Aug. 30, 1932.

C. W. HANSELL

1,874,978

TRANSMISSION SYSTEM

Filed July 20, 1927

2 Sheets-Sheet 1

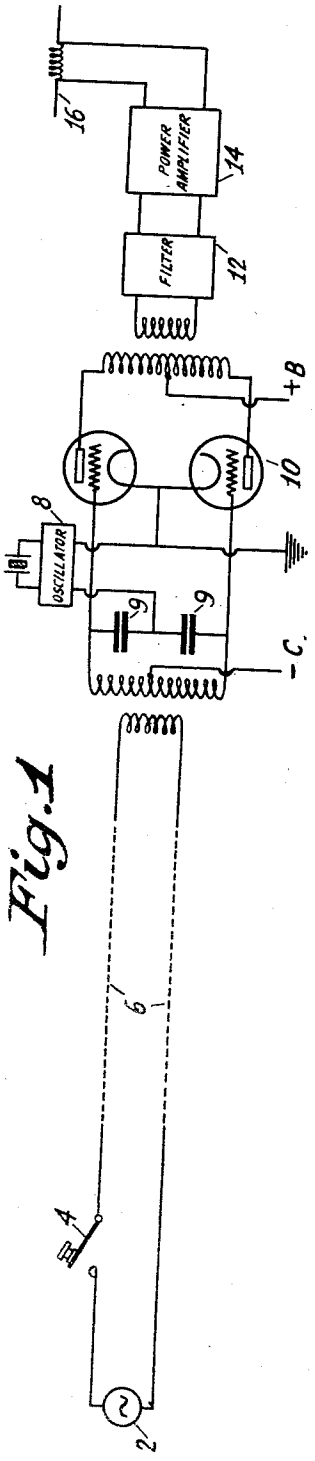


Fig. 1

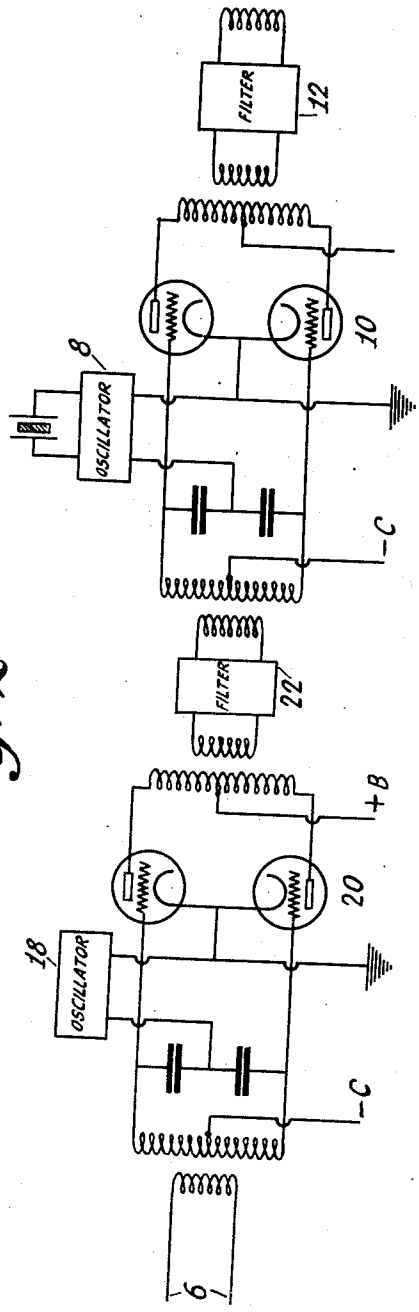


Fig. 2

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TRANSMISSION SYSTEM

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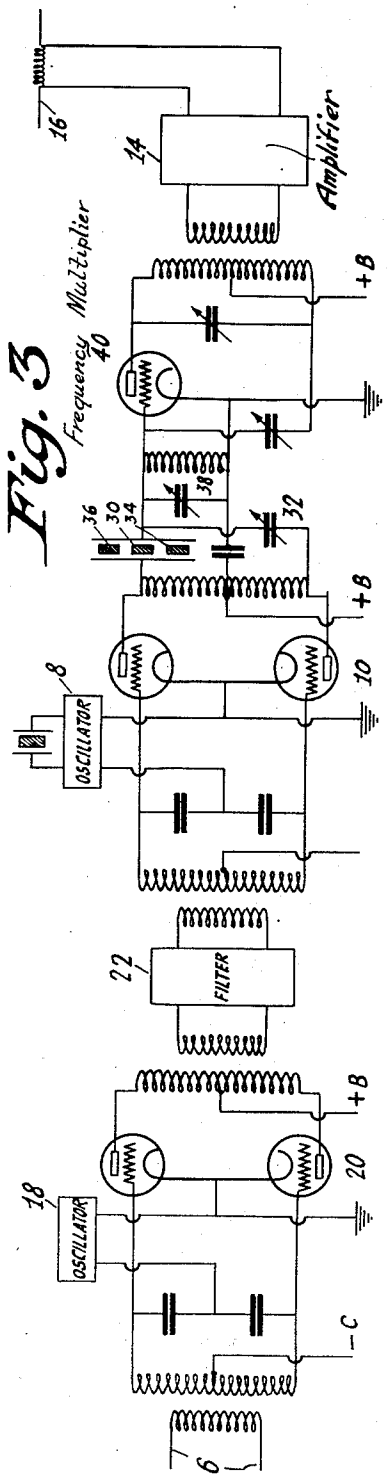


Fig. 3

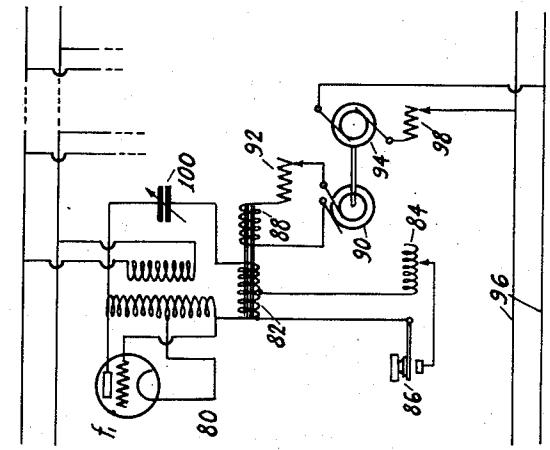


