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Oct. 8, 1929. R. D. DUNCAN, JR 1,730,412

HIGH FREQUENCY BROADCASTING OVER POWER LINES

Filed Dec. 5, 1923 2 Sheets-Sheet 1

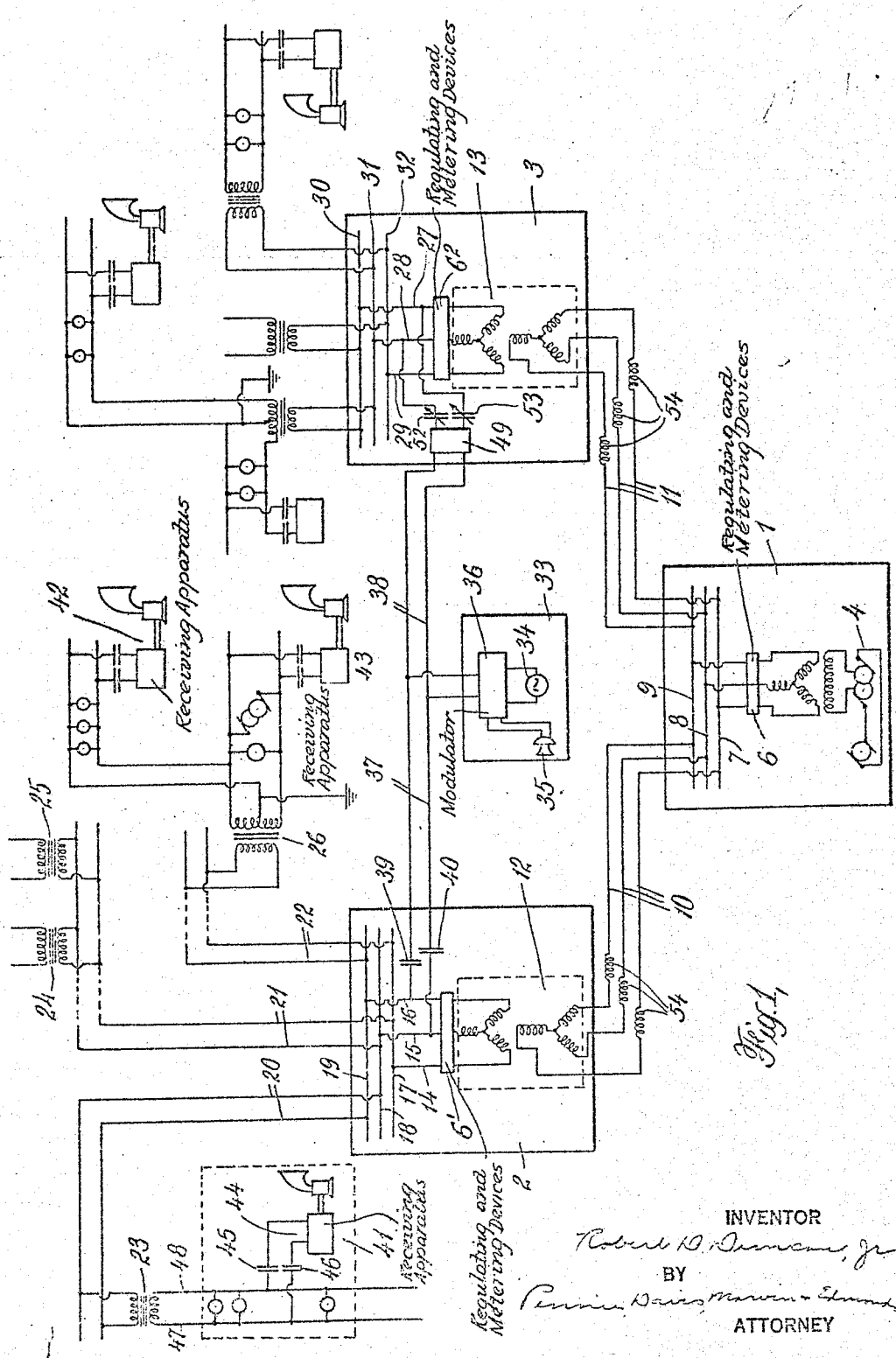

Fig. 1.

