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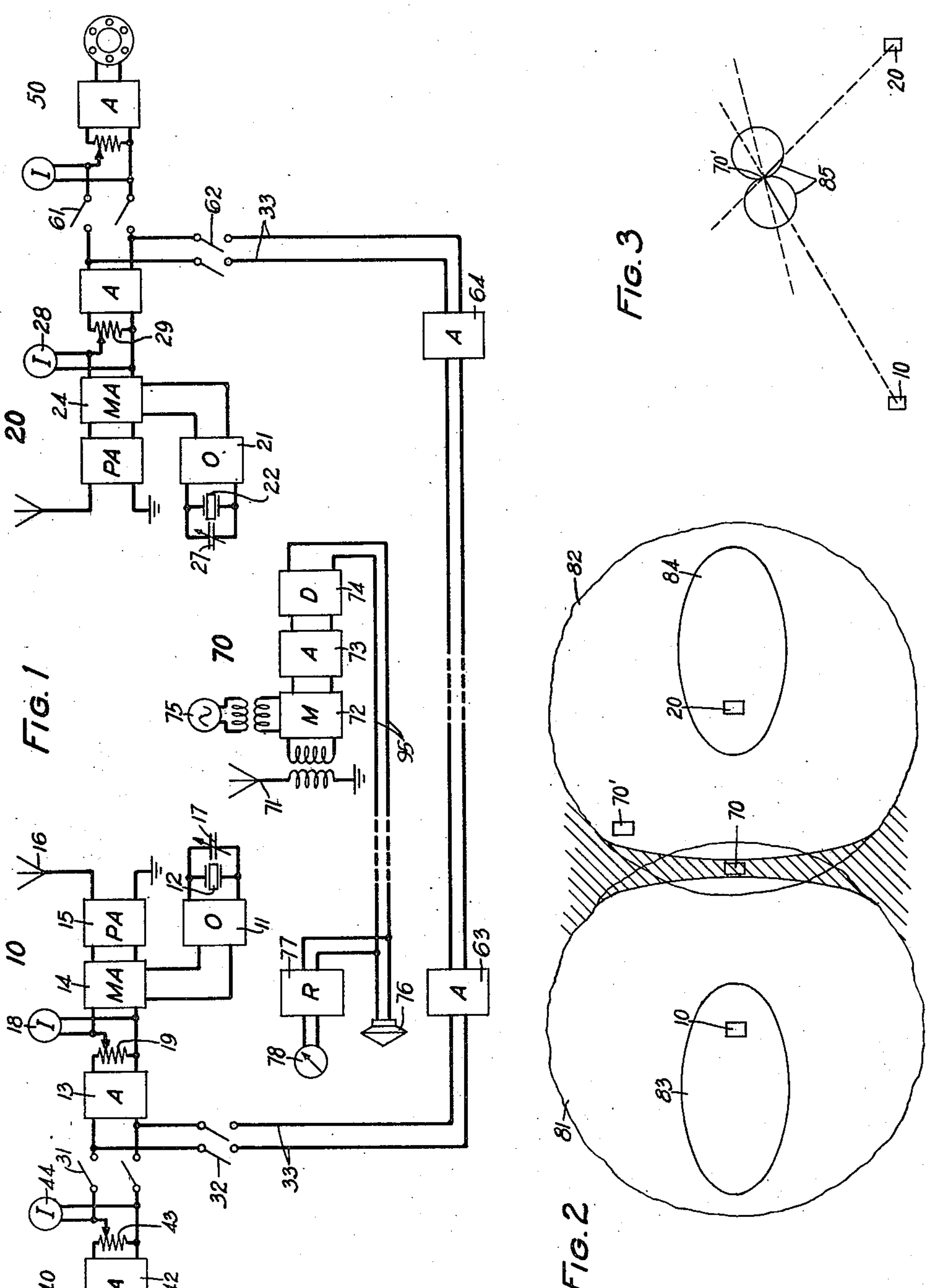

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RADIO TRANSMISSION SYSTEMS

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This invention relates to radio transmission systems and particularly to systems such as chains of broadcasting transmitters in which two or more transmitters operate at a common frequency.

One object of the invention is to improve the synchronization of radio transmitters radiating waves at a common frequency.