Fig. 6

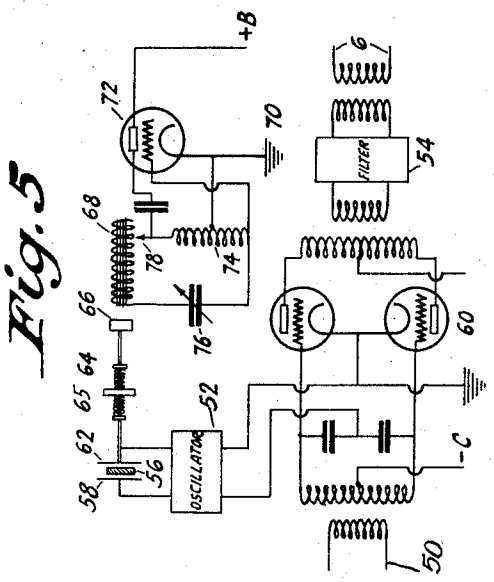


Fig. 5

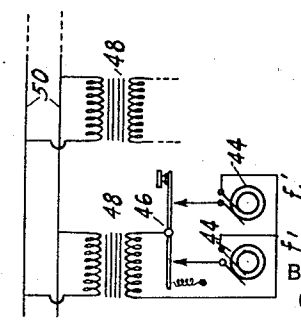


Fig. 4

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UNITED STATES PATENT OFFICE

CLARENCE W. HANSELL, OF ROCKY POINT, NEW YORK, ASSIGNOR TO RADIO CORPORATION OF AMERICA, A CORPORATION OF DELAWARE

TRANSMISSION SYSTEM

Application filed July 20, 1927. Serial No. 207,114.

