when read in connection with the accompanying drawing, in which—

Figure 1 is a diagram of a transmitting apparatus;

Figure 2 is a diagram of a receiving apparatus;

Figure 3 is a diagrammatic view of a control frequency generator;

Figure 4 is a view showing the phase indicating apparatus;

Figures 5 and 6 are partial views similar to Figures 1 and 2 respectively of an alternative construction;

Figure 7 is a diagrammatic view of one form of bridge circuit; and Figure 8 is a diagrammatic view of one form of modulator.

One desirable use of the invention is in connection with aircraft to transmit to a ground recording station signal indications from a plurality of instruments on the aircraft. For this purpose, in connection with which the invention is particularly illustrated and described, the signals are transmitted by radio although it will be understood that the invention is equally applicable to other types of telemetering in which the signals are transmitted either by radio or wire.

The transmitting apparatus illustrated in Figure 1 is adapted to be mounted in the aircraft and comprises a motor 10 of a constant speed type such as a D. C. motor driving a multiple generator 11. The generator 11 may be of the type known as a phonic wheel including a plurality of discs having different numbers of teeth and revolving adjacent pickups to generate a plurality of different frequencies. It will be understood that the frequencies vary in steps of any desired amount and in the example shown, fourteen different frequencies are generated varying in steps of 500 C. P. S. from 3000 C. P. S. to 9500 C. P. S.

The generator also produces an additional con-

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trol frequency which may be generated by one of the stages of the generator 11 but which is shown as being produced by a separate generator unit 12. The control frequency is preferably somewhat lower than the other frequencies and in the example shown may be 1000 C. P. S.

The several frequencies produced by the generator 11 are supplied separately to a series of modulators 13 which may be of any desired construction. One structure which I have found to be highly satisfactory for this purpose is a Wheatstone bridge with two opposed corners connected to the generator and the output connections from the other two corners, although other types of modulators could be used, if desired. In addition to the generated frequency, each of the modulators is supplied with a low frequency signal indication from an instrument of any desired type as indicated at 14. In the case of a Wheatstone bridge, the instrument 14 may be a strain gage operating to vary the resistance of one of the bridge arms. The signal frequency is preferably quite low relative to the generated frequency and in the example shown, may be not in excess of 100 C. P. S.

One Wheatstone bridge construction satisfactory for use in the apparatus of the present invention is illustrated in Figure 7 as comprising four resistances 51, 52, 53 and 54 connected in a bridge circuit. The resistances 51, 52 and 53 may be fixed resistances while the resistance 54 may be variable in accordance with the information to be transmitted. For example, the resistance 54 may be a part of a strain gage such as 14 in Figure 1 whose ohmic resistance varies in proportion to the strain imposed on it. Two corners of the bridge circuit are connected to the generator 11 as indicated diagrammatically and the opposite two corners may be connected to the transmitter 15. A bridge circuit connected as described above, is amplitude responsive and will vary the amplitude of its output in direct proportion to variations in resistance 54.

With this construction, it will be noted that the bridge output reverses phase when the bridge passes thru its balance point. Thus if the resistance of the resistor 54 is less than that required to balance the bridge the output of the bridge circuit will be in phase with the generator. When the resistance of 54 is greater than that required to balance the bridge, the output of the bridge circuit will be 180° out of phase with the generator. In both cases, the amplitude of the output will be varied in direct proportion to changes in resistor 54.

The several modulated frequencies from the modulators 13 and the control frequency from the generator 12 are supplied to the transmitter 15 which mixes the frequencies and transmits the composite wave through an antenna 16.

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The receiving apparatus as shown in Figure 2 is adapted to receive the composite wave and to separate therefrom the several signal indications. As shown, the composite wave is received by an antenna 17 and is supplied to a receiving circuit 18 which may be substantially similar to a conventional radio receiver. The output of the receiver 18 is connected through a lead 19 to a filter 21 adjusted to pass only a range of frequencies including the control frequency supplied by the generator 12. In the example stated, this filter would pass all frequencies below, for example, 2000 cycles so that it will pass the control frequency through a lead 22 to a power amplifier 23. The power amplifier energizes a synchronous motor 24 designed to operate on 1000 cycles and which drives a control generator 25 and multiple generator 26. The control generator 25 generates the same frequency as the control generator 12 and the multiple generator 26 generates the same series of frequencies as the multiple generator 11.

