

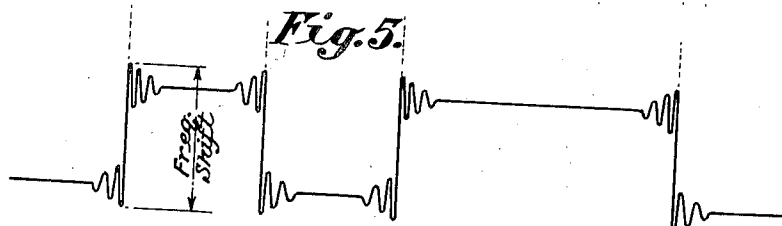
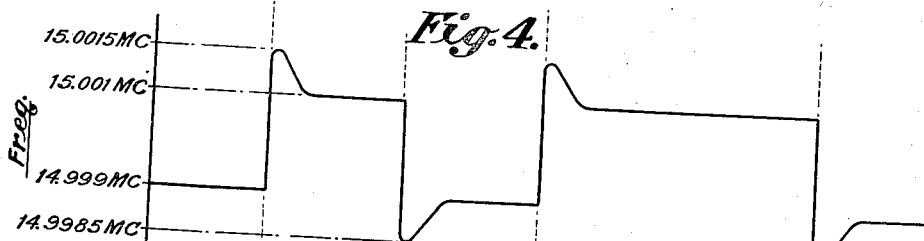
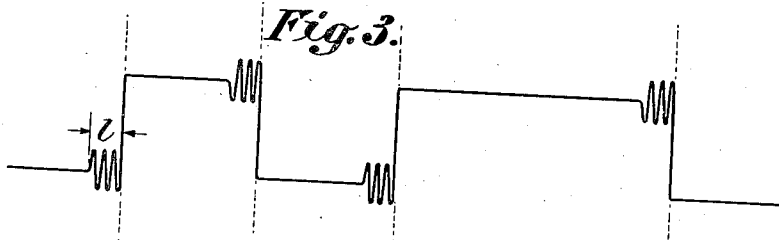
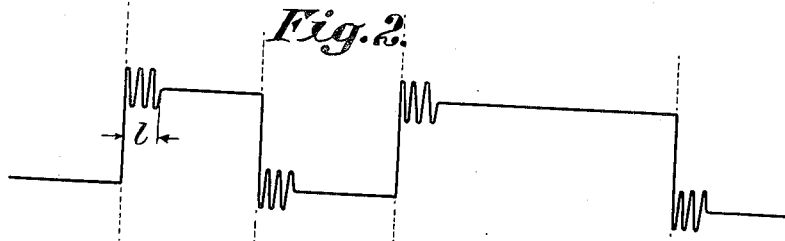
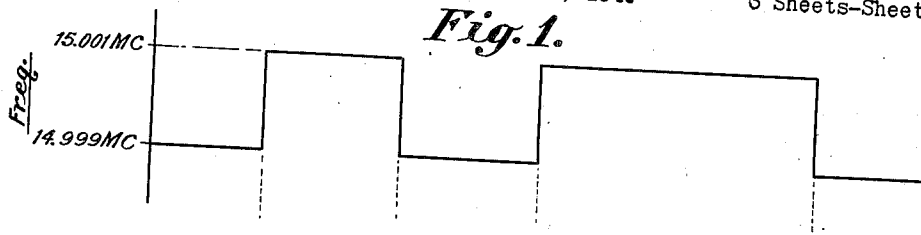
Oct. 20, 1942.

C. W. HANSELL
RADIO COMMUNICATION SYSTEM

2,299,388

Filed Nov. 23, 1940

3 Sheets-Sheet 1



INVENTOR
Clarence W. Hansell
BY *H. S. Snover*
ATTORNEY

Oct. 20, 1942.

C. W. HANSELL

2,299,388

RADIO COMMUNICATION SYSTEM

Filed Nov. 23, 1940

3 Sheets-Sheet 2

Fig. 6a.

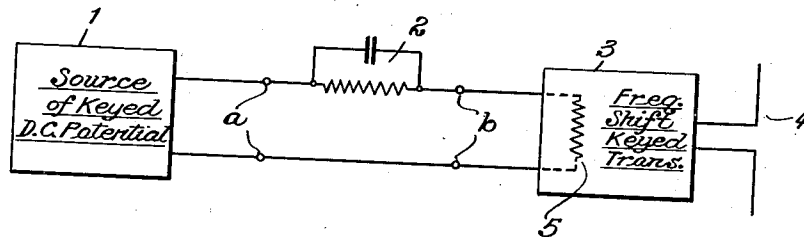


Fig. 6b.

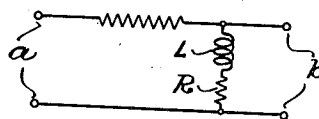


Fig. 7a.

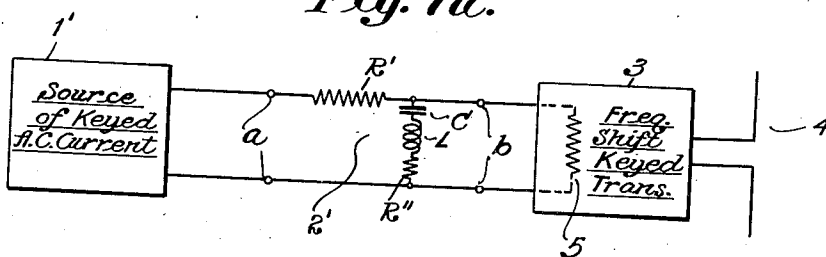
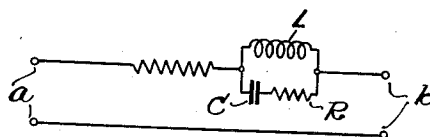


Fig. 7b.