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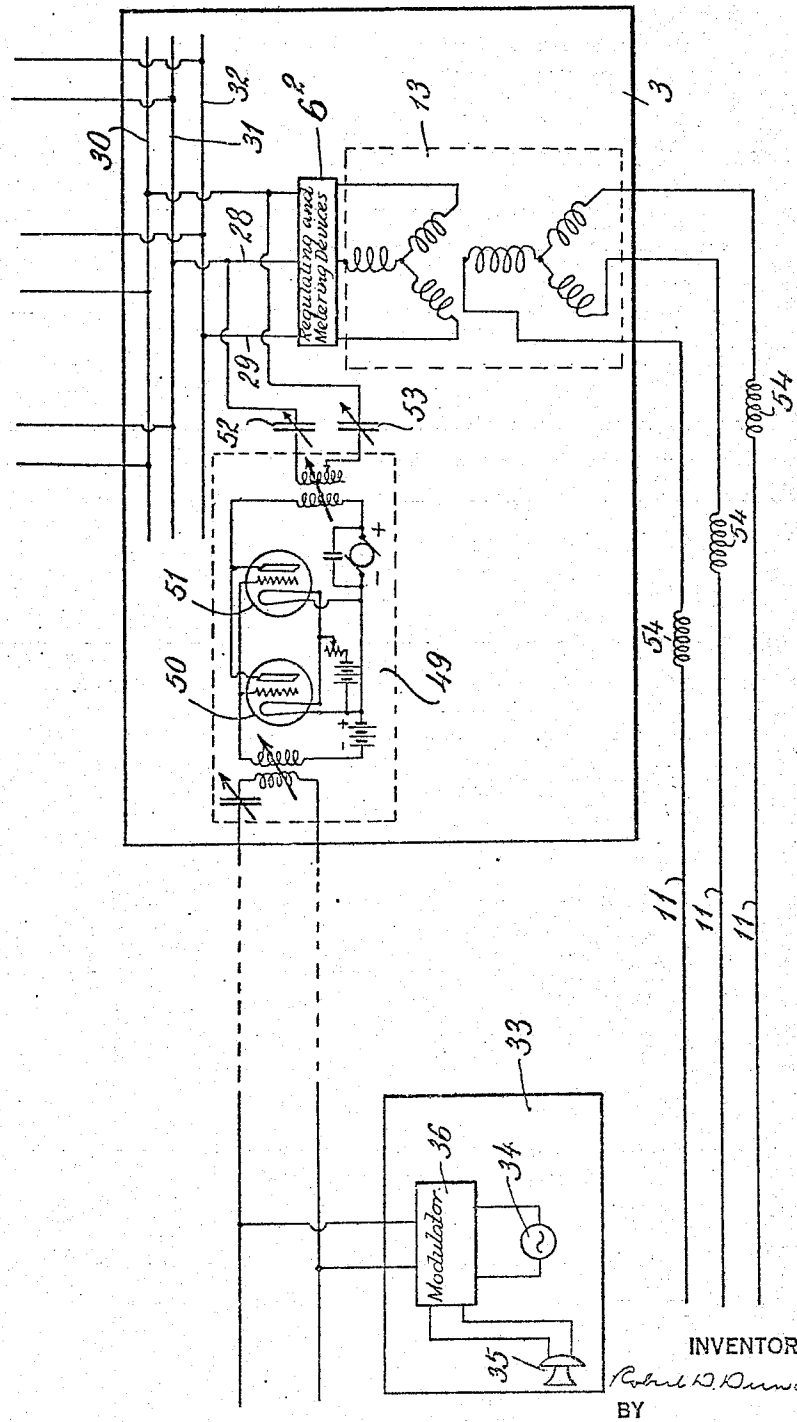

Fig. 2.

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UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY BROADCASTING OVER POWER LINES

Application filed December 5, 1923. Serial No. 678,581.