The generators 25 and 26 are connected to a series of balanced modulators 27 and 28 which are preferably electronic wattmeter circuits as shown for example in the patent to Peterson No. 1,586,533. One suitable modulator circuit is shown in Figure 8 in which the composite signal from the receiver goes to the transformer 55, as illustrated, and one frequency from generator 26 is connected to the grid circuits of the two tubes 56 and the transformer secondary as shown. Due to the inherent action of this circuit, as explained in considerable detail in the Peterson patent, the reading in the meter 57 that is connected between the plates of the two tubes will show the product of the two voltages times the cosine of the angle between them. Now it will be obvious that when the output of the bridge circuit of Figure 7 reverses in phase, on account of resistor 54 going thru the balance point of the bridge circuit, the indication of this plate circuit meter will go from positive to negative, or vice versa. It is also obvious that for any particular voltage output from the bridge circuit to the transmitter, there are two possible values of strain in the strain gage resistor 54, depending on whether the output voltage from the bridge is in phase with the exciting voltage of the bridge, or 180° out of phase. Since this is so, it is necessary to use a phase sensitive receiving device if the bridge is to be permitted to go thru the balance point and ambiguous results are to be avoided. Various other known types of modulator or discriminator circuits may be employed which will reject any frequency applied to one channel differing from a selected frequency applied to the other channel and give a response proportional to the magnitude of the selected frequency in the one channel and to the cosine of the phase angle between the signals in the two channels. Each of the modulators 28 is supplied with the composite transmitted signal through a lead 29 connected to the output of the receiver 18. The modulators 28 are connected to a series of low pass filters 31 which may be identical in construction and which are designed to pass only low frequencies less than the lowest frequency to be excluded but greater than the signal frequency. In the example given, these filters might be adjusted to pass only 250 C. P. S. or less. The filters 31 are connected to a series of recorders 32 which may indicate and record the transmitted information. The filters and recorders may be separate units as shown at 31

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and 32 in which the filters would be electrical filters or they may, if preferred, be combined in the form of recording galvanometers having a low enough inertia to follow low frequency changes but too high an inertia to follow high frequency changes. It is possible to combine modulator 28, filter 31 and recorder 32 by using a wattmeter type of oscillograph element, as distinguished from a galvanometer type, with appropriate damping.

In the operation of the apparatus as so far described and taking for example the 3000 cycle channel, it will be seen that the wattmeter 28 will vary from zero to a positive maximum 6000 times per second if the two frequencies are in phase and if only the 3000 cycle frequencies are present. Since the next higher frequency of 3500 cycles is also present, the product of 3000 and 3500 cycles will give sum and difference frequencies of 6500 and 500 cycles but both of these will vary between positive and negative maximum so that the average over a relatively short period will always be zero and the same analysis holds true for other frequencies present in the receiver output.

If, however, the 3000 cycle channel at the transmitter has been modulated at 100 cycles per second there would also be in the output from the 3000 cycle modulator 28 5900 cycles and 6100 cycles and 100 cycles. Furthermore, the 100 cycle output would be proportional to the 100 cycle modulation. The filter 31 for this channel will filter out all frequencies exceeding 100 cycles and will pass the 100 cycle modulating frequency to the corresponding recorder 32.

The control frequencies generated by the generator stages 12 and 25 may be utilized to provide automatic volume control at the receiver to synchronize the transmitting and receiving generators and to provide phase adjustment between the two generators. For this purpose the 1000 cycle output of the filter 21 and the output of the generator 25 are connected to the wattmeter circuit 27. The wattmeter 27 is connected to a low-pass filter 33 similar to the filters 31 and to an indicator or recorder 34 which will indicate the relative amplitude and phase of the control frequencies. When the two control frequencies are equal in amplitude and phase, the output of the low pass filter 33 will be constant and the indicator 34 will indicate a constant value. If however, the signal from the receiver should change in amplitude as by fading, the wattmeter circuit 27 will produce in its output a voltage that will vary in proportion to the change. This may be utilized automatically to control the output volume of the receiver 18 by connecting the filter 33 through a lead 35 to the grid of one of the tubes in the receiver to vary the bias thereon so that the receiver output will be of substantially constant amplitude. The connections to the receiver for this purpose are substantially the same as the conventional automatic volume control in a radio receiving circuit and will, therefore, not be illustrated or described in further detail.

In order to indicate the relative phase positions of the generators 11 and 26, the control generators 12 and 25 may be constructed, as shown diagrammatically in Figure 3, including a wheel 36 having a series of evenly spaced teeth thereon. All of the teeth except one, as indicated at 37, are of the same size and the other tooth 38 is of a larger size. The teeth move across a pickup device 39 as the wheel is turned to generate a wave. With a wheel of this type having 10 teeth

as shown, a wave of 10 complete cycles will be generated on each revolution. The cycles generated by the teeth 37 will be of uniform amplitude while the cycle generated by the enlarged tooth 38 will be of greater amplitude.