This invention relates to transmission systems, and more particularly to such systems in which the signalling is remotely controlled.

Transmission stations of large size are usually located in suburban localities, whereas the signalling preferably is accomplished from an urban office. Such an arrangement becomes especially necessary when the transmitting and receiving stations for one city are widely separated, and both have land lines leading to a signalling office. The keying means at the office heretofore have controlled, through land lines, a direct current which keys the transmitter through an elaborate system of relays. Consequently the maximum possible keying speed has been limited by the time characteristics of the land line and the rapidity of response of the relays. It is an object of my invention to increase the maximum keying speed by decreasing the effect of the land line, and this I find is possible by using alternating current energy on the line in place of direct current energy.

It is a further object of my invention to simplify transmission apparatus and to increase keying speed by eliminating the relay system previously employed, which I do by utilizing the alternating energy from the land line to modulate high frequency transmission energy and transmitting only a desired portion of the resulting modulated energy. Preferably a carrier suppression modulator is employed to eliminate the carrier component of the modulated energy, and then one of the two resulting side frequencies is selected by a filter and is suitably amplified for transmission. With this arrangement there is no transmitter output when the land line is not keyed.

It is found that rapid interruption of the load on a power amplifier using electron emission tubes shortens the tube life much more than would be the case were the amplifier subjected to a more uniform load. It therefore is a still further object of my invention to so arrange a transmission system that there will be a constant load upon its power amplifier, and this I propose to do by producing a frequency change in the transmitter, upon keying, instead of a total cessation of transmission between signal impulses. This is made possible in a very simple manner when utilizing a system such as I have so far outlined because all that is necessary is to change the frequency of the alternating energy in the land line when keying. The key is made to control the frequency of the alternating energy, specifically, rather than to control the alternating energy, more broadly.

It is a still further object of my invention to allow multiplex transmission over a single land line, and this is readily accomplished by establishing a desired number of signal channels of different frequency ranges on the land line, and signalling either by energy control or frequency control, in each of these channels.

It is a still further object of my invention to prevent or reduce fading of the transmitted signals by wobbling the transmission frequency. This may be done at the transmitter, but preferably the extent and frequency of the wobble should be under the control of the signal operator because he then may vary these quantities in accordance with requests received by him from the station being communicated with. Such remote control of the wobble may be accomplished in accordance with my invention by wobbling the frequency of the alternating energy on the land line. When multiplexing, such a frequency wobble may be introduced at an intermediate frequency, and the wobble then will be about equal for all of the signal channels. An intermediate or even a high frequency wobble may be introduced at the transmitter, or the intermediate frequency may be kept moderately low and the wobble be introduced at the signal office. In the latter case the frequencies of the signal channel on the land line are the sum of the intermediate frequency and the corresponding low frequency channels which are controlled by the individual signalling means.

The alternating energy in each channel may be separately wobbled, in which case each operator will not only change the frequency or otherwise control the energy with-

in the frequency range of his channel by his signalling means, but will also be able to vary the frequency range of wobble and frequency of frequency wobble for his particular signal channel.

As will be pointed out more in detail hereinafter, for some purposes it is desirable to have a carrier current or relatively high frequency land line, but this is not essential, and in order to employ the usual land lines the frequency channels employed should all stay within a range of several thousand cycles per second. As short wave or very high frequency transmission is favored, one consequence of low land line frequency will be a very small separation between the upper and lower side band frequencies, thereby making it difficult to successfully filter one from the other. To overcome this difficulty is a still further object of my invention, and some or all of various expedients may be employed. Thus, successive stages of carrier suppression modulation may be employed, thereby greatly increasing the percentage separation of the side bands in each stage. Instead or in addition recourse may be had to a special filter, such as a crystal filter, which is sufficiently highly selective to discriminate between upper and lower side frequencies even though these are separated by a relatively small amount. Another solution is to employ frequency multiplication before transmission. In such case the carrier frequency at the time of modulation may be much lower, and therefore for a given modulating frequency the percentage difference between the upper and lower side frequencies is increased.

