

Feb. 28, 1928.

J. MILLS

1,661,004

SIGNALING SYSTEM

Filed Aug. 9, 1922

2 Sheets-Sheet 1

Fig. 1.

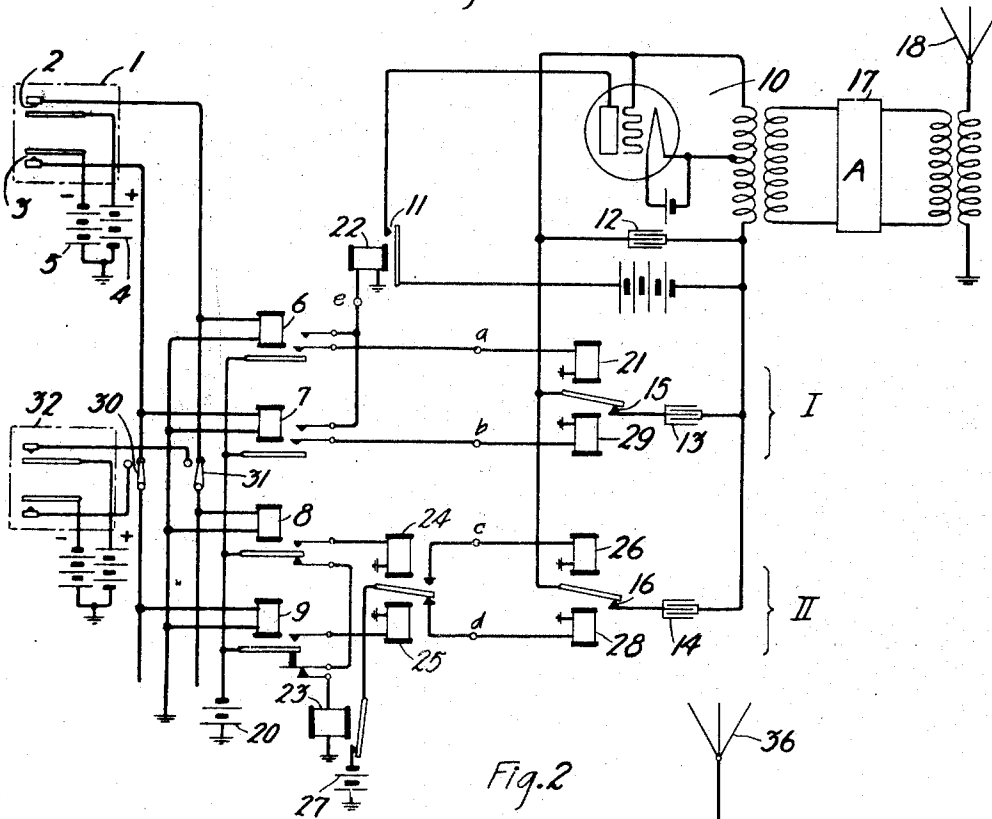
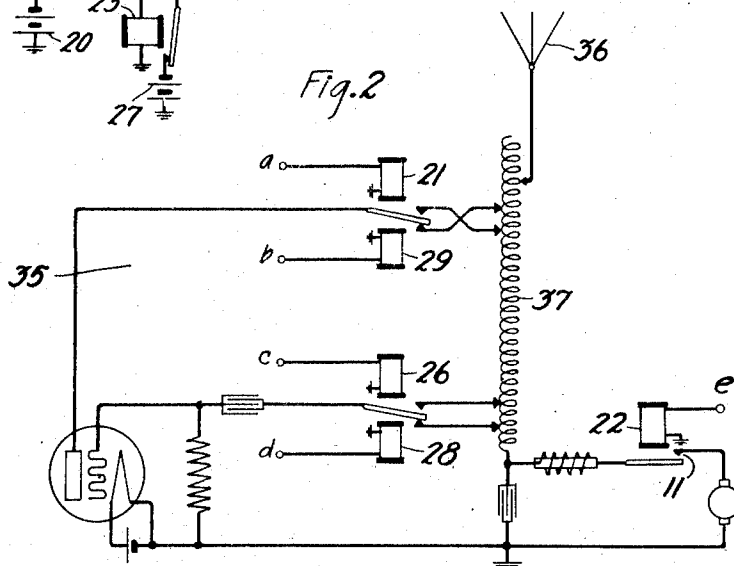