The two control waves generated as described above are connected through clipper circuits 41 to an oscilloscope 42. The clipper circuits 41 are biased so that they will not pass the small amplitude peaks generated by the teeth 37 but will pass the greater amplitude peaks generated by the teeth 38. Since the two clipped waves are impressed simultaneously on the oscilloscope 42, its indication for each wave will be a straight line having a single hump therein. When the generators are out of phase the oscilloscope will show a line such as 43 in Figure 4, having two spaced humps thereon indicating the amount of phase difference in the two signals. By observing the oscilloscope, an operator may adjust the phase of the motor 24 for example, by turning its outer housing carrying the field windings by means of a handle 44 until the two humps on the oscilloscope indication coincide, at which time, the transmitting and receiving generators will be exactly in phase. Since the operating current for the motor 24 is supplied from the control generator 12 through the receiver and amplifier, the motors will necessarily operate in synchronism at all times.

In addition to the phase position indication described above or as a substitute therefor, the relative phase positions of the generators 11 and 26 may be indicated by providing a second pickup in the generator 25 so positioned that its voltage output is 90° out of phase with that of the primary pickup in generator 25. The second pickup may be connected to the modulator 27.

When so connected, the modulator 27 will be supplied with a voltage from the lead 22 in phase with the transmitting generator 12 and with a voltage from the generator 25 which is 90° out of phase therewith when the two generators are in phase. Under these conditions the modulator 27 will read zero and by adjusting the hand-wheel 44 until this modulator does read zero exact synchronization may be accomplished. In the example given with the frequencies of the generators in steps of 500 C. P. S. and if the generators run at 100 R. P. S., the teeth on the phonic wheels will be multiples of 5. This means that for all channels to be in phase, there will be five possible equally spaced positions of the rotor of generator 26 relative to the rotor of generator 11. A ten pole synchronous motor with a polarized rotor has five equally spaced synchronous positions. Thus when the second pickup on generator 25 is spaced $n + \frac{1}{4}$ (where n is any integer) pole pitches from the primary pickup and when the motor 24 is adjusted to provide a zero reading at the modulator 27, exact synchronism of the generators 11 and 26 is insured.

Figures 5 and 6 illustrate an alternative construction for automatically maintaining the two generators in phase and in synchronism, parts in these figures which are identical with like parts in Figures 1 and 2 being indicated by the same reference numerals. In the transmitting apparatus in addition to the generator 12 a second control generator 45 is provided which supplies a still lower control frequency, for example, 100 C. P. S. In the receiving apparatus a second low pass filter 46 designed to pass the second control frequency is provided connected through

a power amplifier 47 to a second synchronous motor 48 connected in tandem to the motor 24.

In operation the low control frequency as filtered out by the filter 46 and amplified by the amplifier 47 energizes the motor 48 to provide the principal source of driving power for the generators 25 and 26. The synchronous motor 24 functions in this construction principally as a synchronizing unit to hold the generators 11 and 26 closely in synchronism. The motor 48 operating on 100 C. P. S. and assuming a speed of 100 R. P. S. would have two poles with only one possible angular position, which would be in phase with the generator 11. This motor, therefore, automatically drives the generator 26 in phase with the generator 11. However, since one degree of hunting in the motor is equivalent to ten degrees of hunting in the 1000 cycle motor 24, the motor 24 is also provided to hold the two generators more closely in synchronization. Thus with this construction, the receiving generator is automatically regulated to be in phase and to be synchronized with the transmitting generator.

While two embodiments of the invention have been shown and described herein in detail it will be understood that these are illustrative only and are not to be taken as a definition of the scope of the invention, reference being had to the appended claims for this purpose.

What is claimed is:

1. Telemetering apparatus comprising a transmitting generator for generating a plurality of separate frequencies, a plurality of modulators connected to the generator each to receive one frequency, means to supply a relatively low modulating frequency to each of the modulators, transmitting means to mix and transmit the modulated frequencies, a receiving generator for generating a plurality of separate frequencies, a plurality of balanced modulators separately supplied with frequencies from the receiving generator and with the transmitted mixed frequencies, and filtering and indicating means connected to each of the balanced modulators.

2. Telemetering apparatus comprising a transmitting generator for generating a plurality of separate frequencies, a plurality of modulators connected to the generator each to receive one frequency, means to supply a relatively low modulating frequency to each of the modulators, transmitting means to mix and transmit the modulated frequencies, a receiving generator for generating a plurality of separate frequencies, a plurality of balanced modulators separately supplied with frequencies from the receiving generator and with the transmitted mixed frequencies, a low pass filter connected to each of the balanced modulators, and indicating means connected to each of the low pass filters.