This invention has to do with communication systems, and relates, more particularly, to systems for broadcasting intelligence to large numbers of listeners.

In my copending application Serial No. 661,037, filed September 5, 1923, Patent No. 1,622,135, granted March 22, 1927, entitled "Wired radio broadcasting system", there is described and claimed a system for broadcasting intelligence through the medium of high frequency carrier current over power and lighting transmission networks to large numbers of listeners simultaneously. In the system described in my copending application the modulated high frequency carrier currents are impressed upon the transmission line at the central power station and are distributed from there by means of the power transmission line and usually through the medium of several substations to a large number of branch distributing circuits extending to power consumers' installations.

In many instances some of the substations are situated at relatively long distances from the central power station, resulting in very considerable attenuation of the high frequency signaling current between the central power station and the more distant stations. Then again, some of the substations may serve a vastly greater number of consumers than others, which means that the high frequency signaling current which reaches the individual consumers served by those substations is correspondingly weaker than is the case in those areas where the number of consumers served by the substation is substantially less. Furthermore, the apparatus at the substations including the transformers and regulating apparatus through which the carrier current must pass, frequently offers very considerable additional attenuation. Due to these conditions, either individually or combined, as the case may be, it sometimes happens that certain subscribers to the broadcast service who are more unfavorably located do not receive the signals as well as do other subscribers whose locations are more favorable.

The present invention has to do with a system which is, in general, similar to that described in my previously mentioned copending application and is an improvement thereon in that it provides an arrangement whereby the broadcast signals may be transmitted to all the subscribers within the area served with approximately equal effect.

Instead of impressing high frequency carrier current upon the power transmission lines at the central power station as described in my copending application, the present invention provides a system wherein the modulated high frequency carrier current is transmitted from a central broadcasting station to each of the several substations over specially provided high frequency transmission lines each of which extends to one of the several substations. Where a substation is a relatively long distance from the central broadcasting station, or where the area or number of subscribers served by such substation is such as to require increased high frequency power, suitable amplifiers are provided at those substations. In some instances it may not be necessary to provide for any amplification at the substation, while in other instances it may be necessary to provide several steps of amplification, depending, in part, upon the distance from the central broadcasting station to the substation, and, in part, upon the area and number of consumers served by the substation. By virtue of this invention it becomes possible to increase the amount of high frequency power impressed upon the lines served by any individual substation merely by adding one or more steps of amplification. Thus, as the outlying areas of cities become more thickly populated, the high frequency signaling current at the substation serving that area may be proportionately increased from time to time.

If instead of providing a system in accordance with the present invention, each substation were to be equipped with a separate and independently operating source of high frequency oscillations and the signals to be broadcast were transmitted from the central broadcasting station to the separate high frequency current generators located in the substations in the form of audio frequency cur-

rents a practically inoperative broadcast system would result, as may be seen from the following considerations. First assume that each of the independent high frequency oscillators are to be operated at the same frequency. It is well known in the radio art that it is impossible to maintain even two independent high frequency oscillators in exact frequency synchronization and that there is an ever present tendency for one or the other to shift in frequency. The practical result of this is that relatively small differences in frequency which would be bound to exist between the several oscillators would result in disturbing beat tones between the various fundamental and harmonic frequencies being heard at some or all of the consumer's receivers due to the inductive relation which frequently exists between lines extending from different substations where the areas served by these different substations either overlap or the transmission lines serving them are in close geographical proximity. Manifestly where there are a large number of substations, say fifteen or twenty, as is the case with large cities, the interference arising from frequency non-synchronization would be prohibitive. Second, assume that the fundamental frequencies of the high frequency oscillators located at the separate substations were displaced by frequency increments so that the resulting beat tones would be above audibility. The practical result of this procedure would be where there are a plurality of substations each served by a separate oscillator, that a vast range of frequencies would be required. It is fundamental in the wired radio art that only a rather restricted band of the lower range of carrier frequencies may be effectively utilized for transmission; even tho this were not the case, to design, construct and maintain vast numbers of receivers, each responsive to a wide range of frequencies, such as this arrangement would require, would be manifestly uneconomical and out of the question. Furthermore, even tho the various fundamental frequencies were displaced by super-audible increments, the ever present harmonic frequencies which it is substantially impossible to suppress, would themselves give rise to a host of disturbing beat tones in the many consumers' receiving sets for the reasons previously set forth.