Fig. 2



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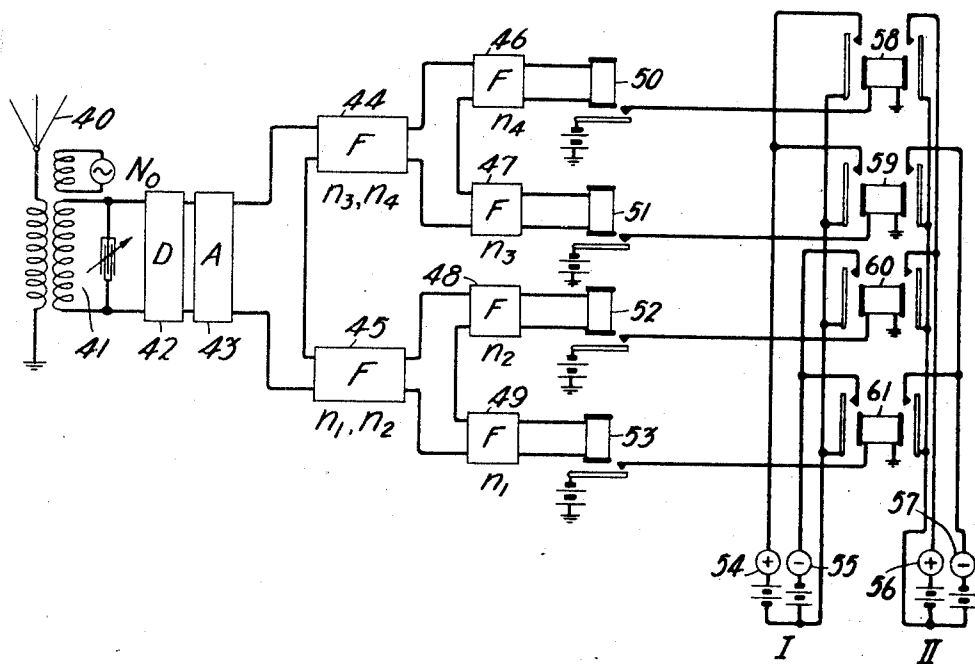
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Fig. 3.



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UNITED STATES PATENT OFFICE.

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SIGNALING SYSTEM.

Application filed August 9, 1922. Serial No. 580,601.

This invention relates to signaling systems and more particularly to systems in which a plurality of signals are simultaneously transmitted over a common path.

5 One object of the invention is to provide a method of, and means for, transmitting a plurality of signals at the same identical time and utilizing a minimum number of wave frequencies at any instant for the transmission of the signals.

10 Another object is to transmit a plurality of signals with a greatly reduced expenditure of energy as compared to that required in the usual types of systems.

15 Another object is to reduce the number of wave frequencies being simultaneously transmitted over the common path in a multiplex signaling system when a plurality of signals are being simultaneously transmitted.

20 Another object is to increase the probable accuracy with which a message may be transmitted when subjected to inaccuracies or interference during transmission. The interference may be due to atmospheric disturbances or other influences which produce disturbances in the circuit.

25 When a message is subjected to interference during transmission, it is desirable to verify the message in some manner. The present invention provides a method of message transmission and verification requiring a minimum amount of time.

30 In accordance with the present invention, a multiplex radio telegraph system is provided in which plus or minus signals combine to select a single transmitting frequency representing the particular combination of plus and minus signals being transmitted at that instant. At the receiving station, a given wave is translated into plus and minus signals corresponding to the original signals.

