

June 24, 1947.

C. B. H. FELDMAN

2,422,664

WOBBLED RADIO CARRIER COMMUNICATION SYSTEM

Filed July 12, 1944

3 Sheets-Sheet 2

FIG. 6

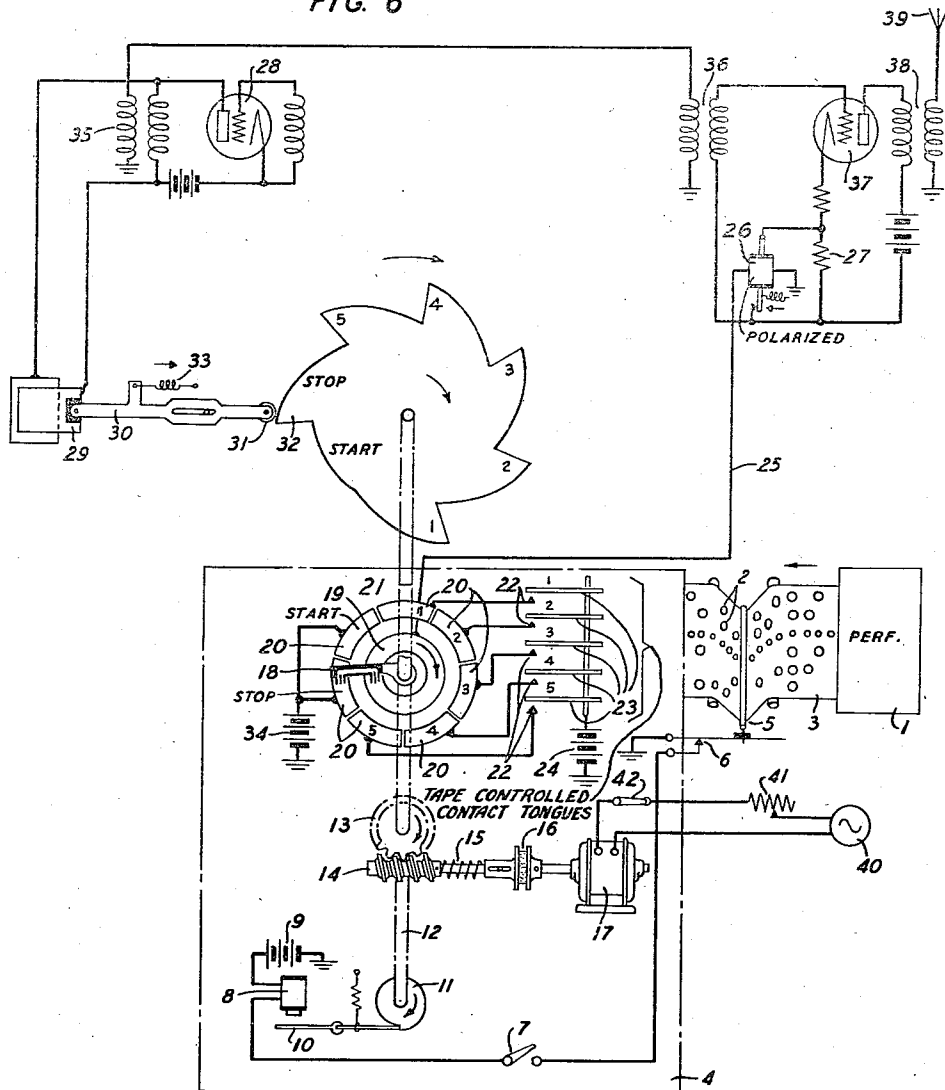
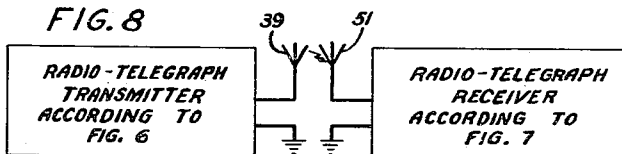


FIG. 8



INVENTOR
C. B. H. FELDMAN

BY

W. H. Haddard

ATTORNEY

June 24, 1947.