It is difficult to operate power amplifiers at very high frequencies under the control of very small amounts of controlling energy, and many of these difficulties are overcome by using, instead of straight amplification, frequency multiplication together with amplification, which presents an additional advantage concomitant with the use of frequency multiplication. Still another advantage, when desired, is the increased separation of the final radio frequencies of the multiplex channels.

The invention is more completely described in the following specification, which is accompanied by drawings in which:

Figure 1 indicates my invention in simplest form;

Figure 2 shows successive modulation;

Figure 3 is a wiring diagram for a transmitter employing successive modulation, crystal side band separation, and frequency multiplication and amplification;

Figure 4 shows multiplexing and signalling by frequency change;

Figure 5 indicates a carrier suppression modulator provided with means for wobbling the carrier frequency; and

Figure 6 shows multiplexing with independently controlled frequency wobble for each signal channel.

Referring to Figure 1 there is shown a source of alternating current energy 2 controlled by a key 4, the energy from which is conducted over a land line 6 to apparatus at the transmitting station. There is a local oscillator 8, which preferably is crystal controlled, the energy from which is applied symmetrically, through radio frequency condensers 9 to a push-pull modulator stage 10. The carrier component of the modulated energy is suppressed because of phase opposition in the output circuit of the modulator. The upper and lower side frequencies are separated by a filter 12, and one of the side frequencies, preferably the upper, is led to a power amplifier 14 from which the amplified energy is radiated by an antenna 16.

It is clear that with this arrangement the key 4 controls the power output without any intermediate use of relays. Furthermore, as was already pointed out, the use of alternating current energy on the land line inherently increases the maximum signal speed on the line.

The arrangement shown in Figure 1 indicates the invention in simplest form, and possesses the defect, owing to the fact that the transmission carrier frequency should preferably be a very high frequency, and that the land line frequency, using existing telephone lines, must be a relatively low frequency, that the upper and lower side frequencies become very closely adjacent relative to the carrier frequency, and are exceedingly difficult to separate. The necessary percentage discrimination of the filter may be reduced by the use of successive modulation stages, as shown in Figure 2.

Referring to that figure, alternating energy from the land line 6 is used to modulate energy of intermediate frequency, produced by an oscillator 18, through the aid of a carrier suppression modulator 20. Of the two side frequencies the filter 22 selects one, and this is used to modulate energy of carrier frequency, generated in an oscillator 8, through the agency of a carrier suppression modulator 10. The side frequencies are separated by a filter 12, which may be followed by a power amplifier, or frequency multiplier, or frequency multiplier amplifier, and then radiated. With such an arrangement the frequency separation of the side frequencies is greatly increased. As a random example, if the line frequency is 1,000 and the intermediate frequency 19,000, then the filter 22 must discriminate between 20,000 and 18,000, which is quite feasible, and then if the carrier frequency is 1,980,000 the filter 12 must discriminate between 2,000,000 and 1,960,000. Even this is difficult, but it is much more practicable than a separation of 2,000,000 from 1,998,000, as if the line frequency

directly modulated the high frequency carrier.

Close frequency selection is aided by the use of a crystal filter, included in Figure 3. As before, the land line 6 is coupled to a modulator 20 to modulate an intermediate frequency produced by an oscillator 18. The side frequencies are separated by a filter 22, and one of the side frequencies is used to modulate a carrier frequency, produced by an oscillator 8, through the aid of a carrier suppression modulator 10.

The separation of the side frequencies is accomplished by a series connected piezo-electric crystal 30, having a resonant frequency equal to the desired side frequency. The natural capacitance of the crystal and crystal holder is neutralized by a neutralizing condenser 32, as is described more in detail in my copending application for a crystal filter, filed July 7, 1927, Serial No. 203,901.

To allow keying by frequency change, multiplexing, and frequency wobbling, it is desirable that the filters used be adapted to separate side bands, rather than side frequencies. Thus, the filter 22 preferably is made a high pass filter with cut-off about at the carrier frequency. A crystal filter is apt to be too sharply selective for use with side bands instead of side frequencies, and therefore its frequency range is broadened by the use of additional crystals 34 and 36, having adjacent but sufficiently different resonant frequencies, and the use of a parallel resonant circuit 38, all as has been described in my copending application already referred to.