In systems according to my previously mentioned co-pending application, wherein the high frequency transmitter is located at the central power station, it has been found to be a very difficult matter to provide amplification at the substation on account of the tendency for such amplifiers to operate regeneratively, thereby generating oscillations which beat with the carrier frequency, resulting in a beat note being heard at each of the listening stations. It is necessary in such a system to arrange the amplifiers, if provided, in shunt to the transformer or transformers at the substation. These transformers provide efficient high frequency paths which function as feedback couplings between the output and input sides of the amplifier.

The improved arrangement avoids the attenuation which might otherwise result from transmitting the signals over the relatively long power transmission lines extending from the central power station to the various substations and the further attenuation of the power transformers and the metering and regulating apparatus at the substations through which the carrier current would, of necessity, have to pass.

In a system according to the present invention the high frequency broadcasting central station may be placed at a favorable location with respect to all of the several substations so that the distances from the broadcasting station to the various substations may not be greatly out of proportion one to the other. Of course, where there are a large number of substations, there is likely to be a considerable difference in the distances from the broadcasting station to the nearest and farthest substation. This difference, however, is offset, in accordance with the present invention, by providing various degrees of amplification at the different substations, depending upon their relative distances from the broadcasting central station and, as before stated, upon the number of consumers and area served by the individual substations.

It is thought that the invention will be more clearly understood from the following detailed description with reference to the accompanying drawings, in which

Fig. 1 is a diagrammatic illustration of an alternating current power distribution system comprising a central power station and two substations with a number of distributing circuits extending from each of the substations to various consumers' installations together with a broadcasting central station, and

Fig. 2 is a circuit diagram illustrating a high frequency amplifier inserted in a high frequency carrier current transmission line extending from a broadcasting central station to one of the substations.

Referring to Fig. 1, a central power station 1, together with two substations 2 and 3, are shown interconnected. An alternating current generator 4 is indicated at the central power station 1. The output of this generator is transmitted through the medium of the regulating and metering devices 6 to the bus bars 7, 8 and 9, from which two three-wire, three-phase transmission circuits 10 and 11 extend to the substations 2 and 3 respectively. At the substations are shown three-phase transformers 12 and 13 respectively, to which the primary windings of the transmis-

sion circuits 10 and 11 are connected. The terminals of the secondary windings of transformer 12 are shown connected through the medium of metering and regulating apparatus 6′ to conductors 14, 15 and 16 and thence to bus bars 17, 18 and 19, respectively. Three single-phase circuits 20, 21 and 22 are shown connected to the bus bars at the substation. These single-phase lines constitute branch distributing circuits for alternating power and lighting current. In accordance with the usual practice, each consumer's installation is connected with a branch circuit through the medium of a step-down transformer such as transformers 23, 24, 25 and 26.

Substation 3 is substantially identical with substation 2. Here the terminals of the secondary winding of transformer 13 are connected through metering and regulating apparatus 6^2 and conductors 27, 28 and 29 to bus bars 30, 31 and 32, respectively. From these latter bus bars there are shown extending three single-phase branch circuits similar to the branch circuits 20, 21 and 22 extending from substation 2.

A high frequency broadcasting central station is indicated at 33. This station comprises a high frequency carrier current generator 34, a microphone 35, and a modulator 36. The high frequency generator may be of any suitable type such as a vacuum tube oscillator or a high frequency rotary generator, and modulation may be effected by any one of the several well-known methods. The modulated high frequency carrier current is transmitted from the broadcasting central station 33 over the high frequency transmission lines 37 and 38 to the substations 2 and 3. At substation 2 the two conductors of the high frequency transmission line 37 are shown connected respectively to conductors 15 and 16 through the medium of condensers 39 and 40. These latter condensers function to prevent short circuit of the low frequency alternating current from the conductors 15 and 16 to the apparatus at the broadcasting central station, and may be utilized for tuning the line to the carrier current frequency.