Another object of the invention is to increase the area that can be effectively served by a plurality of broadcasting transmitters operating at a common frequency and broadcasting the same program.

The problem of maintaining broadcast coverage of a given area by means of a plurality of relatively low power transmitters operating at a common frequency is complicated by the occurrence in the area of zones in which the waves from the several stations interfere and produce a neutralization of the signal. If two transmitters are maintained in exact synchronism, the neutralization of the interference zones will be permanent, but if the frequency or phase of one station varies relatively to the other the area of interfering zones will be marked by a strong periodic fading. At those points where the field intensities of the waves are about equal, the fading will be marked by complete extinction of the signal and at such points reception by ordinary methods is impracticable. At other points where the field intensity of one wave is predominately great, the degree of fading may not be large but, if rapid enough, will so distort the signals that clear reception is impossible. The result of this is that the area that can be served by each station is greatly restricted when both stations are operated together.

It has been found that if the fading period is not permitted to fall below a certain optimum value, the distorting effect is noticeable only in the very small area where the waves have about equal amplitudes. Consequently by maintaining the transmitters in such isochronism that the fading period is of this optimum duration, the area that can be served by each station, when the two are operated together, is practically as great as the area that is served by each when operating separately. Experience has shown that this optimum fading period is of the order of ten to thirty seconds.

To obtain a fading period of more than twenty seconds between the stations, each operating at a carrier frequency of one million cycles per second, requires that the frequencies be equal to within one part of a twenty-million. This degree of isochronism is obtained in accordance with the invention in the following manner:—Quartz crystal oscillators having auxiliary sensitive frequency controlling means are used at each station to furnish the carrier waves. These oscillators are stabilized by known methods to secure a high degree of constancy in the frequency of the generated waves. By the use of the quartz crystal oscillators along the isochronism may be maintained within a few parts in a million, but this is insufficient for the prevention of interference. To effect the more exact isochronism, a radio receiver is located between the two stations at a point where the field intensities are about equal. This receiver is tied to one transmitting station by a wire line over which the detected signals are transmitted to a loud speaking telephone receiver or other suitable indicator. If the stations are not in isochronism, the fading period of the detected signals provides an indication of the frequency difference and by proper adjustment of the oscillator control, the fading period can be maintained at an unobjectionable value.

In order to make the received beat independent of the character of the broadcast signal and to prevent a discrimination to be made between interference fading and musical rythm, an auxiliary low frequency tone may be introduced into the control receiver in such a manner that its amplitude in the receiver output follows the variations in the amplitude of the combined carrier waves.

The invention may be more readily understood by reference to the following detailed description in connection with the drawing in which:—

Fig. 1 shows diagrammatically the circuit arrangements of one embodiment of the invention;

Fig. 2 shows diagrammatically the geographical arrangement of the transmitters and control receiver of Fig. 1; and

Fig. 3 shows diagrammatically the geographical arrangement of the transmitters and control receiver of a modification of the invention employing a directive antenna at the control receiver.

Referring to Fig. 1, there are shown two similar radio broadcasting transmitters 10 and 20. The transmitter 10 per se comprises an oscillator 11, the frequency of which is controlled by a quartz crystal 12, an audio frequency amplifier 13, a modulating amplifier 14 and a power amplifier 15, the output of which is connected to an antenna 16. There is connected across the quartz crystal 12 a variable condenser 17 which permits a sensitive adjustment of the frequency of the generated wave. A volume indicator 18 is connected to the input of the modulating amplifier to permit a measurement of the amplitude of the audio frequency waves impressed thereon. A potentiometer 19 connected to the output of the audio frequency amplifier 13 permits the control of the amplitude of the audio frequency wave impressed on the modulating amplifier. As is the usual practice, a sensitive temperature control (not shown) is provided for the crystal 12.

United States Patent 1,757,727 to Marrison, May 6, 1930, discloses one type of temperature control which has been found satisfactory for such purpose.

By means of the switches 31 and 32, the input of the audio frequency amplifier 13 may be connected either to a studio equipment 40 or to a telephone line 33. The studio equipment 40 is of the conventional type comprising a pick-up microphone 41, an audio frequency amplifier 42, a volume control 43, and a volume indicator 44.