3. Telemetering apparatus comprising a transmitting generator for generating a plurality of separate frequencies, a plurality of modulators connected to the generator each to receive one frequency, means to supply a relatively low modulating frequency to each of the modulators, transmitting means to mix and transmit the modulated frequencies, a receiving generator for generating a plurality of separate frequencies, a plurality of balanced modulators separately supplied with frequencies from the receiving generator and with the transmitted mixed frequencies, said transmitting generator supplying to the mixing and transmitting means with at least one

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unmodulated frequency, and driving means for the receiving generator operated by the transmitted unmodulated frequency.

4. Telemetering apparatus comprising a transmitting generator for generating a plurality of separate frequencies, a plurality of modulators connected to the generator each to receive one frequency, means to supply a relatively low modulating frequency to each of the modulators, transmitting means to mix and transmit the modulated frequencies, a receiving generator for generating a plurality of separate frequencies, a plurality of balanced modulators separately supplied with frequencies from the receiving generator and with the transmitted mixed frequencies, said transmitting generator supplying to the mixing and transmitting means with at least one unmodulated frequency, the receiving generator supplying a frequency corresponding to the unmodulated transmitted frequency, and means operated by the last two named frequencies to indicate the phase relationship of the transmitting and receiving generators.

5. Telemetering apparatus comprising a transmitting generator for generating a plurality of separate frequencies, a plurality of modulators connected to the generator each to receive one frequency, means to supply a relatively low modulating frequency to each of the modulators, transmitting means to mix and transmit the modulated frequencies, a receiving generator for generating a plurality of separate frequencies, a plurality of balanced modulators separately supplied with frequencies from the receiving generator and with the transmitted mixed frequencies, the transmitting generator supplying to the mixing and transmitting means two unmodulated frequencies, and a pair of synchronous motors cooperating to drive the receiving generator energized by the two unmodulated frequencies respectively.

6. Telemetering apparatus comprising a transmitting generator for generating a plurality of separate frequencies, a plurality of modulators connected to the generator each to receive one of the frequencies, means to supply a relatively low modulating frequency to each of the modulators, transmitting means connected to the modulators and to the generator to mix the modulated frequencies and an unmodulated control frequency from the generator and to transmit the same, receiving apparatus to receive the transmitted frequencies, a receiving generator to generate frequencies corresponding to those of the transmitting generator, a plurality of balanced modulators connected to the receiving generator each to receive one of the frequencies and to the receiving apparatus to receive therefrom the transmitted frequencies, indicating means connected to the balanced modulators, and a connection from the balanced modulator receiving the frequency corresponding to the control frequency to the receiving apparatus automatically to control the output volume of the receiving apparatus.

7. Telemetering apparatus comprising a transmitting generator for generating a plurality of separate frequencies, a plurality of modulators connected to the generator each to receive one of the frequencies, means to supply a relatively low modulating frequency to each of the modulators, transmitting means connected to the modulators and to the generator to mix the modulated frequencies and an unmodulated control

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frequency from the generator and to transmit the same, receiving apparatus to receive the transmitted frequencies, a receiving generator to generate frequencies corresponding to those of the transmitting generator, a plurality of balanced modulators connected to the receiving generator each to receive one of the frequencies and to the receiving apparatus to receive therefrom the transmitted frequencies, indicating means connected to the balanced modulators, a filter to pass the control frequency connected to the receiving apparatus, a synchronous motor driving the receiving generator and connected to the filter to be energized therefrom, and means operated by the control frequency and a corresponding frequency generated by the receiving generator to indicate the phase relationship of the transmitting and receiving generators.

8. In a telemetering apparatus, a receiver for transmitted mixed frequencies comprising a generator for generating a plurality of separate frequencies, a plurality of modulators separately supplied with frequencies from the generator and with the transmitted mixed frequencies, and filtering and indicating means connected to each of the modulators.

9. Apparatus as defined in claim 8 in which each of the modulators is wattmeter circuit.

10. In a telemetering apparatus, a receiver for transmitted mixed frequencies comprising a generator for generating a plurality of separate frequencies, a synchronous motor driving the generator, a filter to filter out a selected one of the transmitted mixed frequencies, an amplifier connecting the filter to the motor, a plurality of modulators separately supplied with frequencies from the generator and with the transmitted mixed frequencies, and filtering and indicating means connected to each of the modulators.

11. In a telemetering apparatus, a transmitter for mixed frequencies comprising a generator for generating a plurality of separate frequencies, a plurality of modulators separately supplied with frequencies from the generator and with signal frequencies to be transmitted, and means to mix and transmit the output frequencies from the modulators.

12. In a telemetering apparatus, a transmitter for mixed frequencies comprising a generator for generating a plurality of separate frequencies, a plurality of modulators separately supplied with frequencies from the generator and with signal frequencies to be transmitted, and means to mix the output frequencies from the modulators with an unmodulated control frequency from the generator and to transmit the mixed frequencies.

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