As stated in my previously referred to copending application, I have discovered that high frequency signaling current may be transmitted over three-wire, three-phase power transmission lines and received from any two of the three wires although the high frequency apparatus is connected directly only to two of the three wires comprising the three-phase system. With connections as shown in Fig. 1, the high frequency carrier current finds its way to all the associated branch distribution circuits 20, 21 and 22, over which it is transmitted to the various power consumers' installations such as indicated at 41, 42, 43, etc. At the consumer's station 41 there is indicated apparatus 44 adapted to receive and detect modulated high frequency carrier currents. This apparatus includes a loud speaking telephone instrument. The receiving terminals of the apparatus 44 are connected, preferably, through condensers 45 and 46 to the power lines 47 and 48 respectively. The other consumers' installations such as 42 and 43 are similar, in general, to that of 41.

If the substation 3, for instance, is located at a considerable distance from the broadcasting central station 33, attenuation of the carrier currents due to the impedance of transmission line 38 may be such as to warrant the interposition in this line of an amplifier as indicated at 49. Then again, substation 3 may not be a very great distance from the broadcasting central station but it may serve a thickly populated area or, at any rate, a large number of consumers, with the result that the total available high frequency energy is divided among a much larger number of consumers than in the case of other substation areas. When these conditions exist, it is desirable to increase the amount of high frequency energy available as compared with the energy required to serve a considerably smaller number of consumers. To meet the requirements in each instance, the number of steps of amplification may be increased or decreased as the case may be. Generally it will be necessary to provide at least one stage of amplification, but where the attenuation is low and the number of consumers is relatively small, the amplifier may be dispensed with.

Fig. 2 is a reproduction of a portion of Fig. 1 on a much larger scale including details of a suitable amplifier circuit. There is shown a conventional single-stage radio frequency amplifier or repeater comprising two three-electrode vacuum tubes 50 and 51 with associated circuit connections familiar to those skilled in the art. Condensers 52 and 53 correspond to condensers 39 and 40 and have similar functions, namely, to prevent the short circuit of the low frequency alternating current from the power transmission lines and to tune the power transmission lines to the frequency of the carrier current.

The various branch distribution circuits and consumers' installations associated with substation 3 are similar, in general, to those shown associated with substation 2, and require no discussion.

In some cases it may be found that the amplifiers operate as oscillators due to feedback connections via the power transmission lines. For example, in Fig. 1 the output and input stations of the amplifier 49 are coupled through transformers 12 and 13, conductors 10 and 11, and bus bars 7, 8 and 9. If the attenuation of this coupling path is sufficiently low, oscillations will occur. To overcome the oscillatory condition, radio frequency choke coils 54 may be inserted at any

convenient points on the coupling path, as indicated in Fig. 1. These choke coils should be of sufficient inductance to provide a substantial impedance to the radio frequency, but should not be sufficiently high inductance to substantially impede the low frequency power current.

Although only a three-phase system is shown, the utility of the invention is not limited in any sense to three-phase systems, but is equally applicable to single phase and multi-phase systems of all degrees.

I claim:

1. A high frequency broadcasting system comprising an electric power distribution network including a central power generating station, a plurality of substations connected to said central station, and branch distribution circuits extending from said substations to power consumers' installations, a high frequency broadcasting central station, a plurality of high frequency carrier current transmission lines extending from said broadcasting station to different substations, said transmission lines being connected at said substations to said branch distribution circuits for impressing modulated high frequency current upon said branch distribution circuits, means for preventing undesired oscillations between said central station and said substations and high frequency signal receiving devices at a plurality of said consumers' installations.