35 For increasing the probable accuracy of message transmission through interfering disturbances, the same message is transmitted over a plurality of channels simultaneously, the message in one channel lagging behind the message in the other channel. A disturbing impulse will then mutilate a different part of a message in each of the channels and, in general, a complete message

can be assembled from the unutilized fragments.

Other objects of the invention will be apparent from the more detailed description of the invention which follows taken in view of the accompanying drawings.

Referring to the figures, Fig. 1 is a circuit diagram showing the general arrangement of a multiplex radio telegraph transmitter embodying certain features of the invention. Fig. 2 is a circuit diagram showing a modification of the oscillator and antenna connections which may be substituted in Fig. 1. Fig. 3 is a circuit diagram showing a receiver adapted for use in connection with the transmitter shown in Fig. 1.

In Fig. 1, the station 1 is provided with contacts 2 and 3 for transmitting plus or minus signals respectively from the current sources 4, 5 to the relays 6, 7, 8, 9. Contacts 2 and 3 may be operated by a perforated tape, electromagnets, manually, or by any other well known means. It will be noted that contacts 2 energize relay magnets 6 and 8 while contacts 3 energize relay magnets 7 and 9.

Relays 6, 7, 8 and 9 control the energization of, and the frequency of the oscillator 10 of well known type. The energization of the oscillator is accomplished by closure of the contacts 11 and the frequency is determined by the value of capacity connected in parallel with the condenser 12. Condensers 13 and 14 are connected in parallel with condenser 12 by closure of contacts 15 and 16, respectively, the frequency of the oscillator 10 being a minimum when condensers 13 and 14 are connected in parallel with the condenser 12. Condenser 14 is smaller in value than condenser 13 and it is therefore possible in the circuit shown to obtain any one of four predetermined frequencies of oscillation from the oscillator 10 by connecting or disconnecting condensers 13 or 14 or both in parallel with the condenser 12. Designating these four frequencies as N_1 , N_2 , N_3 , N_4 , the lowest frequency is obtained when contacts 15 and 16 are both closed to connect condensers 13 and 14 in parallel with condenser 12; N_2 , the next higher frequency, is obtained by closing contacts 15 while contacts 16 are open whereby

condenser 13 is connected in parallel with condenser 12; N_3 , a higher frequency than N_2 , is obtained by closing contacts 16 and opening contacts 15 whereby condensers 12 and 14 are connected in parallel; and N_4 , the highest frequency, is obtained by opening contacts 15 and 16 whereby condenser 12 determines the frequency of oscillations without the assistance of condensers 13 and 14. It is obvious that by providing additional condensers of progressively different values to be connected in parallel with the condenser 12, any one of a larger number than four wave frequencies can be selectively generated by the oscillator 10.

The oscillations generated are transmitted through the amplifier 17, of any suitable type free from substantial distortion, to the antenna 18 from which waves are radiated to the distant station.

If it be assumed that a positive impulse is being transmitted from station 1 by closure of contacts 2, relays 6 and 8 will be energized, relay 6 first closing its lower contacts, closing a circuit from ground through battery 20, lower contacts of relay 6, relay winding 21 to ground, thus energizing the winding 21 and opening contacts 15 whereby condenser 13 is disconnected from parallel connection with condenser 12. Upper contacts of relay 6 are then closed, providing an energizing circuit for the relay winding 22 from ground through battery 20, upper contacts of relay 6, winding 22 to ground thereby closing contacts 11 in the space current circuit of the oscillator 10 to cause its energization. The energization of relay 8 causes the lower contacts of relay 8 to open whereby the energizing circuit from ground through battery 20, lower contacts of relay 8, lower contacts of relay 9, relay winding 23 to ground for the relay 23 is opened thus causing the contacts of relay 23 to be open. The relay 8 also closes its upper contacts establishing a circuit from ground through battery 20, upper contacts of relay 8, winding 24 to ground, energizing winding 24 and closing upper contacts of relay 24, 25 to prepare for the energization of relay winding 26, around the circuit traced from ground through battery 27 contacts of relay 23, upper contacts of relay 24, 25, winding 26 to ground. It will be noted, however, that contacts of relay 23 are open due to the deenergization of relay 23, as described above. The armature of relay 24, 25 assumes a position toward the winding 24 or the winding 25 depending on which of these windings was last energized. It will, therefore, be seen that upper contacts of relay 24, 25 will remain closed even when winding 24 becomes deenergized. In view of the fact that contacts 15 have been opened and contacts 16 have remained closed, it will be seen that condensers 12, and 14 are in par-