The transmitter 20 is identical to the transmitter 10 and consequently will not be described in detail. In a similar manner to that provided for transmitter 10, the input of the transmitter 20 may be connected by means of the switches 61 and 62 either to a studio equipment 50 or to the telephone line 33. This line is provided with telephone repeaters or amplifiers 53 and 54. The studio equipment 50 is similar to the studio equipment 40.

There is also provided a radio receiver 70 which is located at a point intermediate the transmitters 10 and 20 as will be later described in detail with reference to Fig. 2. This receiver comprises an antenna 71, coupled to a modulator 72, the output of which is connected to an audio frequency amplifier 73, which in turn operates into a detector 74. An audio frequency generator 75, which generates a suitable tone, for example, of a frequency of 150 cycles per second is also coupled to the modulator 72. The output of the detector 74 is connected to a telephone or telegraph line 95 which interconnects the points at which the receiver 70 and the transmitter 10 are located. At the transmitter 10 this line 95 is connected to a loud speaker 76 and to the input of a rectifier 77, the output of which is connected to an indicating meter such as a milliammeter 78. As will be later described in connection with the operation of the system, either of the loud speaking telephone receiver 76 or the rectifier-indicator combination 77, 78 or both, may be employed.

The two radio transmitters 10 and 20 are individually adjusted to operate on the same carrier frequencies by the adjustment of the crystal oscillators 11 and 21. In practice this initial adjustment can be made very accurate so that initially the carrier frequencies of the two transmitters are practically identical. However, variations in room temperature and the like tend to cause a variation in the frequencies of one or both carriers. A program from either of the studios 40 or 50 may be transmitted from both transmitters by the proper adjustment of the switches 31, 32, 61, and 62. For example, if it is desired to transmit a program from the studio 40, switches 31, 32 and 62 will be closed and the switch 61 opened. Under these conditions the transmitters 10 and 20 will be transmitting the same program at the same carrier frequency.

As will be later described in detail in connection with Fig. 2, the receiver 70 is located at such a point that the amplitudes of the carrier waves from the transmitters 10 and 20, received in the antenna 71, are substantially equal. These received carrier waves are modulated in the modulator 72 by the audio frequency wave from the generator 75. The resultant wave is amplified in the amplifier 73 and detected in the detector 74. The detected wave is transmitted back to the station 10 by the line 95. At the station 10, the detected wave gives an audible indication in the loud speaking receiver 76 and a visual indication in the indicating meter 78.

As the frequency of the carrier wave of one or both the transmitters 10 or 20 varies to throw the two transmitters out of isochronism, the output of the detector 74 will go through a fading cycle, the frequency of which is the actual difference in the frequencies of the carrier waves of the two transmitters. By observing the frequency of this fading cycle as audibly indicated in the receiver 76, for example, the operator at station 10 is able to so adjust, by means of the variable condenser 17, the frequency of that carrier wave that the fading period is unobjectionable.

It has been found in practice that when the transmitters have very accurately calibrated crystal controlled oscillators, it is possibly by a manual adjustment as just described to hold the transmitters so closely in isochronism that the period of fading of the signal output of the detector 74 is of the order of several minutes. While such a close isochronism would appear to be the ideal condition, it has been found that with such a control the receiving conditions in the interference zone, which can never be entirely eliminated, are very objectionable. The reason for this is that such a long fading period will tend to wipe out entire phrases or sentences in the received program, thus making it unintelligible. By controlling the isochronism so that the fading period is of the order of ten to thirty seconds, the interfering zone can be kept almost as small as with the more accurate isochronism and the receiving conditions in that zone will be such that only an occasional word will be missed. It has been found that such a receiving condition is not at all unobjectionable.

If it is desired the modulator 72 and the tone generator 75 may be omitted from the receiver 70. With such a circuit the output of the detector 74 contains the fading signal as in any ordinary broadcast receiver located in the interfering zone. When so operating the system, the control operator at the station 10 can control the frequency of the oscillator 11 by observing the fading period of the signal itself. However, the fading of the signal may be of the same order as the musical rhythm of a program being transmitted, and consequently the proper control of the oscillator may be rather difficult. With the preferred circuit embodiment shown, the amplitude of the audible tone in the generator 75 can be made such that the tone can be easily discriminated from any signal which is being transmitted. In addition by the use of the signal tone of the order of 150 cycles it is possible to use a line for the transmission line 95 which has only a narrow frequency range such as a telegraph channel. Since the cost of such lines is considerably less, the use of the audible tone gives an economical advantage.