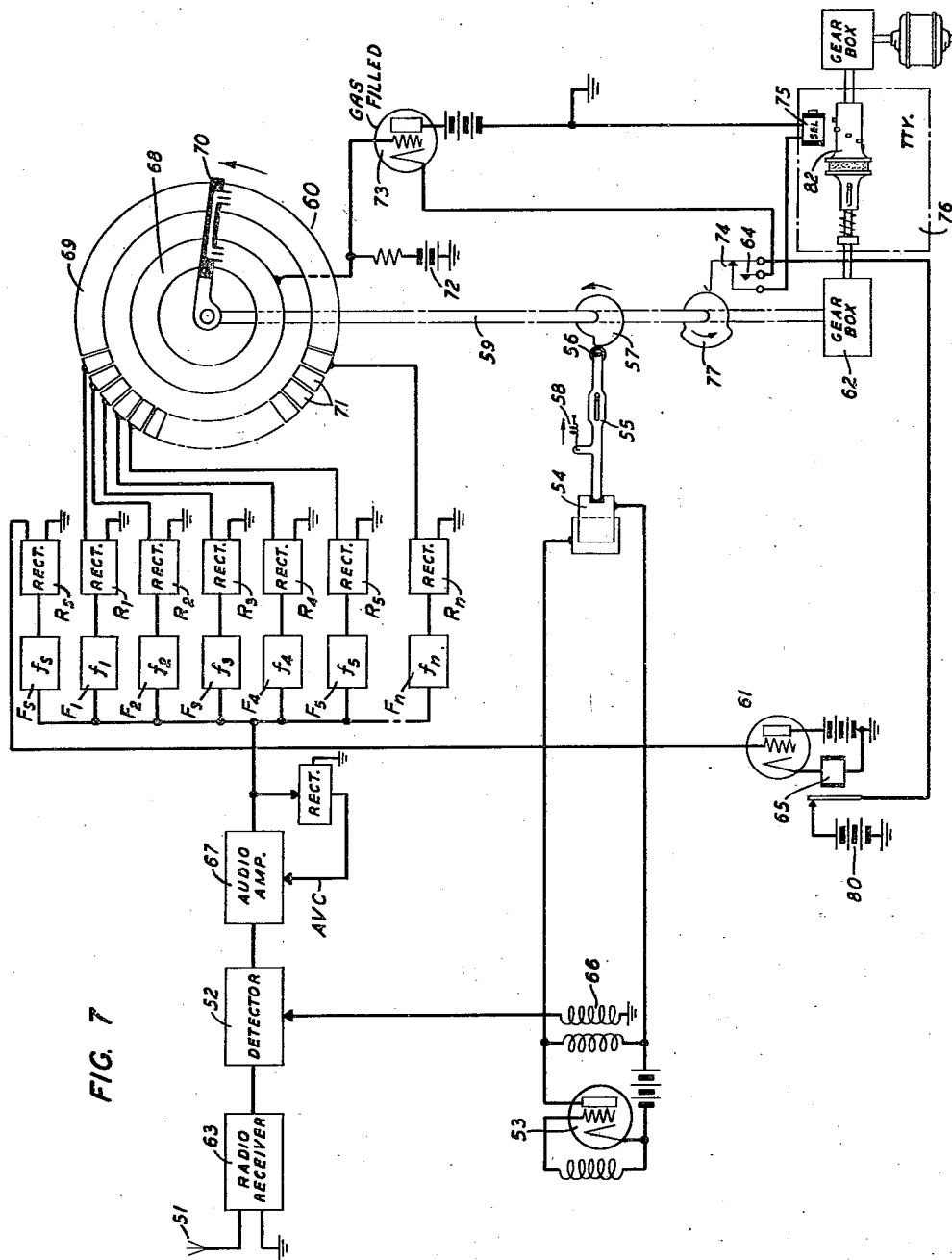
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3 Sheets-Sheet 3



INVENTOR
C. B. H. FELDMAN
BY

BY

B. Stoddard

ATTORNEY

UNITED STATES PATENT OFFICE

2,422,664

WOBBLED RADIO CARRIER COMMUNICATION SYSTEM

Carl B. H. Feldman, Summit, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application July 12, 1944, Serial No. 544,493

11 Claims. (Cl. 250—8)

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This invention relates to radio signaling and, more particularly, to methods and systems for obtaining a high degree of accuracy in receiving and recording radio signals.

Ordinary narrow band telegraph transmission over radio circuits is subject to two main troublesome factors which tend to produce errors in the recording of the received signals. One of these factors is fading which causes the signals to vary in level and the other factor is crashing static which produces extreme variations in the noise level. When the transmitted signals are received by a radio telegraph receiving system of the type in which the received signals effect the operation of a two-position electromechanical device, continual adjustments must be made in order to prevent the above-mentioned factors from causing errors in the recording of the signals. These adjustments can be made in either the sensitivity of the electromechanical device or in the level of the signals applied to it so that its operate and release values will lie continuously in the interval between the signal level and the noise level when such an interval exists. With this type of receiving system, completely errorless operation is impossible when fading carries the signal level below the noise level or when noise crashes exceed the signal level.

Errors due to fading can be rendered less frequent by employing some form of diversity reception. Since fading which carries the signal level below the noise level is due usually to interference produced by the signaling radiant energy traveling through the ionosphere over a multiplicity of space paths, any means for separating the duplicate signal waves received over these various space paths and for preventing destructive interference between them will reduce this type of fading. One form of such a separation of the multiple signal waves is a separation based on a time standpoint. This is made possible by the fact that the multiple space paths generally possess slightly different travel times which produce various delays having differences of a millisecond or more, in the arrival of the duplicate signal waves.

Heretofore, one way of accomplishing such a time separation of the received duplicate signal waves has been to transmit a short pulse of about 0.3 millisecond duration in place of the 30 millisecond marking signal commonly employed in printing telegraphy. This results in the reception by the radio receiving system of a succession of short pulses between which there can be no interference. Transmission of these short pulses

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requires a wider transmission band than is required for transmission of the longer pulses and is consequently subject to a higher degree of noise. However, if the peak pulse power is increased sufficiently to make the average power the same as that employed in transmitting the 30 millisecond type of pulses, no penalty will result from the attendant higher noise.

For example, if the signaling speed of the transmitter is maintained the same as that used during transmission of the 30 millisecond type of pulses, then, when the duration of each pulse is shortened to 0.3 millisecond, the peak power can be increased one hundred fold without increasing the average power used by the transmitter. Since this requires that the band width of the receiver be increased one hundred fold, the noise power will be one hundred-fold greater. As was stated above, no penalty will result from the higher noise because the pulse signal-to-noise ratio, which is determined by the values of the noise and the peak pulse power, will remain the same as it was in the case of the transmission and reception of the 30 millisecond pulses.