allel and that the frequency N_3 is generated by the oscillator 10 and transmitted to the antenna 18.

Upon the opening of contacts 2 at the termination of the positive signal, the relay 6 deenergizes opening its contacts causing the deenergization of relay 22, the opening of contacts 11 and the deenergization of oscillator 10, thus discontinuing the transmission of the radiated wave from the antenna 18.

Upon deenergization of relay 8, the lower contacts of the relay are closed completing the energizing circuit for relay 23, causing the closing of contacts of relay 23 and establishing a circuit from ground through battery 27, upper contacts of relay 24, 25, relay winding 26 to ground, thus causing the contacts 16 to be opened. The armature operating contact 16 remains in a position toward the relay winding 26 or the relay winding 28 depending on which of these windings was last energized. The contact 16, therefore, remains open after winding 26 becomes deenergized.

If now a second positive signal be transmitted from the station 1 by closure of contacts 2, contacts 15 remain opened as in the case of the previous positive impulse which was transmitted. Relay 8 upon being energized causes the deenergization of relay 23, thus opening contacts of relay 23 and preventing the energization of either winding 26 or 28. Contacts 16, therefore, remain open and the oscillator 10 generates a wave frequency N_4 determined by condenser 12. Relay 8, being energized, closes its upper contact thereby energizing relay winding 24 as in the case of the previous positive signal but introduces no change in the circuit for relay windings 26 or 28 inasmuch as the upper contacts of relay 24, 25 have been closed since the first positive impulse. Upon cessation of the second positive impulse, the winding 26 is again energized but produces no effect as the contacts 16 are already open. Each positive impulse following a previous positive impulse will thus cause a wave of frequency N_4 to be radiated in the manner just described.

If station 1 now transmits a negative impulse by closure of contacts 3, relays 7 and 9 are energized, relay 7 closing its lower contacts and energizing relay winding 29 thereby closing contacts 15 and connecting condenser 13 in parallel connection with condenser 12. At the same time, relay 9 energizes, closing its upper contacts and energizing relay winding 25 around a circuit traced from ground through battery 20 upper contacts of relay 9, winding 25 to ground causing the upper contacts of relay 24, 25 to be broken and the lower contacts to be closed to prepare an energizing circuit for relay winding 28. Upon the energization of relay

9, it will be noted that the lower contacts of relay 9 are broken causing the deenergization of relay 23 and the opening of contacts of the relay 23, thus preventing the energization of relay winding 28 through the circuit prepared therefor. Contacts 16, therefore, remain open as in the case when positive impulses were transmitted. Relay 7, on closing its upper contacts, causes the energization of relay 22, the closure of contacts 11 and energization of oscillator 10 whereby oscillations are generated at a frequency determined by condensers 12 and 13 in parallel. The frequency N_2 is, therefore, generated and transmitted. Upon opening contacts 3 at the end of the negative telegraph signal, relay 9 deenergizes and closes its lower contacts to cause the energization of relay 23 whereby its contacts are closed to energize relay 28 which, in turn, closes contact 16 and connects condenser 14 in parallel with condenser 12.