Fig. 2 shows the geographical arrangement of the units of the system of this invention. The two transmitters are indicated by the rectangles 10 and 20 respectively. The areas 81 and 82 represent the areas in which good quality reception can be effected with either transmitter operating alone.

When the two transmitters are operating at the same frequency with only the ordinary individual controls, the areas in which good reception is possible are indicated by the inclosures 83 and 84. Under such conditions reception at all points outside of these areas is practically impossible.

When employing the control system of this invention, good quality reception is possible at all points within the two inclosures 81 and 82 except in the cross-hatched portion where noticeable interference effects will be observed. However, even within this area, it is possible to obtain fair reception and by the use of receivers having directive antennæ such as loops so that one transmitter may be discriminated against, it is possible to obtain quite good reception.

As indicated in the diagram by the rectangle 70, the receiver 70 is located at a point at which the amplitudes of the carrier waves from the two stations are substantially equal. In the ideal condition in which the terrain is uniform and the two transmitters employ similar antennæ, giving uniform fields, this point would be at equal distance from the two stations.

In practice it may be very difficult to locate a point at which the amplitudes of the carrier waves are exactly alike or when such a point can be located, it may be a very inconvenient point at which to locate the control receiver. This difficulty can be overcome by the use of a directive antenna, for example, a loop or double loop. When employing such an antenna it is possible to locate the control receiver at a point such as 70′ and to so adjust the antenna that the amplitudes of the received waves impressed upon the receiver are equal. Fig. 3 shows diagrammatically such an arrangement. In this figure the rectangles 10 and 20 the two transmitters, as in Fig. 2, and the point 70′ represents the location of the control receiver, as also shown in Fig. 2. The curve 85 represents the characteristic of the loop antenna and as indicated this loop may be adjusted so as to favor the reception from the transmitter 10 as regards that from the transmitter 20, the receiver being closer to the transmitter 20 than to the transmitter 30 so that the intensity of the electromagnetic field set up by the latter is lower.

In the circuit shown in Fig. 1 the wave observed by the control operator gives an indication of the carriers rather than the programs or side bands. Consequently in order that the best conditions exist it is necessary that the percentages of modulation of the two transmitters be equal. When employing radio transmitters of similar types such a condition can be achieved by adjusting the input levels to the modulating amplifiers so that they are equal. This is accomplished in the system shown in the drawing by adjusting the potentiometers 19 and 29 so that equal indications are given in the indicators 18 and 28. After such an adjustment has been made, the entire control of the amplitude level of the program being transmitted is left in the hands of the operator at the studio. This operator makes the adjustment by controlling the volume 43 and observing the indicator 44 in the set up, the operation of which is described above.

This invention may be employed for controlling the simultaneous operation of more than two radio transmitters by employing one of the transmitters as the master transmitter locating a control receiver between that transmitter and each of the other transmitters, and controlling each of the other transmitters by an indication from its respective control transmitter. Similarly one transmitter may be controlled by comparing it with a master transmitter and a second transmitter controlled by comparing it with the first controlled transmitter.

In order to adapt the system to meet a particular situation, it is possible by adjusting the directive characteristics of the transmitting antennæ to shift the location and change the shape of the interference zone. One method of so controlling the directive characteristics of the antennæ is by employing insulated, tuned towers.

What is claimed is:

1. The method of operating a plurality of radio transmitters at a common carrier frequency which comprises detecting the resultant signals at a point where the field strengths of the waves from the several transmitters are approximately equal, transmitting the detected signals to one transmitter and adjusting the frequency of the carrier wave of that transmitter to substantially eliminate the beats from the detected signals.

2. The method of radio broadcasting which comprises operating a plurality of radio transmitters on carrier waves of the same frequency, modulating the carrier waves of said transmitters by the same program, receiving the waves transmitted by said transmitters at a common point, controlling the amplitudes of received waves so that they are substantially equal, detecting the received waves to produce a signal having a fading cycle of frequency proportional to any difference in frequency between the carrier waves of said transmitters, transmitting the detected signal to one of said transmitters and controlling the frequency of the carrier of said one transmitter to maintain the frequency of the fading cycle at a desired value.