Accordingly, it is an object of this invention to obtain a high degree of accuracy in receiving and recording radio signals by preventing destructive interference between signal waves traveling over different space paths.

It is also an object of this invention to improve the transmission characteristics of radio signals.

An additional object of this invention is to provide a radio communication system with improved means for transmitting and receiving radio signals.

Another object is to provide a radio communication system with improved means for separating from a time standpoint duplicate signal waves received over a multiplicity of space paths.

A further object is to provide a radio communication system with improved means for avoiding the harmful effects which noise currents tend to produce in the recording of received signals.

Still another object is to provide a radio communication system with improved means for converting duplicate signal waves having a time diversity separation into waves having a frequency diversity separation.

These and other objects of the invention are attained by modulating the frequency of a continuous wave of radiant energy over a wide band intermittently in a saw-tooth manner in accordance with the signals to be transmitted. For example, if the signals to be transmitted are marking and spacing telegraph signals, then, when

the continuous wave is modulated intermittently in a saw-tooth manner, each tooth would represent one type of signal, such as a marking signal, and each interval between the teeth would represent a different type of signal, such as a spacing signal. The resulting modulated continuous wave is then radiated through space. Since the radiated energy travels over multiple space paths having different travel times, the receiver is consequently provided with duplicate, or multiple, signal waves having a time diversity characteristic. A species of frequency diversity might also be considered to be present because not all of the wide band of modulated frequencies is suppressed simultaneously by interference fading.

As each space path is affected by different degrees of fading and different types and amounts of interference, some of the received multiple signal waves are less suitable than others for use by the receiver in actuating the recording device. In order to effect a selection of the more desirable duplicate signal waves and to insure that the recording device will be operated by signal waves of at least a minimum strength, all the received multiple signal waves are detected at the receiver by detecting means employing a beating oscillator having its frequency modulated over a wide band in a saw-tooth manner similar to the saw-tooth frequency wave generated at the transmitter with which it is synchronized. The audio frequency output of the detector is applied, after amplification, to a plurality of narrow band-pass filters connected in parallel. The limits of each filter are different from the limits of all the other filters and the pass-bands of all the filters are continuously distributed in an overlapping manner over the frequency range of the signaling energy applied thereto. For example, in a preferred embodiment of the invention in which the pass-bands of the signal filters are continuously distributed over a range of 1140 cycles, forty overlapping filters are used, each having a pass-band of 57 cycles.

The currents passed by the filters are separately rectified by a plurality of rectifiers which have their outputs separately connected to a scanning device which determines whether any of the rectified filter outputs have a magnitude above a preassigned minimum value desirable for proper operation of the recorder. If at least one of the rectified filter outputs has a magnitude in excess of the preassigned minimum value, then the recording mechanism will be actuated to effect the recording of a marking signal. Thus, in accordance with the invention, the diversity channels of the above-described frequency modulation diversity radio communication system are scanned or sampled during the reception of each signal to insure that, when the recording device is operated by a marking signal, said marking signal will have at least a minimum strength. Continuous wave interference is suppressed because the pass-bands of the filters are not sufficiently wide to allow the varying frequency currents, produced by the continuous wave interference and the variable frequency oscillator, to build up to full amplitude.

These and other features of the invention are more fully described in connection with the following detailed description of the drawings in which:

Fig. 1 is a diagram of the characteristics of radio-telegraph signals transmitted in accordance with this invention;

Fig. 2 illustrates the time diversity separation

obtained when the signals shown in Fig. 1 are received over two space paths having different travel times;

Figs. 3 and 4 represent detected signal waves having a frequency separation instead of the time separation illustrated in Fig. 2;

Fig. 5 indicates the duration and occurrence of scanning operations performed upon the rectified output of one of the narrow band-pass filters;

Fig. 6 shows a radio transmitting station for transmitting radio telegraph signals having the characteristics illustrated in Fig. 1;

Fig. 7 illustrates a radio receiving station for receiving and recording signals transmitted by the radio transmitting station shown in Fig. 6; and

Fig. 8 is a block schematic diagram of a complete radio telegraph system employing the radio transmitter of Fig. 6 and the radio receiver of Fig. 7.

In Fig. 6, a tape perforator 1 forms permutation code signals, represented by the holes 2, in transmitting tape 3. The transmitting tape 3 is fed in a well-known manner into a transmitting teletypewriter 4. The tape 3 is fed in the direction indicated by the arrow and, just before it enters the teletypewriter 4, it passes under an automatic stop lever 5 which normally rests on the upper arm of a control contact 6 as is described in Patent 2,055,567 granted September 29, 1936, to E. F. Watson. The disclosure of this Watson patent is incorporated herein by reference as a part of this specification. Control contact 6 is connected through a manually operable switch 7 and through the winding of a magnet 8 to a battery 9. The armature 10 of magnet 8 forms a stop arm for stopping rotation of a stop cam 11 mounted on a main drive shaft 12. This main drive shaft 12 is driven by means of a gear wheel 13, fixedly mounted on the shaft 12, in mesh with a worm 14 carried on a shaft 15 driven through a friction clutch 16 by a motor 17. Motor 17 is supplied with current from a source 18 and its speed can be regulated by manually adjusting the rheostat 19. A manual switch 20 is provided for stopping and starting motor 17.