The output from the crystal filter is led to a frequency multiplier stage 40, followed by a power amplifier 14, the output from which is led to radiating means 16. It is to be understood that any suitable number of successive stages of modulation may be used, and that the stage 40 may be a simple amplifier stage, but that on the other hand the amplifier 14 may be a frequency multiplier and amplifier, such as has been disclosed in my copending application, Serial No. 177,505, filed March 23rd, 1927.

Attention is now directed to Figure 4 which represents the signalling end of a land line arranged for multiplexing and for keying by frequency change. The energies of different frequencies are preferably supplied by a plurality of small rotary converters or frequency changers 44, which are respectively adapted to give outputs at frequencies f_1, f_1', f_2, f_2' etc., where f_1, f_2, etc. are the signalling frequencies of the various multiplex channels, and f_1', f_2', etc. are corresponding changed frequencies for transmission between signal impulses. Keying means 46 are arranged as shown to connect either of each pair of generators 44 to a transformer 48 the secondary of which is connected to a line 50, which may lead directly to the land line 6 indicated in Figures 1, 2 and 3. In such case the generators 44 must generate the land line frequencies, and in the case of a low frequency land line this is probably a simple and feasible arrangement. However, if a carrier frequency land line is available, then it is preferable to keep the frequencies f_1, f_2, etc. reasonably low and therefore below the carrier frequencies. To do this the low frequencies may be used to modulate a land line carrier frequency, say F, side frequencies of which are then sent over the land line.

Thus, in Figure 5, the conductors 50 supply low frequency signal energy to a carrier suppression modulator 60. Energy of approximately the desired land line frequency is generated by an oscillator 52, and is supplied symmetrically to the modulator 60. A filter 54 separates the side bands, and the output from the filter, after amplification if necessary, is led to the land line 6. In one sense we may say that the first modulation stage has been moved from the transmitter to the signal office. But in a broader sense I prefer to consider the entire apparatus at the signal office as establishing various land line channels, the frequencies of which happen to be $F+f_1$, $F+f_2$, etc.

To prevent fading it has been found that frequency wobbling is helpful, and one means for doing this has been schematically indicated in Figure 5. Oscillator 52 is crystal controlled by a crystal 56 which is situated between a stationary electrode 58 and a movable electrode 62. The latter is oscillated by a rod 64 the movement of which is dampened or resisted by a spring system 65. The rod 64 is attached to a polarized armature 66 which is under the influence of the field of an alternating current magnet 68. For obtaining a relatively high frequency of wobble the magnet 68 has been shown as energized by a vacuum tube oscillator 70, comprising a vacuum tube 72 regeneratively coupled to a coil 74, which is series connected with the magnet 68 and a tuning condenser 76.

Means are provided to control the characteristics of the wobble. The extent of wobble, that is, the amount of frequency variation taking place during each wobble cycle, depends on the amplitude of movement of the electrode 62, and is controlled by an adjustment of the contactor 78. For any one setting of 78, the frequency of wobble is controlled by tuning the oscillator circuit by means of the condenser 76.

The arrangement so far described provides for a wobble which may be at a relatively high frequency, tho it should be low relative to the carrier being wobbled. This wobble preferably is small in amplitude or extent of frequency change, in order not to interfere with the characteristic frequency differences

which make the distinction between signal impulses and the spaces between them, as well as the differences in frequency of the several multiplex frequency channels. Placing the modulation stage at the signal end of the line permits of the characteristics of the wobble being controlled by the signalling operator, which I think is preferable, but it is clear that if a low frequency land line is employed then the entire modulator stage 60 may be shifted to the transmitter end of the land line, in which case it may supplant, or be used in addition to stages such as 10 and 20 shown in Figure 3. It should also be understood that the frequency wobble, when applied at the transmitter, may be applied to any suitable stage, including the final stage at the carrier frequency, as well as the preceding intermediate frequency stages.

