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RADIO SYSTEM

Filed Jan. 6, 1927

Fig 1.

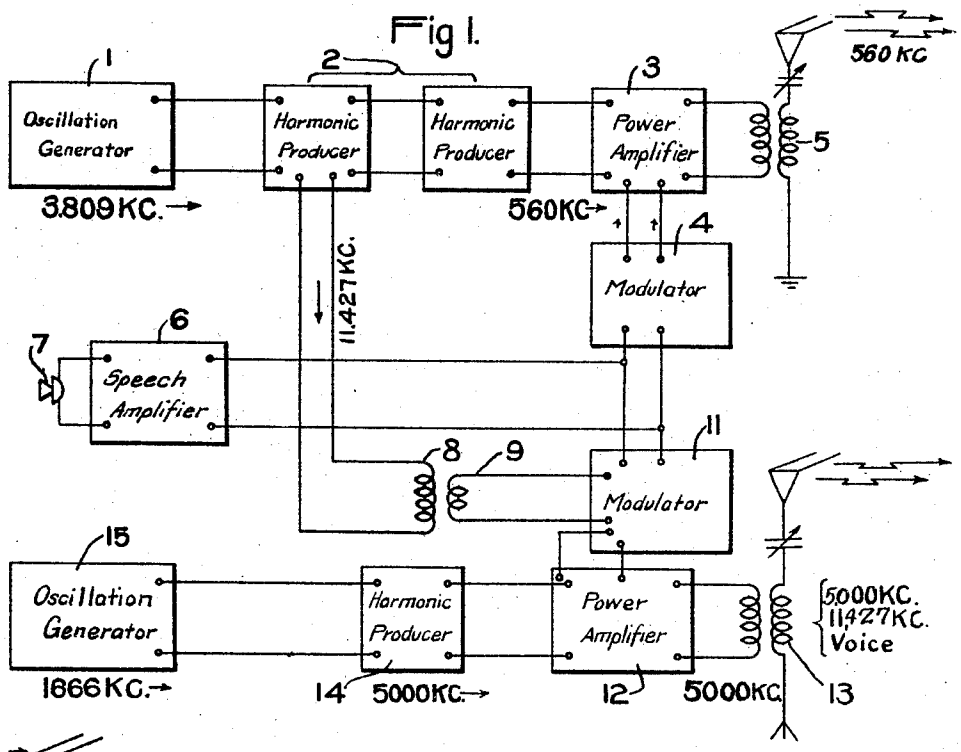
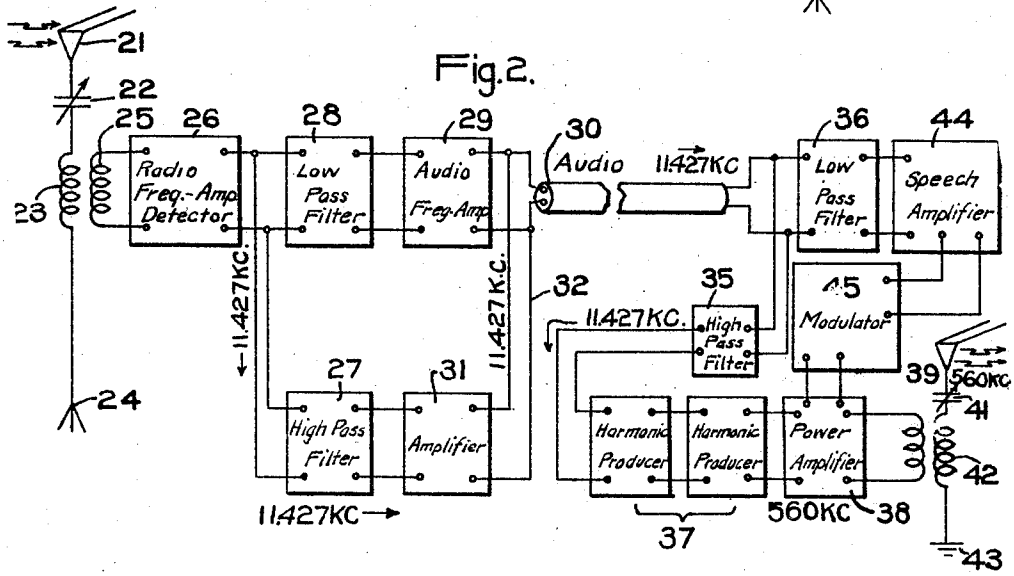


Fig.2.