A rotary distributor brush arm 21 is fixedly mounted on the main drive shaft 12 for rotation therewith. The brush arm 21 is equipped with two brushes adapted to sweep over a solid inner commutator ring 22 and a segmented outer ring 23. The outer ring 23 is provided with five segments corresponding to the five units of a permutation code, a "stop" segment, and a "start" segment, each segment being insulated from the other segments. The two rings 22 and 23 constitute the face-plate of a transmitting distributor 24 comprising, in addition to this face-plate, the rotary brush arm 21. Each of the five code segments of ring 23 are separately connected to one of the five marking contacts 25 which are adapted to be selectively operated by the five contact tongues 26. These five contact tongues 26 are selectively operated in the manner described in the above-mentioned Watson patent in accordance with the permutation code signals 2 punched in the transmitting tape 3.

When any of the contact tongues 26 are operated to their associated marking contacts 25, a path is closed from battery 27, over the operated tongues 26 and their associated contacts 25, and then to the corresponding segments of ring 23. The brush arm 21, in rotating, electrically connects seriatim the above-mentioned segments of ring 23 to the solid inner ring 22 which is con-

ected by conductor 25 to the winding of a relay 26. Thus, the battery 24 is connected through the operated contact tongues 23 and over the above-described path to the winding of the relay 26 to hold its armature against its left-hand contact. As is shown in Fig. 6, the armature of relay 26 is normally in engagement with its left-hand contact thereby shunting a resistance 27 for a purpose explained hereinafter. In the case of a spacing signal, no current will be supplied to the winding of relay 26 which will accordingly release its armature which will move to its right-hand contact thereby opening the shunt across the resistance 27. A battery 34 is connected to both the "stop" and the "start" segments of ring 20 so that the shunt across the resistance 27 will always be closed while the brush arm 18 is sweeping over the "stop" and the "start" segments.

The radio portion of this transmitting station includes a variable electronic oscillator 28 of an appropriate design. A variable condenser 29 is suitably connected to the oscillator 28 for cyclically varying the frequency of the current generated by the oscillator 28. The capacitance of the capacitor 29 is varied by a sliding member 30 which has one end affixed to the movable plates of the condenser 29 and which has a cam follower 31 mounted on its other end. The cam follower 31 is adapted to ride along the edge of a rotating cam 32 and is held in contact therewith by a coiled spring 33.

Cam 32 is fixedly mounted on the main drive shaft 12 for rotation therewith. Six risers are formed in the edge of cam 32 of which five correspond to the five permutation code segments of ring 20 and the remaining riser corresponds to the "stop" segment of ring 20. These six risers each have a periphery designed to vary the capacitance of capacitor 29 in such a way as to cause the frequency of the current generated by the oscillator 28 to vary over a wide range in a saw-tooth manner. Instead of a "start" riser, the cam 32 is provided with a portion having an edge evenly spaced from the center of cam 32 to hold the cam follower 31 steady while the brush arm 18 is sweeping over the start segment. During this period, oscillator 28 will generate a wave of steady frequency which is the "start" signal. In the position of rest, the cam follower 31 is shown to be practically at the top of the "stop" riser so that the oscillator 28 will be generating waves having approximately the maximum frequency.

The current thus generated by oscillator 28 is picked up by a coil 35 and is supplied by means of the transformer 36 to the control grid of an electronic power amplifier 37 to vary the frequency of its oscillations over a wide range in a saw-tooth manner. The resulting frequency modulated wave is supplied through a transformer 38 to the supply circuit for the transmitting antenna 39 which radiates the frequency modulated wave into space.

In order to "key" the power amplifier 37 for effecting an intermittent modulation of the continuous wave in accordance with marking and spacing signals, the resistance 27 is connected into the cathode return circuit of tube 37. When the system is in the condition of rest, as shown in Fig. 6, a shunt path across resistance 27 is closed by the armature of relay 26. Under this condition, the power amplifier 37 will function to transmit marking energy. However, a spacing signal effects the operation of the armature of relay 26 to its right-hand contact thereby opening

the shunt across resistance 27. This allows resistance 27 to change the current relationships in the power amplifier 37 to make its grid so much more negative with respect to its cathode that the plate current will be reduced to zero and no signaling energy will be supplied to the transmitting antenna 39. This condition exists until a marking signal effects the operation of the armature of relay 26 to its left-hand contact thereby again closing the shunt path across resistance 27 to allow the power amplifier 37 to transmit marking energy. Thus, the relay 26 selectively suppresses one saw-tooth frequency modulation cycle of the wave for each spacing signal. This enables the radio transmitting station of Fig. 6 to transmit radio-telegraph signals in the form of a continuous wave of radiant energy which has its frequency modulated over a wide band intermittently in a saw-tooth manner in accordance with the signals to be transmitted.

The characteristics of the radio telegraph signals transmitted by the transmitting system of Fig. 6 are illustrated in Fig. 1 in which F_0 represents the width of the wide band over which the frequency of the continuous wave is modulated. T_1 represents the duration of each unit of a permutation code signal, all such units being of equal duration. As is indicated in Fig. 1, each saw-tooth modulation of the frequency of the continuous wave represents a marking signal and each time interval T_1 between the teeth of the saw-tooth frequency modulations represents a spacing signal.