As I have already mentioned, it is desirable to have the characteristics of the wobble controlled at the signal end of the line in order that the operator may suitably vary the wobble characteristics in response to suggestions received from the station receiving the signals. With different channels being directed to different receiving stations, or because of different fading effects experienced by the different frequency channels, it may be desirable to have the characteristics of the wobble of each signal channel under independent control. Such an arrangement has been shown in Figure 6, which represents the signalling end of a land line used for multiplex signalling by frequency change with an independent frequency wobble for each channel. In that figure there are shown a plurality of vacuum tube oscillators 80, for generating land line frequencies f_1, f_2, etc. The direct current circuits for these have been omitted for simplicity. In the output circuit of these oscillators there is an iron core inductance 82 which is adjusted to operate at a linear portion of its saturation curve. A portion of the windings of the inductance 82 is by-passed by an inductance 84, in series with a key 86. The inductance 82 has magnetically coupled to it a coil 88, which is energized from a wobble generator 90, through a series resistance 92. The wobble generator 90 is driven by a direct current motor 94 which is energized from a direct current supply line 96 through a control rheostat 98.

The signalling frequency is adjusted by the tuning condenser 100. The amount of frequency change which occurs upon keying is controlled by adjusting the inductance 84. The extent of frequency wobble is controlled by adjusting the resistance 92. The frequency of frequency wobble is controlled by adjusting the resistance 98. All of these adjustments may be made independently for each signalling channel, and all or any of them may be under the control of an operator who is in communication with the station to which the signal channel in question is transmitting.

In the claims which follow I shall by the term "keying" mean signal interrupting means for transmitting intelligence by means of on and off or frequency change signals of varying time duration, such as, a code signalling key, a code tape machine, or picture transmission relays, such as are disclosed in my copending application, Serial No. 212,803 filed Aug. 13, 1927. "Signalling means", however, is meant to include broadly any intelligence control of signal energy. "Land line" refers to a relatively long line, whereas "wire line" means merely conductively connected.

The foregoing modifications are by way of illustration and not limitation of my invention, which I claim is:

1. The method of transmitting multiplex code signals by frequency change from a transmitter under the control of a plurality of keying means connected to the transmitter by a wire line which includes putting alternating energy of different frequency ranges on the line for each signal channel, shifting the frequency of the energy from one extreme to the other of each range by a keying means, modulating a relatively higher frequency with the resulting alternating energy, and transmitting a desired portion of the modulated energy.

2. The method of transmitting multiplex code signals by frequency change from a transmitter under the control of a plurality of remotely located keying means connected to the transmitter by a land line which includes putting alternating energy of different frequency ranges on the line for each signal channel, shifting the frequency of the energy from one extreme to the other of each range by a keying means, modulating a relatively higher frequency with the resulting alternating energy, and transmitting only a side band of the modulated energy.

3. The method of wobbling the transmission frequency of a transmitter controlled by a code signal keying means connected to the transmitter by a wire line which includes wobbling the frequency of alternating energy, putting the frequency wobbled alternating energy on the line, controlling the alternating energy with the keying means, modulating a relatively higher carrier frequency with the frequency wobbled alternating energy, and transmitting a desired portion of the modulated energy.

4. The method of wobbling the transmission frequency of a transmitter controlled by a remotely located code signal keying means connected to the transmitter by a land line which includes wobbling the frequency of alternating energy, putting the frequency wobbled alternating energy on the line, controlling the alternating energy with the keying means, modulating a relatively

higher carrier frequency with the frequency wobbled alternating energy, and transmitting a side band of the modulated energy.

5. The method of wobbling and keying the transmission frequency of a transmitter controlled by a keying means connected to the transmitter by a wire line which includes wobbling the frequency of alternating energy, putting the wobbled alternating energy on the line, shifting the mean frequency of the alternating energy with the keying means, modulating a relatively higher carrier frequency with the wobbled and frequency-controlled alternating energy, and transmitting a desired portion of the modulated energy.