If now a second negative telegraph signal be transmitted, contacts 15 remain closed and contacts 16 remain closed so that upon energization of relay 22 and of oscillator 10, the wave frequency generated is determined by condensers 12, 13, and 14 in parallel whereby the wave of frequency N_1 is generated. For each negative signal immediately following a previous negative signal, a wave of frequency N_1 will always be transmitted in the manner just described.

Upon closure of contacts 2 to transmit a positive impulse subsequent to a negative impulse, a wave frequency N_3 will be generated, as described above, in connection with the first positive signal transmitted.

It will be noted that in the transmission of each of the signals described above, the frequency transmitted from the oscillator 10 is determined not only by the identity of the signal being transmitted from station 1 at that instant but it is also determined by the identity of the signal transmitted from the station 1 just prior to the signal now being transmitted from said station. In other words, a wave is transmitted to represent at the same time a signal being transmitted from a sending station and a signal which was sent just prior to the one being sent. The system embodying relays 8; 9; 23; 24; 25; 26 and 28; accomplishes the delay or lag in transmission of a signal behind the transmission of a signal through the system embodying relays 6; 7; 21 and 29. Relays 6 and 7 may be looked upon as relays for transmitting plus or minus signals, respectively, over one channel, while relays 8 and 9 may be looked upon as relays for transmitting plus or minus signals, respectively, over another channel of a multiplex signaling system. Each transmitted signal frequency N_1 , N_2 , N_3 , N_4 , etc., represents a signal going through the first channel 6, 7 and

a signal transmitted through a second channel 8, 9, the signal passing through the second channel 8, 9 being the same as the signal previously sent through the first channel 6, 7. Instead of signals in the second channel lagging one signal behind, signals in the first channel, signals in the second channel may lag any desired predetermined number of signals behind those in the first channel depending upon the amount of delay introduced in the channel 8, 9 in preparing and closing energizing circuits for the relay windings 26, 28.

Each radiated wave frequency carries with it the identity of a signal being transmitted as a part of a message and in addition thereto carries the identity of a signal forming some other portion of the same message. For this reason, if portions of the message are mutilated by interference or other cause, the wave frequencies which escape mutilation contain a means of identifying the mutilated portions of a message. Let it be supposed for example, that a portion of a message consists of the following series of signals: plus, plus minus, minus, plus, minus. In the usual form of system, if the second and fourth signals were lost by mutilation, there would be no means of determining their identity. In the present system, the same message may be transmitted over two or more channels in staggered relation with respect to time with one message lagging one signal behind the other. In transmitting the above named series of signals over two channels, the radiated wave frequencies will be in the order of time N_3 , N_4 , N_2 , N_1 , N_3 , N_5 . It is evident that the loss of the second and fourth radiated waves does not involve a loss of the message inasmuch as the third radiated signal wave N_2 represents not only the minus signal being transmitted in the first channel but represents a positive signal being transmitted in the second channel which corresponds to the lost second signal in the first channel. Similarly, the fifth radiated signal frequency N_3 represents not only a positive signal in the first channel but represents also a negative signal being transmitted in the second channel which corresponds to the lost fourth signal in the first channel. In the case of a two channel multiplex system, if it be assumed that a disturbance lasts for a greater period than a single radiated signal, at least a portion of the message will be saved by the method of the present invention. By increasing the number of channels in staggered relation with each other, the probable accuracy of transmission is greatly increased, it being merely necessary to furnish as many channels as there are signals bridging a period of mutilation in order to transmit a message without any loss of identity.

Instead of employing two channels to

transmit a single message, switches 30, 31 may be moved to the left to connect an independent transmitting station 32 to the second channel employing relays 8, 9. In this case, two independent messages may be transmitted at the same time without using at any given instant more than one transmitted wave frequency. Signals in channels 1 and 2 should be substantially in unison with each other in order to insure the generation of the correct wave frequency to be transmitted. The signals in the two channels may be held in unison by operating the contacts by means of perforated tapes in a well known manner whereby one of the contacts of transmitter 1 is always operated simultaneously with the operation of either of the contacts of transmitter 32.