The radio receiving and recording station shown in Fig. 7 is provided with an antenna 51 for receiving the signals, illustrated in Fig. 1, that are transmitted by the transmitting system of Fig. 6. The signals received by the antenna 51 are delivered to a radio receiver 53 which in turn supplies them to a detector 52 where they are combined with oscillations from an electronic beating oscillator 53. The frequency of the oscillations generated by the oscillator 53 is varied over a wide band in a saw-tooth manner similar to the saw-tooth frequency wave generated in the transmitting system, of Fig. 6. This is accomplished by means of the variable condenser 54 which is electrically connected into the plate circuit of the oscillator 53. The capacitance of the capacitor 54 is varied by means of a sliding member 55 which has one end attached to the movable plates of condenser 54 and which carries at its other end a cam follower 56. Cam follower 56 is adapted to ride along the edge of a rotating cam 57 and is held in physical contact therewith by means of a coiled spring 58. The periphery of the cam 57 is designed to vary the capacitance of condenser 54 in such a way as to cause the frequency of the oscillations generated by oscillator 53 to vary in a saw-tooth manner.

Cam 57 is fixedly mounted on the drive shaft 59 of a rotary distributor 60. The drive shaft 59 is driven by means of a gear box 62 which is mechanically coupled to the cam barrel 82 in the teletypewriter 76. This teletypewriter 76 is of the type described in Patent 1,904,164 granted April 18, 1933, to S. Morton et al., and it is also provided with a selecting magnet 75. The disclosure of this Morton et al. patent is incorporated herein by reference as a part of this specification. The rotation of the cam barrel 82 is synchronized with the rotation of the brush arm 18 of the transmitting distributor 21 of Fig. 6 in the manner described in the Morton et al. patent. Since the gear box 62 is designed to rotate the drive shaft

59 and the brush arm 70 seven times as fast as the drive shaft 12 and the brush arm 18 at the transmitting station of Fig. 6, the saw-tooth frequency variations of oscillator 53 will consequently be synchronized with those of oscillator 28 at the transmitting station of Fig. 6. The resulting synchronized oscillations of oscillator 53, illustrated by the saw-tooth wave represented by the heavy line in Fig. 2, are supplied by a coil 66 to the detector 52.

The signaling radiant energy transmitted by the antenna 39 of Fig. 6 travels through the ionosphere over a multiplicity of space paths having slightly different travel times which produce different delays in the arrival of the duplicate signal waves at the receiving antenna 51 of Fig. 7. Consequently, the radio receiver 63 will supply the detector 52 with a multiplicity of duplicate signal waves having slight time separations. Two of these waves are represented by the light lines in Fig. 2. These waves are combined in the detector 52 with oscillations from the oscillator 53. As is indicated in Fig. 2, the received duplicate signal waves, due to their time diversity characteristic, will, in general, be slightly delayed with respect to the sweep frequency generated by the beating oscillator 53.

Since the degree of delay is not the same for all the received duplicate signal waves, the output of the detector 52 will consist of a plurality of concurrent waves of different audio frequencies. For example, Fig. 3 shows a wave having a frequency f' which represents the output of the detector 52 due to one of the received duplicate signal waves shown in Fig. 2, and Fig. 4 shows a wave having a frequency f'' simultaneously produced by the detector 52 in response to the other received duplicate signal wave shown in Fig. 2. The frequencies of the waves of Figs. 3 and 4 differ by amounts proportional to the differences in the travel times of the space paths traversed by their corresponding duplicate signal waves. Thus, the instantaneous output of the detector 52 will consist of a plurality of concurrent waves of various audio frequencies extending from f_1 to f_n in accordance with the instantaneous delay characteristics of the duplicate signal waves received at any one time by the antenna 51.

The detector 52 has its output connected to an audio amplifier 67 of any suitable design. It is desirable to vary the gain of the amplifier 67 by means of an appropriate automatic volume control circuit indicated in Fig. 7 by the reference designation AVC. The output of the amplifier 67 is connected to a plurality of parallel filters $F_1, F_2, F_3, F_4, F_5 \dots$ and F_n , each having a narrow pass-band, for separating the concurrent audio frequency waves into a plurality of different frequency bands. One advantage resulting from the use of these narrow pass-bands is that noise and interfering waves are effectively suppressed because the band widths are insufficient to allow the varying frequency currents produced by the noise, or interfering waves, and the variable frequency oscillator to build up to full amplitude. As was stated above, each filter has limits different from all the other filters and the pass-bands of all the filters are continuously distributed over the frequency range of the signaling energy applied thereto. In a preferred embodiment of the invention in which the pass-bands of the filters are continuously distributed in an overlapping manner over a range of 1140 cycles, forty overlapping filters are used, each having a pass-band of 57 cycles.

Each of the filters F_1 to F_n , inclusive, has its output separately connected to a different one of a plurality of rectifiers $R_1, R_2, R_3, R_4, R_5 \dots R_n$ in the manner illustrated in Fig. 7 for transforming the filter outputs into unidirectional potentials proportional to the magnitudes of their corresponding audio frequency waves. The resulting rectified filter outputs are of positive polarity with respect to ground and are individually supplied to a scanning device represented by the scanning distributor 60.

The scanning distributor 60 is shown, by way of example, as being a mechanical rotary distributor. It is to be understood that the invention is not limited to this type of distributor but can employ various other types of distributors, such as the electronic distributors disclosed in Patent 2,185,693 granted January 2, 1940, to P. Mertz, and Patent 2,217,774 granted October 15, 1940, to A. M. Skellett. The distributor 60 comprises a solid commutator ring 68 and a segmented commutator ring 69.