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UNITED STATES PATENT OFFICE

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RADIO SYSTEM

Application filed January 6, 1927. Serial No. 159,327.

My invention relates to radio signaling systems, and it has particular relation to relay systems wherein signals emanating at radio frequency from a master station are utilized to control the output of a plurality of distant transmitting stations.

One object of my invention is to provide a relay system in which all relay transmitting stations may be operated at the same radio frequency if desirable.

Another object of my invention is to provide a relay system in which a constantly definite relation may be maintained among the frequencies utilized for re-transmission by the several relay stations.

Another object of my invention is to eliminate the necessity of transmitting a control frequency over metallic conductors from a master control station to a plurality of relay stations.

Another object of my invention is to provide a relay system in which signals representing intelligence, and also a control frequency, may be simultaneously impressed upon a single carrier frequency, and may be separately utilized at the relay stations for controlling the output of the relay transmitters.

By reason of the large increase in the number of broadcasting stations, it is becoming desirable that all transmitting stations simultaneously sending the same program shall utilize the same transmitting frequency, or harmonics of the same frequency. It has been proposed to link a plurality of broadcasting stations together by metallic conductors, and to supply a control frequency to such linked stations from a central, or master, control station. It has further been proposed to equip each relay station with means for producing harmonics from the control frequency, and for utilizing such harmonics to control the transmission frequency of the said station.

Systems utilizing wire channels for the transmission of either the control or modulating frequencies have proved very satisfactory if the distance between the master control station and the relay station is not excessive. A system of this type has been in successful operation for many months between Boston and Springfield, Massachusetts, over wire channels approximately 104 miles in length, substantially perfect synchronization being attained. For greater distances, however it becomes necessary to interpose repeater stations in the wire-channels, to compensate the attenuation, and such repeater stations necessarily introduce a certain amount of distortion. In addition, the expense of maintaining repeater stations, and the investment necessary to provide a large number of linking wire circuits, both tend toward making the wire-channel system undesirable.

According to my invention, I substitute a carrier wave of an extremely high frequency for the wire channel heretofore used for the transmission of the control frequency, impressing the control frequency thereon as a modulation, and, at the same time, I also impress sound-modulation on the high-frequency carrier if it is desirable that the same program shall be radiated by a plurality of the relay stations. At the relay stations, the carrier frequency is demodulated in order to obtain both the control frequency and the signal modulation, suitable filters being utilized to separate the two. The control frequency is then stepped up by harmonic producers to the desired broadcast frequency for re-radiation, and the signal, after appropriate amplification may be utilized to modulate the re-radiated energy.

The novel features which are considered characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawing, in which—

Figure 1 is a diagrammatic view of the apparatus and circuits involved at the master control station, and

Fig. 2 is a diagrammatic view of the apparatus and circuits associated with a single relay station.

Referring specifically to Fig. 1, an oscillation generator 1, which may be controlled as to frequency by either a tuning fork or a piezo-electric crystal, is connected to a harmonic producer 2. The output of the harmonic producer is amplified in a power amplifier 3, the output of which is modulated by a modulator 4, and is radiated from an antenna-ground system 5 of any well known type. The modulator 4 is controlled by a speech amplifier 6, which, in turn, is energized by a source 7 of audio-frequency variations.

The harmonic producer preferably comprises a plurality of thermionic devices arranged according to the U. S. application of D. G. Little, Serial No. 78,115, filed Dec. 29, 1925, and assigned to the Westinghouse Electric and Manufacturing Company. As explained in the application referred to, a plurality of thermionic devices may be coupled in cascade and be so arranged that the ultimate output of the system may be any desired harmonic of the frequency energizing the first device of the series. The final output frequency of the harmonic producer is arrived at by so arranging each stage that the output thereof is distorted, and tuning the succeeding stage to one of the harmonic frequencies causing the distortion.

The power amplifier 3 and the modulator 4 may be of any type familiar to those skilled in the art, and it is not necessary to specifically describe the circuits involved therein.