If desired, in the case where the first and second channels are transmitting entirely different messages, relay windings 24 and 25 may be substituted in place of relay windings 26 and 28, respectively, to actuate contacts 16 directly instead of indirectly by means of windings 26 and 28. This connection avoids the delay, described above, in the transmission of a signal over the second channel.

Fig. 2 shows an oscillator 35 of a different type from oscillator 10, Fig. 1. The terminals *a, b, c, d, e*, correspond respectively to the terminals *a, b, c, d, e*, in Fig. 1. When the armatures of relays 21, 29; and 26, 28 are in the positions shown and contacts 11 are closed, the oscillator 35 generates a frequency N_1 which corresponds to that generated with the same positions of the armatures in the circuit of Fig. 1. In the same manner, the oscillators 10 and 35 generate the same frequency when the armatures of relays 21, 29 and 26, 28 of oscillator 10 are in the same positions as the same armatures in oscillator 35. Oscillator 35 is shown conductively connected to the antenna 36 but it is obvious that the inductance 37 may be coupled to the antenna through an amplifier, as in Fig. 1. It is thus seen that the operation of the circuit of Fig. 2 when substituted in the circuit of Fig. 1, is similar to that of the circuit shown in Fig. 1.

Fig. 3 shows a receiving station adapted to receive signals transmitted from antenna 18, Fig. 1, and to translate these signals into plus and minus signals corresponding to those being transmitted through the first and second channels of the transmitter. Receiving antenna 40 is coupled to the circuit 41 tuned to select the wave frequencies N_1, N_2, N_3 , etc., which are to be detected. A local source of oscillations of frequency N_0 of approximately the same order of frequency as the transmitted waves N_1, N_2 , etc., supplies a wave to the circuit 41 to provide a heterodyne beat wave in the output circuit of the detector 42. If the frequency

of the wave N_0 be less than that of the received waves N_1 , etc., the beat waves n_1, n_2, n_3 , and n_4 will be produced as follows:

$$\begin{aligned} N_1 - N_0 &= n_1 \\ N_2 - N_0 &= n_2 \\ N_3 - N_0 &= n_3 \\ N_4 - N_0 &= n_4 \end{aligned} \quad 70$$

Where:

$$N_4 > N_3 > N_2 > N_1 > N_0 > n_4 > n_3 > n_2 > n_1 \quad 75$$

By choosing some different value of N_0 , values of n_1, n_2, n_3 , and n_4 may be made any desired value, as is well known in the art. In case that more than two channels are provided at the transmitting station, more than four wave frequencies will be transmitted and consequently, a correspondingly larger number of beat waves will be produced at the receiving station. The beat waves produced in the output circuit of the detector 42 may be transmitted through the amplifier 43 to the band filters 44 and 45 which selectively transmit the wave frequencies n_3, n_4 and n_1, n_2 , respectively. If desired, filters 44 and 45 may be high and low pass filters respectively, instead of band filters, each filter having a sharp cut-off so that the waves n_3, n_4 can pass only through filter 44 while n_1, n_2 will pass only through filter 45. Waves n_3, n_4 pass from filter 44 through filters 46, 47 which selectively transmit waves n_4, n_3 respectively. Filters 46, 47 may be of the band type or filter 46 may be a high pass filter to pass only the wave n_4 , while filter 47 may be a low pass filter to pass only the wave n_3 . Filters 48, 49 may be band filters adjusted to selectively transmit waves n_2, n_1 , respectively, or filter 48 may be of the high pass type to pass only n_2 , and filter 49 may be of the low pass type to pass only n_1 .