2. In a high frequency broadcasting system, an electric power distribution network comprising a plurality of distribution areas, a power generating central station, a plurality of substations, power transmission lines connecting said central station with said substations, each of said substations serving one of said areas, a plurality of branch distribution circuits extending from each of said substations, and a plurality of power consumers' installations connected to the said branch circuits of each area, a high frequency broadcasting central station comprising means for generating and modulating high frequency carrier current in accordance with signals to be broadcast, a plurality of carrier current transmission lines extending from said broadcasting station, each of said carrier current transmission lines extending to a different one of said distribution areas and operatively associated with the branch distribution circuits of said area for impressing modulated high frequency current upon said branch circuits for effecting the transmission of high frequency signals thereover, means for preventing the circulation of undesired oscillations between said central station and said substations, and high frequency signal receiving devices at a plurality of said consumers' installations, said devices being connected to said branch distribution circuits and adapted to receive signals transmitted from said broadcasting central station.

3. In a high frequency broadcasting system, an electric power distribution network comprising a plurality of distribution areas, a central power generating station, a plurality of substations connected to said central generating station, each of said substations being individual to one of said distribution areas, a plurality of branch distribution circuits extending from each of said substations, a plurality of power consumers' installations connected to said branch distribution circuits, a high frequency broadcasting central station comprising means for generating and modulating high frequency carrier current in accordance with signals to be broadcast, a plurality of carrier current transmission lines each extending from said broadcasting central station to a different one of said substations and operatively associated with the branch distribution circuits extending therefrom for impressing modulated high frequency signaling current upon said branch distribution circuits whereby high frequency signals can be transmitted from said broadcasting central stations to said consumers' installations through the medium of said high frequency carrier current transmission lines and said branch distribution circuits, high frequency signal receiving devices at a plurality of said consumers' installations, said devices being connected to said branch distribution circuits and adapted to receive signals transmitted from said broadcasting central station, means disposed in the circuits between said central station and said substations for preventing the circulation of undesired oscillations in said circuits, and means for amplifying high frequency carrier currents interposed in at least one of said carrier current transmission lines.

4. In a high frequency broadcasting system, an electric power distribution network comprising a plurality of distribution areas, a central power generating station, a plurality of substations connected to said central generating station, each of said substations being individual to one of said distribution areas, a plurality of branch distribution circuits extending from each of said substations, a plurality of power consumers' installations connected to said branch distribution circuits, a high frequency broadcasting central station comprising means for generating and modulating high frequency carrier current in accordance with signals to be broadcast, a plurality of carrier current transmission lines each extending from said broadcasting central station to a different one of said substations and operatively associated with the branch distribution circuits extending therefrom for impressing modulated high frequency signaling current on said branch distribution circuits, means con-

nected in series with said carrier current transmission lines for preventing undesired oscillations in said lines whereby high frequency signals can be transmitted from said broadcasting central station to said consumers' installations through the medium of said carrier current transmission lines and said branch distribution circuits, high frequency signal receiving devices at a plurality of said consumers' installations, said devices being connected to said branch distribution circuits and adapted to receive signals transmitted from said broadcasting central station, and means for amplifying high frequency carrier currents interposed in at least one of said carrier current transmission lines, in at least one of said substations.

5. In a high frequency broadcasting system, a multi-phase power generating central station, a plurality of multi-phase power transmission lines extending from said central station, a plurality of substations, each of said substations including a multi-phase transformer, the primary windings of each of said transformers being connected to one of said power transmission lines, a plurality of branch distribution circuits associated with each of said substations, said branch distribution circuits extending to consumers' installations, a broadcasting central station comprising means for generating and modulating high frequency carrier current, a plurality of high frequency carrier current transmission lines extending from said broadcasting central station, each to one of said substations, said high frequency transmission lines being connected to the output circuits of the transformers at their respectively associated substations for impressing modulated high frequency signaling current on said branch distribution circuits, means connected in series with said lines for preventing the circulation of undesired oscillations therein, means at certain of said substations for amplifying the high frequency carrier current means operable to prevent the flow of low frequency current from the power transmission system to the high frequency carrier current transmission lines, said means being inoperative to prevent the flow of high frequency carrier current from said high frequency carrier current transmission lines to the power distribution system, and means at a plurality of consumers' installations for receiving and indicating modulated high frequency carrier current transmitted over the power distribution system.