In the course of its passage through the harmonic producer, the frequency supplied by the oscillation generator 1 is increased in definite steps, each step involving a harmonic of the original frequency. At one of the intermediate steps, the frequency thereof is tapped off, and is applied through a coupling circuit 8 to the input 9 of a second modulator 11, to which modulator is also applied audio frequency from the speech amplifier 6 previously referred to.

The second modulator 11 controls a power amplifier, the output of which is applied to a specially designed short-wave radiation system 13, preferably of the type disclosed in the U. S. application of F. Conrad, Serial No. 84,341, filed Jan. 28, 1926, and assigned to the Westinghouse Electric and Manufacturing Co. The power amplifier is energized from a harmonic producer 14, which, in turn, is controlled by an oscillation generator 15.

The radiation system 5 first referred to is designed to radiate power at one of the customary broadcast frequencies, that of 560 kilocycles being chosen as illustrative. In order that this radiation frequency may be obtained, I prefer to adjust the oscillation generator to 3.809 kilocycles, the 147th harmonic of which is 560 kilocycles.

The frequency tapped off from the intermediate stage of the harmonic producer, and applied to the second modulator, is preferably 11,427 kilocycles, this frequency being chosen for a reason which later will be explained.

The frequency of the second oscillation generator 15 is preferably 1666 kilocycles, which is changed in the harmonic producer 14 to 5000 kilocycles before being applied to the power-amplifier 12 energizing the short-wave radiation system 13.

By reason of the circuits and apparatus thus far described, it is apparent that two carrier waves, one at 560 kilocycles and the other at 5000 kilocycles, may be simultaneously modulated by the single audio-frequency source 7. It is also apparent that the 5000 kilocycle carrier wave also carries a modulation at 11.427 kilocycles, which frequency is sufficiently high to avoid interference with the distant reception of the audio frequency.

Should the carrier-wave frequency of the first transmitting system 5 vary, by reason of a variation in the oscillation generator, the intermediate frequency tapped off from the harmonic producer will also vary, and the modulation of the high-frequency output of the second transmitting system will vary proportionately. The modulation frequency, 11.427 kilocycles in the present instance, is what I prefer to term the "control frequency," and is utilized at the distant relay station in a manner that will be explained later in more detail.

Referring to Fig. 2, the receiving apparatus at a distant relay station preferably comprises an antenna 21, a tuning condenser 22, an inductor 23, and a ground or counterpoise 24. The antenna system is tuned to the carrier frequency of the short-wave transmitting system previously described, namely 5000 kilocycles, and the inductor 23 is coupled to the input circuit 25 of a radio-frequency amplifier and detector 26.

The output of the detector, which comprises the original audio frequencies from the source 7, as well as the control frequency, 11.427 kilocycles, is impressed upon the input circuit of a high-pass filter 27 and the input circuit of a low-pass filter 28. The output of the low-pass filter 28, which comprises audio frequencies only, is impressed on an audio-frequency amplifier 29, the output of which, in turn, is passed through a connecting cable 30 to the re-transmitting portion of the relay station.

The high-pass filter 26 is designed to permit the control frequency, 11.427 kilocycles, to be impressed upon the input circuit of an amplifier 31, while preventing the access of the audio frequencies thereto. After amplification, the control frequency is impressed, through the circuit 32, on the cable 30 leading to the re-transmitting portion of the

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relay station, at which it is utilized to control the re-radiation frequency.

It is preferable that the re-transmitting portion of the relay station shall be several miles distant from the receiving portion thereof, in order to prevent interference therebetween. A preferred arrangement of receiving and transmitting antennæ is disclosed in the co-pending application of Frank Conrad, Serial No. 84,341, previously referred to, in which application it is pointed out that, for best results, both the receiving and the transmitting antenna should be strongly directional. It is not necessary, however, that the re-transmitting antenna shall be directional, if proper steps are taken to prevent energy therefrom from affecting the receiving antenna. In view of the directional characteristics of loop-antennæ, an antenna of this type may advantageously be substituted for the receiving antenna 21, provided signal strength from the master-station is sufficient.

At the location of the re-transmitting station, the cable conductors are connected to a high-pass filter 35 and to a low-pass filter 36. The high-pass filter 35 permits the control frequency, 11.427 kilocycles, to be impressed upon the input of a harmonic producer 37, which is adjusted to give, as an output frequency, the 49th harmonic of whatever frequency is impressed thereon. In the example chosen, the broadcast frequency 560 kilocycles, is the 49th harmonic of the control frequency, and is the 147th harmonic of the frequency, 3.809 kilocycles, of the master oscillation generator.