Relays 50, 51, 52 and 53 control means for translating the received beat wave into signals corresponding to those originally transmitted over the circuit shown in Fig. 1. The receiving elements 54 and 55 respond respectively to plus and minus signals transmitted over channel 1 while the receiving elements 56, 57 respond respectively to plus and minus signals transmitted over channel 2. These receiving elements may be telegraph sounders, recorders, relays for retransmission of the signals to other circuits, or any well known signal receiving means.

Assuming a wave of frequency N_4 is received over antenna 40, a beat wave of frequency n_4 passes from the detector 42 through filters 44 and 46 and energizes relay 50 causing it to close its contacts to energize relay 58 which, in turn, closes its left-hand contacts and transmits a positive signal to the receiving element 54 in the first channel. At the same time, relay 58 closes its right-hand contacts and transmits a positive signal to receiving element 56 in the second

channel. If, instead of a wave frequency N_4 , a wave of frequency N_3 be received, beat wave n_3 will energize relay 51 causing it to close its contacts and energize relay 59 which, in turn, transmits a positive signal to receiving element 54 in the first channel and transmits a negative signal to receiving element 57 in the second channel. Similarly, a received wave of frequency N_2 causes the actuation of relays 52, and 60 and the transmission of a negative signal to receiving element 55 in the first channel and a positive signal for receiving element 56 in the second channel. A received wave of frequency N_1 causes the actuation of relays 53 and 61 and the transmission of a negative signal to receiving element 55 in the first channel and a negative signal to receiving element 57 in the second channel. The positive and negative signals transmitted to the receiving elements 54, 55, 56, 57 correspond precisely to the positive and negative signals transmitted over the first and second channels at the transmitting station, shown in Fig. 1. It is thus seen that the means shown in Fig. 1 translate positive and negative signals existing at the same identical time in a plurality of channels into a single sine wave which is radiated by the antenna 18, is received by the antenna 40, Fig. 3 and is translated by means of the circuits shown in Fig. 3 into plus and minus signals identical with those originally transmitted over the first and second channels of the circuit in Fig. 1, this being true whether or not the switches 30, 31 be in the left hand or the right hand position.

A large saving in the amount of energy expended for transmitting a plurality of signals is accomplished by means of the described system. If it be assumed that a certain minimum amount of energy is required to be transmitted from a sending station to produce an intelligible or a suitable response at a given receiving station, it will be seen that in the system described, where two channels are employed, two signals may be transmitted without requiring any more energy than is necessary for the transmission of one signal in the usual form of system. There is, therefore, a saving of one-half the usually required energy. Similarly if three channels are provided, three signals are transmitted on a single wave frequency and each signal is sent with a saving of two-thirds the usually required energy. By increasing the number of channels, or in other words, the number of signals transmitted at any given instant on a single wave frequency, the average amount of energy per signal may be indefinitely decreased below the above mentioned minimum value of energy required to transmit one signal in the usual form of system. It will be noted that in the usual form of system the amount of energy required to transmit a given

number of signals is equal to the product of the number of signals by the minimum value of energy required to transmit one signal, while in the present system the total transmitted energy is preferably less than said product.

When certain of the messages to be transmitted are of relatively greater importance than others, the important messages may be transmitted over one channel which selects for transmission the wave frequency N_4 or N_3 to represent the plus signals and the frequency N_2 or N_1 to represent the minus signals, where $N_4 - N_3$ is equal approximately to $N_2 - N_1$ and is very small. The frequency interval $(N_4 \text{ or } N_3) - (N_2 \text{ or } N_1)$ may be considered to be equal approximately to $N_4 - N_2$ and is large enough to permit of positive identification of said signals even though there are slight undesired variations in the wave frequency transmitted or in the adjustments of the transmitting and receiving stations. The less important messages are transmitted over the second channel which selects for transmission the wave frequency N_4 or N_3 to represent the plus signals and N_3 or N_1 to represent the minus signals.