The segmented commutator ring 69 comprises a plurality of segments 71 which are insulated from each other. The number of the segments 71 is the same as the number of the filters F_1 to F_n , inclusive. Each of the rectifiers R_1 to R_n , inclusive, has its output separately connected to a different one of the segments 71 in the manner illustrated in Fig. 7. The distributor 60 also includes a rotary brush arm 70 which is equipped with two brushes adapted to sweep over the rings 68 and 69. The brush arm 70 is fixedly mounted on the drive shaft 59 for rotation therewith, the period of rotation being T_r .

In accordance with the principles of start-stop telegraph operation, the brush arm 70 does not rotate during idle periods since neither the drive shaft 59 nor the cam barrel 82 are rotating at this time. Also, during idle periods, the cam follower 56 remains practically at the top of the cam 57 so that the oscillator 53 will be generating constant frequency waves having approximately the maximum frequency. In order to begin the rotation of the brush arm 70, a "start" signal is transmitted which, as was described above, is a wave of steady frequency. At the receiving station, the steady wave constituting the "start" signal is combined in the detector 52 with the steady waves from oscillator 53. The resulting output wave of the detector 52 will have a constant frequency and is applied, after amplification, to the "start" filter F_s which is a narrow band-pass filter designed to pass waves having this particular frequency, f_s . The output of filter F_s is rectified by a rectifier R_s and the resulting output energy is delivered to the grid of a triode 61 to render tube 61 conductive. The current which now flows in the cathode return circuit of tube 61 passes through the winding of an electric relay 65 thereby energizing relay 65 and causing it to operate its armature. This opens the circuit extending from battery 80 to the contact 74 leading to the selector magnet 75. The removal of current from selector magnet 75 causes it to start the teletypewriter 76 in the manner described in the above-mentioned Morton et al. patent thereby initiating rotation of the cam barrel 82. Rotation of cam barrel 82 causes the drive shaft 59 to rotate, as was explained above, and this, in turn, causes the brush arm 70 to rotate and sweep over the commutator rings 68 and 69 for scanning the rectified filter outputs.

In order that all the rectified filter outputs may be scanned during the time that their values are

at, or near, a maximum, the segments 71 are disposed along only four-tenths of the ring 69 as is indicated in Fig. 7, the remaining portion of the ring 69 being depressed so as not to contact its brush. Thus, all the rectified filter outputs are scanned during a period of time equal to four-tenths of the period T_r . This is indicated in Fig. 5 as is explained hereinafter. In a preferred embodiment of the invention, each rectified filter output is scanned, or sampled, for a period of 0.3 millisecond.

To determine whether any of the scanned rectified filter outputs have a magnitude in excess of a preassigned minimum value, the common ring 68 is connected to a trigger device, such as the control grid of a gas discharge tube 73. A negative biasing voltage from battery 72 is also supplied to the control grid of the tube 73. The value of the biasing voltage from battery 72 is sufficiently large to bias the tube 73 beyond cut-off. Tube 73 has its cathode return circuit connectable over a contact 64 to the selecting magnet 75 of the receiving teletypewriter 76. Contact 64 is adapted to be repeatedly opened and closed in response to the closing and opening of the contact 74 by a cam 77 fixedly mounted on the drive shaft 59 for rotation therewith. The periphery of the cam 77 is so designed as to hold the contact 74 open during four-tenths of the period of rotation of the cam 77, this being the same period in which the brush arm 70 sweeps over the segments 71. During this period the contact 64 will be closed so that the circuit extending from the cathode of tube 73 to the selecting magnet 75 will be closed while the brush arm 70 is sweeping over the segments 71 and will be opened during the remainder of the period of rotation of the brush arm 70.

Whenever the brush arm 70 sweeps over one of the segments 71 which is supplied with a rectified filter output having a value sufficiently large to overcome the biasing voltage from battery 72, the tube 73 will break down and become conductive. This will cause current to flow over the cathode return circuit of tube 73 and over the contact 64 to energize the selecting magnet 75 in the teletypewriter 76 thereby effecting the recording of a marking signal by the teletypewriter 76. After the tube 73 becomes conductive, it remains conductive until the rotation of cam 77 allows the contact 74 to close thereby opening contact 64 and the circuit from the cathode of tube 73 to the selector magnet 75. Consequently, if several of the segments 71 are supplied with strong currents, tube 73 will break down when the brush arm 70 sweeps over the first of these segments and the currents supplied to the other segments will perform no useful function. If, during one sweep cycle of the brush arm 70, none of the rectified filter outputs are sufficiently large to overcome the biasing voltage from the battery 72, then the gas discharge tube 73 will remain non-conductive and no current will be sent to the selecting magnet 75 which will therefore cause the teletypewriter 76 to record a spacing signal. Thus, the rectified filter outputs are scanned in respect to their magnitudes to determine whether any of their magnitudes are in excess of a preassigned value; namely, the value of the biasing voltage from the battery 72.

This scanning feature is illustrated in Fig. 5 in which the horizontal line B—B represents the value of the steady biasing voltage from the battery 72. The rectified output of one of the filters is represented by the curve SW. One complete

scanning cycle of all the rectified filter outputs is performed during each of the time intervals indicated by the short lines t_1-t_2 , t_3-t_4 , t_5-t_6 , and t_7-t_8 . As was stated above, the value of all the rectified filter outputs will be at, or near, a maximum if marking signals have been received during these particular time intervals. It can be seen in Fig. 5 that the value of the particular rectified filter output represented by the curve SW fails to exceed the value of the bias voltage B—B during the scanning period indicated by the line t_5-t_6 but that it exceeds the bias voltage B—B during the other scanning periods. Therefore, the scanning operations performed during the period t_1-t_2 and t_3-t_4 will result in the recording by the teletypewriter 76 of two successive marking signals, that performed during the period t_5-t_6 will effect the recording of a spacing signal, and that during the period t_7-t_8 will cause the recording of a marking signal.