6. The method of wobbling and keying the transmission frequency of a transmitter controlled by a remotely located keying means connected to the transmitter by a land line which includes wobbling the frequency of alternating energy, putting the wobbled alternating energy on the line, shifting the mean frequency of the alternating energy with the keying means, modulating a relatively higher carrier frequency with the wobbled and frequency-controlled alternating energy, and transmitting a side band of the modulated energy.

7. The method of multiplex keying and wobbling the transmission frequency of a transmitter controlled by keying means connected to the transmitter by a wire line which includes putting alternating energy of different frequency ranges on the line, controlling the energy of each frequency range with a keying means, wobbling the frequency of the alternating energy, modulating a relatively higher frequency with the resultant alternating energy, and transmitting a desired portion of the modulated energy.

8. The method of multiplex keying and wobbling the transmission frequency of a transmitter controlled by remotely located keying means connected to the transmitter by a land line which includes putting alternating energy of different frequency ranges on the line, controlling the energy of each frequency range with a keying means, wobbling the frequency of the alternating energy, modulating a relatively higher frequency with the resultant alternating energy, and transmitting a side band of the modulated energy.

9. The method of wobbling and multiplex keying by change of the transmission frequency of a transmitter controlled by keying means connected to the transmitter by a wire line which includes putting alternating energy of different frequency ranges on the line, controlling the frequency of the energy of each frequency range with a keying means, wobbling the frequency of the alternating energy, modulating a relatively higher frequency with the resultant alternating energy, and transmitting a desired portion of the modulated energy.

10. The method of wobbling and multiplex keying by change of the transmission frequency of a transmitter controlled by remotely located keying means connected to the transmitter by a land line which includes putting alternating energy of different frequency ranges on the line, controlling the frequency of the energy of each frequency range with a keying means, wobbling the frequency of the alternating energy, modulating a relatively higher frequency with the resultant alternating energy, and transmitting a side band of the modulated energy.

11. The method of wobbling and multiplex keying of a transmitter controlled by keying means connected to the transmitter by a wire line which includes independently wobbling the frequency of each of a plurality of alternating energies of different frequency range, putting the wobbled alternating energies on the line, controlling the energy of each frequency range with a keying means, modulating a relatively higher frequency with the resultant alternating energy, and transmitting a desired portion of the modulated energy.

12. The method of wobbling and multiplex keying of a transmitter controlled by remotely located keying means connected to the transmitter by a land line which includes independently wobbling the frequency of each of a plurality of alternating energies of different frequency range, putting the wobbled alternating energies on the line, controlling the energy of each frequency range with a keying means, modulating a relatively higher frequency with the resultant alternating energy, and transmitting a side band of the modulated energy.

13. The method of wobbling and multiplex keying by change of the transmission frequency of a transmitter controlled by keying means connected to the transmitter by a wire line which includes independently wobbling the frequency of each of a plurality of alternating energies of different frequency range, putting the wobbled alternating energies on the line, controlling the mean frequency of the energy of each frequency range with a keying means, modulating a relatively higher frequency with the resultant alternating energy, and transmitting a desired portion of the modulated energy.

14. The method of wobbling and multiplex keying by change of the transmission frequency of a transmitter controlled by remotely located keying means connected to the transmitter by a land line which includes independently wobbling the frequency of each of a plurality of alternating energies of different frequency range, putting the wobbled alternating energies on the line, controlling the mean frequency of the energy of each fre-

quency range with a keying means, modulating a relatively higher frequency with the resultant alternating energy, and transmitting a side band of the modulated energy.

15. In transmission with wobbled frequency to reduce fading the method of remotely controlling the frequency wobble through a wire line which includes putting alternating energy on the line, frequency wobbling the alternating energy, controlling the characteristics of the frequency wobble, using the frequency wobbled alternating energy to modulate energy of a relatively higher frequency, and transmitting a desired portion of the modulated higher frequency energy.

16. In transmission with wobbled frequency to reduce fading the method of remotely controlling the frequency wobble through a wire line which includes putting alternating energy on the line, frequency wobbling the alternating energy, controlling the frequency and the amplitude of the wobble, using the frequency wobbled alternating energy to modulate energy of a relatively higher frequency, and transmitting a desired portion of the modulated higher frequency energy.