The frequency interval $N_4 - N_3$ or $N_2 - N_1$ is less than the approximate interval $N_4 - N_2$ and may represent a very small shift in the frequency N_4 or N_2 which would be too small an interval to permit of satisfactory discrimination between the plus and minus signals in the important messages while for less important messages the accuracy of transmission would be sufficient. In the above manner the band of wave frequencies required for transmission of all the messages is maintained at a minimum width and is smaller than is employed in the usual systems in the art which transmit four or more distinct signals on a corresponding number of wave frequencies. The use of a single oscillation generator whose frequency is varied in accordance with the signal to be transmitted permits the frequencies N_4 , N_3 , N_2 and N_1 to be nearer together than in a system employing independent generators without a common frequency determining means.

When all the messages to be transmitted are of equal importance, the frequency separations between adjacent frequencies should be of approximately equal value.

Many variations from the specific circuit shown are obviously possible without departing from the invention disclosed, for example, the amplifier 17 may be omitted from the circuit shown in Fig. 1, or amplifiers may be inserted at points where it is desired to increase the energy being transmitted. Similarly the amplifier 43 may be omitted from the circuit of Fig. 3 or other amplifiers may be added to the circuit to

provide sufficient energy for the operation of the relays 50, 51, 52, 53, etc. Instead of employing the antennæ 18, 36 and 40, wire connections, or other means may be employed to convey signals from the transmitting to the receiving station.

The system is particularly adapted for transmission of signals over power circuits where switching, lighting, and other disturbances tend to mutilate the signals. By means of the described method of staggered transmission the effects of disturbances may be avoided.

While the invention has been illustrated and described with particular reference to specific circuit arrangements, it is to be understood that the invention is not limited to the particular circuits shown as a whole, or to the specific details, but only by the scope of the appended claims.

What is claimed is:

1. In a signaling system, a source of signal impulses, a source of oscillations including tuning elements, a plurality of paths between said first mentioned source and said elements, means for simultaneously transmitting impulses from said source over the plurality of paths for controlling said elements, and means for delaying the impulses in one of said paths.

2. In a signaling system subject to inaccuracies or interference in the transmission of a given series of signals, means for transmitting said given series of signals as a first series, means for transmitting said given series of signals as a second series lagging behind said first series, and means including a single detector and a plurality of receiving devices traversed by waves from said detector for independently receiving said two series of signals.

3. In a signaling system subject to inaccuracies or interference in the transmission of a given series of signals, means for transmitting said given series of signals as a first series, means for transmitting said given series of signals as a second series lagging behind said first series, and a wave transmitter including a space discharge tube oscil-

lator having a resonant circuit and a normally disconnected space current source, and means controlled by said two first mentioned means for connecting said space current source and for varying the tuning of said resonant circuit.

4. In a signaling system subject to inaccuracies or interference in the transmission of a given series of signals, means for transmitting said given series of signals as a first series, means for transmitting said given series of signals as a second series lagging behind said first series, and a space discharge oscillator having a resonant circuit including a plurality of elements adapted to be connected and disconnected under control of said two first mentioned means to generate a wave frequency corresponding to signals being transmitted at any given instant in said two series of signals.

5. In a signaling system subject to inaccuracies or interference in the transmission of a given series of signals, means for transmitting said given series of signals as a first series, means for transmitting said given series of signals as a second series lagging behind said first series, an oscillator responsive to said two mentioned means to generate waves having frequencies corresponding to signals being transmitted at any given instant in said two series of signals, and means including a single detecting device and a plurality of receiving devices connected to said detecting device to receive said generated waves and selectively translate said waves into signals corresponding to said original series of waves.

6. In a signaling system, an antenna, a space discharge tube oscillator coupled to said antenna, a signal transmitter arranged to control the frequency generated by said oscillator, said transmitter being arranged to transmit a series of signals represented by oscillations of predetermined frequency and having means for transmitting said signals in a series out of step with said first series.

In witness whereof, I hereunto subscribe my name this 5th day of August, A. D. 1922.

JOHN MILLS.