In applying the principles and features of operation of the invention to any suitable type of radio-telegraph system, the principal design features may be obtained as follows:

Let

t =minimum delay difference between the paths which are to be resolved.

T =spread in delay differences likely to be encountered.

Δ =band width of the band-pass filters $F_1, F_2 \dots F_n$.

B =total audio band covered by the band-pass filters $F_1, F_2 \dots F_n$.

F_0 =width of the band over which the frequency of the continuous wave is modulated.

T_r =duration of each unit of a permutation code signal.

In order to separate waves of t delay difference by means of the band-pass filters $F_1, F_2 \dots F_n$, it is necessary to have, approximately:

$$\frac{t}{T_r} F_0 = 2\Delta \quad (1)$$

In order to permit the filter output to build up to a flat output during the time T_r , it is necessary to have approximately:

$$\Delta = \frac{1.7}{T_r} \quad (2)$$

From (1) and (2) the following value is obtained:

$$F_0 = \frac{3.4}{t}$$

The total audio band to be provided is:

$$B = \frac{T_r}{T_f} F_0 = f_1 \text{ to } f_n$$

where f_1 and f_n are the values of the peak frequencies, or the mid-band frequencies, of the waves passed by the filters F_1 and F_n .

Typical values might be:

$t=0.3$ millisecond

$T=3.0$ milliseconds

$T_r=30$ milliseconds, for printing telegraphy.

Whence:

$\Delta=57$ cps.

$F_0=11400$ cps.

$B=1140$ cps.

What is claimed is:

1. A radio transmitting and receiving system including in combination a transmitting station adapted to transmit a wave of radiant energy having its frequency modulated over a wide band

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intermittently in a saw-tooth manner in accordance with signals, a receiving station adapted to receive the transmitted wave in the form of a plurality of duplicate waves having different delays characteristic of the different travel times of the various space paths traversed by said duplicate waves, said receiving station comprising a beating oscillator having its frequency modulated over a wide band in a saw-tooth manner, a detector for combining said duplicate received waves with the output of the beating oscillator, a plurality of narrow band-pass filters, each of said filters having limits different from all the other filters, connecting means for connecting the output of the detector to each of said filters in parallel, a plurality of rectifiers, circuit means for connecting the output of each of said filters to a different one of said rectifiers, a scanning device, and connecting means for separately connecting the output of each of said rectifiers to the scanning device, said scanning device being adapted to scan each of said rectified filter outputs in respect to their magnitudes for determining whether at least one of the rectified filter outputs has a magnitude in excess of a preassigned minimum value.

2. A radio communication system including in combination a transmitting station adapted to transmit a wave of radiant energy having its frequency modulated over a wide band in a saw-tooth manner intermittently in accordance with at least two types of signals, each tooth representing one type of signal and each interval between the teeth representing a different type of signal, an antenna for transmitting said intermittently modulated wave, a receiving station having a receiving antenna adapted to receive the transmitted wave in the form of a plurality of duplicate waves having different arrival times in accordance with the different travel times of the various space paths traversed by said duplicate waves, said receiving station comprising a beating oscillator having its frequency cyclically modulated over a wide band in a saw-tooth manner, a detector for combining said duplicate received waves with the output of the beating oscillator, a plurality of narrow band-pass filters each having limits different from all the others, connecting means for connecting the output of the detector to each of said filters in parallel, rectifying means for separately rectifying the output of each of said filters, a scanning device adapted to scan each of said rectified filter outputs in respect to their magnitudes for determining whether at least one of the rectified filter outputs has a magnitude in excess of a preassigned minimum value, a recording device, and selective operating means for selectively causing the recording device to record one type of signal when all of the scanned rectified filter outputs have a magnitude less than said preassigned minimum value and to record another type of signal when at least one of the scanned rectified filter outputs has a magnitude greater than said preassigned minimum value.

3. A radio communication system comprising in combination a radio transmitting station having generating means for generating a wave, means for modulating the frequency of said wave over a wide band in a saw-tooth manner, radiating means for radiating said frequency modulated wave through space, and receiving means for receiving said frequency modulated wave over a plurality of different space paths having different travel times, said receiving means including de-

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tecting means for producing a plurality of concurrent audio frequency waves whose frequencies differ by amounts proportional to the differences in the travel times of said different space paths.

4. A radio communication system comprising in combination a radio transmitting station having generating means for generating a wave, means for modulating the frequency of said wave over a wide band in a saw-tooth manner, radiating means for radiating said frequency modulated wave through space, and receiving means for receiving said frequency modulated wave over a plurality of different space paths having different travel times, said receiving means including a beating oscillator for generating a wave, means for varying the frequency of the wave generated by said beating oscillator over a wide band in a saw-tooth manner, detecting means for combining the variable frequency wave produced by said beating oscillator with said received waves for producing a plurality of concurrent audio frequency waves whose frequencies differ by amounts proportional to the differences in the travel times of said different space paths, and a plurality of filters for separating said concurrent audio frequency waves into a plurality of different frequency bands.