3. The method of radio broadcasting which comprises operating a plurality of radio transmitters on carrier waves of the same frequency, modulating the carrier waves of said transmitters by the same program, receiving the waves transmitted by said transmitters at a common point, controlling the amplitudes of received waves so that they are substantially equal, detecting the received waves to produce a signal having a fading cycle of frequency proportional to any difference in frequency between the carrier waves of said transmitters, transmitting the detected signal to one of said transmitters, and controlling the frequency of the carrier of said one transmitter to maintain the period of the fading cycle at the order of 10 to 30 seconds.

4. The method of operating two radio transmitters in isochronism for transmitting the same signals, which method comprises receiving the waves transmitted at a point where the field strengths of the two waves are approximately equal, modulating the received waves by an audible frequency wave, detecting the resultant combined wave, transmitting the detected wave to one of said transmitters and controlling the frequency of the carrier of said one transmitter in accordance with said detected wave to maintain said transmitters in substantial synchronism.

5. The method of broadcasting a radio program from two radio transmitters operating on the same carrier frequency, which method comprises receiving the two waves in a directive antenna located intermediate said transmitters, adjusting said antenna so that the amplitudes of the two received carrier waves are substantially equal, simultaneously modulating said carrier waves by an audible frequency wave, detecting the resultant combined wave, transmitting the detected wave to one of said transmitters and controlling the frequency of the carrier of said one transmitter to hold the fading period of the detected wave at a predetermined value.

6. The method of radio broadcasting from two radio transmitters which method comprises modulating the carrier wave at one of said transmitters by a program to obtain a modulated wave having a predetermined percentage of modulation, modulating a carrier wave of substantially the same frequency at the other of said transmitters by the same program to obtain a modulated wave having said percentage of modulation, receiving the two modulated waves in a directive antenna located intermediate said transmitters, adjusting said antenna so that the amplitudes of the two received carrier waves are substantially equal, simultaneously modulating said carrier waves by an audible frequency wave, detecting the resultant combined wave, transmitting the detected wave to one of said transmitters, and controlling the frequency of the carrier of said one transmitter to hold the fading period of the detected wave at a predetermined value.

7. In combination, a plurality of radio transmitters having carrier oscillators operating at substantially the same frequency, adjustable means for giving a sensitive control of the frequency of the oscillator of one of said transmitters, a source of signals, means for modulating the carrier wave of each of said transmitters by signals from said source, a radio receiver for simultaneously receiving waves from both of said transmitters at a point where the field strengths produced by

said transmitters are approximately equal, said radio receiver including means for detecting the received waves, and means for giving an indication of the detected waves at said one transmitter.

8. In combination, a plurality of radio transmitters, each having a crystal-controlled carrier oscillator, said oscillators operating at substantially the same frequency, adjustable means for giving a sensitive control of the frequency of the oscillator of one of said transmitters, a source of signals, means for modulating the carrier waves from each of said transmitters by signals from said source, a radio receiver for simultaneously receiving waves from both of said transmitters and including means for adjusting the received waves to substantially the same energy level, a source of audible frequency waves, means for modulating the received waves by waves from said source of audible frequency waves and means for detecting the resultant waves, means for transmitting the detected wave to said one transmitter, and means at said one transmitter for giving an indication of the fading period of said detected wave.

9. The combination according to the next preceding claim, in which transmitters operate to give substantially the same percentages of modulation.

10. The method of operating three or more radio transmitters in isochronism for transmitting the same signal, which method comprises detecting the resultant signals of two of said transmitters at a point where the strengths of the fields set up by said two transmitters are approximately equal, transmitting the detected signal to one of said two transmitters, adjusting the frequency of the carrier wave of said one transmitter in accordance with the fading period of said detected signal to maintain said two transmitters in substantial synchronism and similarly maintaining another of the transmitters in substantial synchronism with one of said two transmitters.

In witness whereof, I hereunto subscribe my name this 10th day of June, 1930.

GLENN D. GILLETT.