17. The method of frequency wobbling and signalling under remote control over a land line which includes putting alternating energy on the line, signalling on the alternating energy, frequency wobbling the alternating energy to a controlled extent at a controlled frequency, using the frequency wobbled signal energy to modulate energy of a relatively higher frequency, and transmitting a desired portion of the modulated higher frequency energy.

18. A remotely controlled transmission system comprising a source of alternating energy, code signal keying means to control said energy, means to wobble the frequency of said energy to reduce fading, a line for conducting the wobbled signalling energy to a source of relatively high frequency energy, means to modulate the high frequency energy with the signalling energy, and means to radiate a desired portion of the modulated energy.

19. A remotely controlled multiplex transmission system comprising a plurality of sources of alternating energy of different frequency ranges, signalling means to control each of said energies, means to wobble the frequencies, a line for conducting the wobbled signalling energy, a source of relatively high frequency energy, means to modulate the high frequency energy with the signalling energy, and means to radiate a desired portion of the modulated energy.

20. A remotely controlled multiplex transmission system comprising a plurality of sources of alternating energy of different frequency ranges, signalling means to control the frequency of each of said energies, means to wobble the frequencies, a line for conducting the wobbled signalling energy, a source of relatively high frequency energy, means to modulate the high frequency energy with the signalling energy, and means to radiate a desired portion of the modulated energy.

21. A transmission system for wobbling under remote control to reduce fading comprising a source of alternating energy, means to wobble the frequency of said energy, means to control the characteristics of the wobble, a line for conducting the wobbled energy to a source of relatively higher frequency energy, means to modulate the higher frequency energy by the wobbled energy, and means to radiate a desired portion of the modulated energy.

22. A transmission system for wobbling and signalling under remote control over a line comprising a source of alternating energy, keying means to control said energy according to code signals to be transmitted, means to wobble the frequency of said energy, a line for conducting the wobbled signal energy to a source of relatively higher frequency energy, means to modulate the higher frequency energy by the signal energy, and means to radiate a desired portion of the modulated energy.

23. A transmission system for wobbling and signalling under remote control over a line comprising a source of alternating energy, means to control said energy according to signals to be transmitted, means to wobble the frequency of said energy to reduce fading, means to control the extent and frequency of wobble, a line for conducting the wobbled signal energy to a source of relatively higher frequency energy, means to modulate the higher frequency energy by the signal energy, and means to radiate a desired portion of the modulated energy.

24. A transmission system comprising a source of alternating energy, keying means to control irregularly the energy in accordance with intelligence to be transmitted, a source of intermediate frequency energy, a carrier suppression modulator to modulate the energy of intermediate frequency with the signal energy, means to filter a side band, a source of high frequency energy, a land line between two of said sources, a carrier suppression modulator to modulate the energy of high frequency with said side band of the modulated intermediate frequency energy, means to filter a side band, means to amplify the side band, and means to radiate the amplified side band.

25. A transmission system comprising a source of alternating energy, signalling means to irregularly control the energy according to a signal to be transmitted, a source of higher frequency energy, a carrier suppression modulator to modulate the energy of higher frequency with the signal energy, means to filter a side band, and means to multiply the side band frequency.

26. A transmission system comprising a source of alternating energy, signalling means to irregularly control the energy according to a signal to be transmitted, a source of higher frequency energy, a carrier suppression modulator to modulate the energy of higher frequency with the signal energy, means to filter a side band, means to multiply the side band frequency and amplify the side band energy, and means to radiate the frequency multiplied amplified energy.

27. A transmission system comprising a source of alternating energy, signalling means to control the energy, a source of relatively high frequency energy, a carrier suppression modulator to modulate the energy of high frequency by the signal energy, and a crystal filter to filter a side band.

28. A transmission system comprising a source of alternating energy, signalling means to control the energy, a source of relatively high frequency energy, a carrier suppression modulator to modulate the energy of high frequency by the signal energy, a crystal filter to filter a side band, and a frequency multiplier and amplifier for the filtered side band.

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