5. A radio communication system comprising in combination a radio transmitting station having generating means for generating a wave, means for modulating the frequency of said wave over a wide band in a saw-tooth manner, radiating means for radiating said frequency modulated wave through space, receiving means for receiving said frequency modulated wave over a plurality of different space paths having different travel times, detecting means for producing a plurality of concurrent audio frequency waves whose frequencies differ by amounts proportional to the differences in the travel times of said different space paths, a plurality of filters for separating said concurrent audio frequency waves into a plurality of different frequency bands, a plurality of rectifiers for separately rectifying the filter outputs, and scanning means for cyclically scanning the rectified filter outputs.

6. A radio communication system comprising in combination a radio transmitting station having generating means for generating a wave, means for modulating the frequency of said wave over a wide band in a saw-tooth manner, radiating means for radiating said frequency modulated wave through space, receiving means for receiving said frequency modulated wave over a plurality of different space paths having different travel times, detecting means for producing a plurality of concurrent audio frequency waves whose frequencies differ by amounts proportional to the differences in the travel times of said different space paths, a plurality of filters for separating said concurrent audio frequency waves into a plurality of different frequency bands, a plurality of rectifiers for separately rectifying the filter outputs, scanning means for cyclically scanning the rectified filter outputs, a recording device, and operating means for selectively operating the recording device in accordance with the scanning operations performed by said scanning means.

7. A radio communication system comprising in combination a radio transmitting station having generating means for generating a wave, means for modulating the frequency of said wave over a wide band in a saw-tooth manner, radiating means for radiating said frequency modulated

wave through space, receiving means for receiving said frequency modulated wave over a plurality of different space paths having different travel times, detecting means for producing a plurality of concurrent audio frequency waves whose frequencies differ by amounts proportional to the differences in the travel times of said different space paths, a plurality of filters for separating said concurrent audio frequency waves into a plurality of different frequency bands, a plurality of rectifiers for transforming the filter outputs into unidirectional potentials proportional to the magnitudes of their corresponding audio frequency waves, scanning means for sampling said unidirectional potentials, a trigger device, and operating means for operating the trigger device in accordance with the sampling operations performed by said scanning means.

8. A radio communication system comprising in combination a radio transmitting station having generating means for generating a wave, means for modulating the frequency of said wave over a wide band in a saw-tooth manner, radiating means for radiating said frequency modulated wave through space, receiving means for receiving said frequency modulated wave over a plurality of different space paths having different travel times, detecting means for producing a plurality of concurrent audio frequency waves whose frequencies differ by amounts proportional to the differences in the travel times of said different space paths, a plurality of filters for separating said concurrent audio frequency waves into a plurality of different frequency bands, a plurality of rectifiers for transforming the filter outputs into unidirectional potentials proportional to the magnitudes of their corresponding audio frequency waves, scanning means for cyclically scanning said unidirectional potentials in respect to their magnitudes for determining whether at least one of said scanned potentials has a magnitude in excess of a preassigned minimum value, a normally non-conductive trigger tube, operating means for rendering said trigger tube conductive whenever the magnitude of at least one of said scanned potentials is greater than said preassigned minimum value, and control means for rendering said trigger tube non-conductive after the completion of each of said scanning cycles.

9. A radio communication system for communicating at least two types of signals between a transmitting station and a receiving station, said system comprising in combination a transmitting station having generating means for generating a wave, means for cyclically modulating the frequency of said wave over a wide band in a saw-tooth manner, control means for selectively suppressing one saw-tooth frequency modulation cycle of said wave for each signal of one type, radiating means for radiating said wave through space, receiving means for receiving said wave over a plurality of different space paths having different delay characteristics, detecting means

for producing a plurality of concurrent audio frequency waves whose frequencies differ by amounts proportional to the differences between said different delay characteristics, a plurality of filters for separating said concurrent waves into a plurality of different frequency bands, rectifying means for separately converting said different frequency bands into unidirectional potentials, scanning means for scanning said unidirectional potentials in respect to their magnitudes for determining whether at least one of said scanned potentials has a magnitude greater than a preassigned minimum value, a recording device, and selective operating means for selectively causing the recording device to record a signal of one type when all of said scanned potentials have a magnitude less than said preassigned minimum value and to record a signal of another type when at least one of said scanned potentials has a magnitude greater than said preassigned minimum value.

10. The method of radio communication which comprises generating a continuous wave of electrical energy, modulating the frequency of said wave over a wide band in a saw tooth manner, intermittently suppressing selected saw-tooth frequency modulation cycles of said wave, radiating the resulting intermittent frequency modulated wave through space, receiving said wave over a diversity of space paths having different delay characteristics, and producing a plurality of concurrent audio frequency waves having frequencies differing by amounts proportional to the differences in said different delay characteristics.

11. The method of radio communication which comprises generating a continuous wave of electrical energy, modulating the frequency of said wave over a wide band in a saw-tooth manner, intermittently suppressing selected saw-tooth frequency modulation cycles of said wave, radiating the resulting intermittent frequency modulated wave through space, receiving said wave over a diversity of space paths having different delay characteristics, producing a plurality of concurrent audio frequency waves having frequencies differing by amounts proportional to the differences in said different delay characteristics, converting said audio frequency waves into unidirectional potentials, cyclically scanning said unidirectional potentials, and selectively operating a recording device in accordance with said cyclical scanning operations.

CARL B. H. FELDMAN.

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