6. In a high frequency broadcasting system, a central power generating station, a plurality of substations, conductors for the transmission of power current interconnecting said central generating station with said substations, branch distribution circuits extending from each of said substations to a plurality of consumers' installations, a high frequency broadcasting central station, high frequency carrier current transmission lines extending from said broadcasting central station, each to one of said substations, a high frequency amplifier interposed in one of said high frequency carrier current transmission lines, the arrangement being such that there is an inherent feedback path from the output side of said amplifier to the input side thereof by way of the conductors interconnecting the central power generating station and the substations and impedances inserted in said conductors, said impedances being effective to prevent said amplifier functioning as an oscillator by reason of said feedback path but inoperative to substantially impede the flow of low frequency power current.

7. In a high frequency broadcasting system, a central power generating station, a plurality of substations, conductors for the transmission of power current interconnecting said central generating station with said substations, branch distribution circuits extending from each of said substations to a plurality of consumers' installations, a high frequency broadcasting central station, high frequency carrier current transmission lines extending from said broadcasting central station, each to one of said substations, a high frequency amplifier interposed in one of said high frequency carrier current transmission lines, the arrangement being such that there is an inherent feedback path from the output side of said amplifier to the input side thereof by way of the conductors interconnecting the central power generating station and the substations and choke coils inserted in said conductors, said choke coils being effective to prevent said amplifier functioning as an oscillator by reason of said feedback path but inoperative to substantially impede the flow of low frequency power current.

8. In a wired radio broadcasting system the combination of an electric power distribution net work comprising a plurality of distribution areas, a central power generating station, a plurality of power substations connected to said central station, each of said substations being individual to one of said distribution areas, a plurality of branch distribution circuits extending from each of said substations, a plurality of power consumer's installations connected to said branch distribution circuits, a high frequency broadcasting central station comprising means for generating and modulating high frequency carrier current in accordance with the signals to be broadcast, a plurality of carrier current transmission lines extending from said broadcasting central station to the said plurality of substations, high frequency power amplifiers including input and output circuits located in said sub-

stations, connections between said carrier current transmission lines and the input circuits of said power amplifier, means in said connections for suppressing undesired circulatory oscillations, additional connections between said branch distribution circuits and the output circuits of said power amplifiers, said first mentioned and additional connections providing means for impressing amplified modulated high frequency signaling current on said branch circuits whereby high frequency signals may be transmitted from said broadcasing central station to said consumer's installations thru the medium of said carrier current transmission lines, said power amplifiers and said branch distribution circuits, high frequency signal receiving and reproducing devices at a plurality of said consumer's installations, said devices being operatively connected with branch distribution circuits.

9. In a wired radio broadcasting system the combination of a polyphase electric power generating central station, a plurality of polyphase transmission lines extending from said central station, a plurality of substations, each of said substations including at least one polyphase transformer, the input winding of said transformer being connected to one of said polyphase transmission lines, a plurality of branch distribution circuits associated with each of said substations, connections between said branch distribution circuits and the output windings of said polyphase transformer, a plurality of power consumers' installations, a plurality of additional transformers, connected to said branch distribution circuits, additional connections between said consumers' installations and said additional transformers, a broadcasting central station comprising means for generating and modulating high frequency carrier current, high frequency carrier current transmission lines extending from said broadcasting central station to said substations, high frequency power amplifiers including input and output windings, located in at least one of said substations, connections between said carrier current transmission lines and the input windings of said power amplifier, means in said connections for suppressing undesired oscillations, additional connections between said branch distribution circuits and the output windings of said power amplifier for impressing amplified modulated high frequency signaling current on said branch distribution circuits, high frequency signal receiving and reproducing devices at a plurality of said consumers' installations, said devices being operatively connected with said additional transformers whereby high frequency signals transmitted from said broadcasting central stations are rendered audible at said signal receiving and reproducing devices at said consumers' installations.