The output of the harmonic producer 37 energizes a power-amplifier 38 which, in turn, supplies energy to a re-radiation system comprising an antenna 39, a tuning condenser 41, an inductor 42, and a ground connection 43.

The output of the low-pass filter 36, comprising the audio-frequency components of the received signal, is amplified in a speech amplifier 44 and applied to a modulator 45 which controls the output of the power amplifier 38.

It is believed obvious that the output of the re-transmission antenna system may be modulated from a local source (not shown), if desirable, in which case, only the control frequency from the master station is utilized to control the re-transmission frequency.

It is also feasible to utilize any desired harmonic of the control frequency at any one of the relay stations, in the event that it is undesirable to have all the stations of the system operating on the same frequency.

The control frequency itself, however, should be kept just above the limit of audibility, which is generally conceded to be in the neighborhood of 10,000 cycles per second, in order that attenuation in the cable 30 connecting the receiving and re-transmitting portion of each relay station may be as little as possible. Frequencies materially higher than 10,000 cycles will give marked attenuation, while lower frequencies will introduce serious interference with the desired signal frequencies.

It will, of course, be understood that the frequencies hereinbefore referred to are given for purposes of illustration only, and that certain of these frequencies may be varied as practical conditions require.

The advantages attending my invention lie principally in the reduction of expense over systems of the prior art which involved the use of long metallic linking channels. Distortion is noticeably absent in the re-radiated signals, and the interference between a plurality of stations transmitting the same program on differing frequencies is entirely eliminated.

I claim as my invention:—

1. The method of simultaneously transmitting a single program from a plurality of radio stations which comprises generating a radiation frequency at one of said stations, generating a second radiation frequency at said station, modulating said second radiation frequency by a sub-harmonic of said first frequency, modulating both of said radiation frequencies by a signal frequency, and utilizing the double modulation of said second radiation frequency at a distant station to control the generation of a radiation frequency thereat and to modulate said generated frequency.

2. The method of controlling the transmission of radiant energy from a plurality of stations which comprises generating a radiation frequency at one of said stations, generating a second radiation frequency at said station, modulating said second frequency by a third frequency which bears a sub-harmonic relation to said first frequency and which is generated incidentally to the generation of said first frequency, and utilizing said modulation at a distant station to control the radiation frequency thereof.

3. The method of distantly controlling the output of a radio station which comprises transmitting thereto a carrier frequency modulated by signals and by a control frequency, utilizing said control-frequency modulation to determine the radiation frequency of said station, and utilizing the signal modulation to determine the amplitudes of said radiation frequency.

4. The method of simultaneously broadcasting a program from a plurality of stations which comprises generating a radiation frequency at one end of said stations, generating a second, materially higher, radiation frequency at said station, modulating said second radiation frequency by a sub-harmonic of said first radiation frequency, mod-

ulating both of said radiation frequencies by a signal, radiating said frequencies, utilizing the sub-harmonic-frequency modulation at a distant relay station to control the generation of a radiation frequency, and utilizing the signal modulation at said distant station to control the modulation of the radiation frequency of such station.

5. The method of remotely controlling the output of a radio station which comprises transmitting thereto a carrier frequency modulated by a control frequency and by a signal frequency, demodulating said carrier frequency at said station to obtain therefrom said control frequency and said signal frequency, utilizing a harmonic of said control frequency to determine the radiation frequency of said station, and utilizing said signal frequency to modulate the radiation frequency of said station.

6. In a radio system, means for generating and radiating a signal-modulated carrier frequency, means for generating a second carrier frequency, means for modulating said second carrier frequency by a sub-harmonic of said first carrier frequency, means for modulating said second carrier frequency by said signal, distantly-situated receiving means, means associated therewith for deriving from said second carrier frequency said sub-harmonic modulation frequency and said signal, transmitting means, means whereby said sub-harmonic modulation frequency controls the radiation frequency thereof, and means whereby said signal controls the amplitude of said radiation frequency.

In testimony whereof, I have hereunto subscribed my name this 31st day of December, 1926.

FRANK B. FALKNOR.