10. In a wired radio broadcasting system the combination of a polyphase electric power generating central station, a plurality of polyphase transmission lines extending from said central station, a plurality of substations each of said substations including a plurality of transformers connected in a polyphase manner, the input windings of said transformers being connected to one of said polyphase transmission lines, a plurality of branch distribution circuits associated with each of said substations, connections between said branch distribution circuits and the output windings of said polyphase transformer a plurality of power consumers' installations a plurality of additional transformers connected to said branch distribution circuits additional connections between said consumers' installations and said additional transformers, a broadcasting central station comprising means for generating and modulating high frequency carrier current, high frequency carrier current transmission lines extending from said broadcasting central station to said substations, high frequency power amplifiers including input and output windings located in at least one of said substations, connections between said carrier current transmission lines and the input windings of said power amplifier, means in said connections for suppressing undesired oscillations, additional connections between said branch distribution circuits and the output windings of said power amplifier for impressing amplified modulated high frequency signaling current on said branch distribution circuits, high frequency signal receiving and reproducing devices at a plurality of said consumers' installations, said devices being operatively connected with said additional transformers whereby high frequency signals transmitted from said broadcasting central stations are rendered audible at said signal receiving and reproducing devices at said consumers' installations.

11. A system for broadcasting signaling energy over electric power transmission systems comprising means for generating high frequency carrier current, means for modulating the carrier current in accordance with audible signals, means for transmitting the modulated carrier current to a plurality of power substations, a central station, transmission wires interconnecting said substations and said central station, means for raising the level of the high frequency modulated carrier current at one or more of the substations, means for preventing the undesired circulation of high frequency energy through the path formed by the interconnection of said central station with said substations over said transmission wires and means for impressing the modulated carrier current at increased amplitude on out going power

transmission lines at selected power substations.

12. A system of wired radio signal transmission over electric power transmission systems comprising means for generating high frequency carrier current, means for transmitting the generated carrier current to a plurality of power substations, a central power station, transmission wires interconnecting said central power station with said substations, means for amplifying the carrier current at one or more substations, means for preventing the undesired circulation of energy between the input and output circuits of said amplifying means over the path provided by said transmission wires between said central station and said substations and means for impressing the amplified carrier current on the outgoing power transmission lines at selected power substations.

13. A wired radio broadcasting system comprising in combination a central polyphase electric power generating station, a plurality of substations located in a restricted area in geographically spaced positions with respect to said central station, a polyphase electric power distribution network extending between said central station and said substations, a plurality of branch circuits extending from said substations to a plurality of subscriber stations, transforming equipment at each of said substations, a high frequency central control station having line circuits extending to each of said substations and connected with each of said branch circuits, means in said line circuits for suppressing undesired circulatory oscillations, a generator of high frequency oscillations at said control station, means for modulating said oscillations for supplying high frequency current over said line circuits to each of said branch circuits for transmission to said subscriber stations and means at selected ones of said substations for raising the level of the high frequency current impressed upon the corresponding branch circuit in proportion to the number of subscriber stations supplied from said branch circuits.

14. A wired radio broadcasting system comprising in combination a central polyphase electric power generating station, a plurality of substations located in a restricted area in geographically spaced positions with respect to said central station, a polyphase electric power distribution network extending between said central station and said substations, a plurality of branch circuits extending from said substations to a plurality of subscriber stations transforming equipment at each of said substations, a high frequency central control station having line circuits extending to each of said substations and connected with each of said branch circuits, means in said line circuits for suppressing undesired circulatory oscillations, a generator of high frequency oscillations at said control station, means for modulating said oscillations for supplying high frequency current over said line circuits to each of said branch circuits for transmission to said subscriber stations, and a high frequency electron tube amplification system located at selected ones of said substations and interposed between said line circuits and said branch circuits for controlling the level of the high frequency current impressed upon the corresponding branch circuit in proportion to the number of subscriber stations supplied by said branch circuits.

In testimony whereof I affix my signature.

ROBERT D. DUNCAN, JR.