INVENTOR
Clarence W. Hansell
BY *H. S. Swer*
ATTORNEY

Oct. 20, 1942.

C. W. HANSELL

2,299,388

RADIO COMMUNICATION SYSTEM

Filed Nov. 23, 1940

3 Sheets-Sheet 3

Fig. 8a.

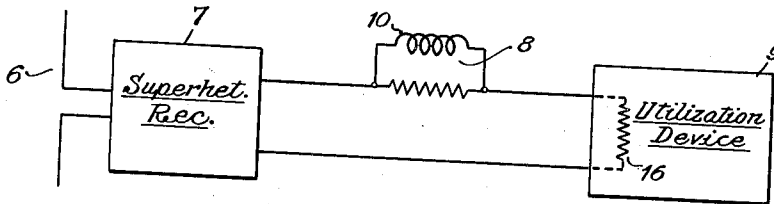


Fig. 8b.

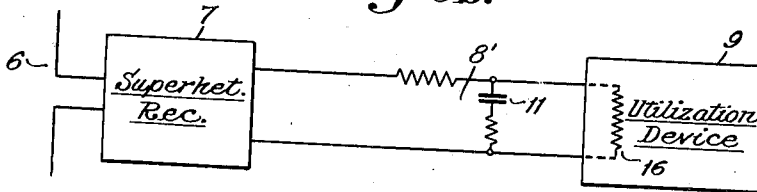


Fig. 9a.

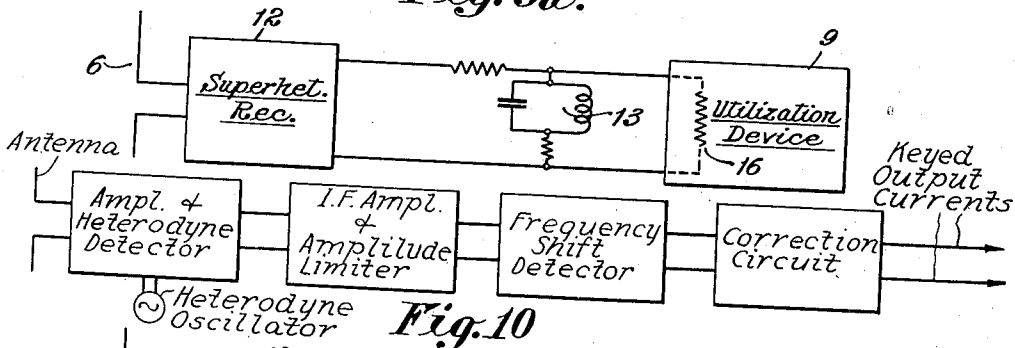


Fig. 10

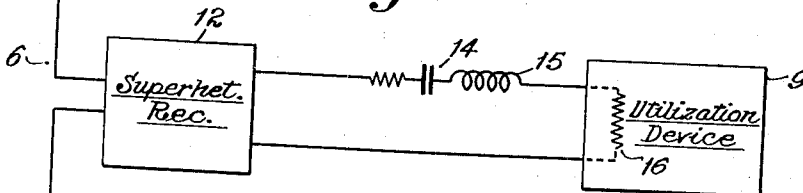


Fig. 9b

INVENTOR
Clarence W. Hansell
BY H. S. Brover
ATTORNEY

UNITED STATES PATENT OFFICE

2,299,388

RADIO COMMUNICATION SYSTEM

Clarence W. Hansell, Port Jefferson, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application November 23, 1940, Serial No. 366,860

9 Claims. (Cl. 250—8)

The present invention relates to the improvements in the transmission of telegraph characters by means of spacing wave or frequency shift keying. More specifically, the invention is concerned with rectangular wave keyed systems useful primarily in the transmission and reception of telegraph and telegraph printer signals.

It is known in the radio art that short wave radio transmission is accompanied by the arrival of signal power at the receiver over more than one path and with different time delays in the several paths. Several explanations have been given for these multiple paths, among which are: First, that the received waves are composed of several components which have been refracted and reflected between the ionosphere and the earth a different number of times, and second, that there exists refraction from different ionized layers or regions in the ionosphere. There have also been many instances in long distance communication of the transmission of the same signal simultaneously around the world in different directions. A common result of the multipath phenomenon between transmitter and receiver is that the useful signal modulations arriving at the receiver are distorted and do not faithfully reproduce the modulations of the transmitter.

The present invention has for its primary object to reduce the effects of the multipath phenomenon which produces distortion at the receiver, and this I accomplish first by employing what is known as spacing wave or frequency shift keying, which requires the transmission of two relatively close frequencies, one frequency being known as the marking wave while the other frequency is known as the spacing wave; second, by intentionally introducing momentarily at the transmitter an overswing to produce a slight amount of distortion, i. e., to continue the marking and spacing frequencies past their normal steady values; and third, receiving the radiated waves with a frequency modulation type of receiver designed to respond to modulation frequencies down to the lowest required to reproduce the signals, which may require response down to zero frequency, and after frequency swing detection, preferably applying a counterdistortion to restore the signals to approximately their original rectangular wave form which they had before distortion at the transmitter.

In using frequency shift keying for the transmission of telegraph signals, the carrier frequency is changed more or less suddenly at the

transmitter from one value to another. At the receiver, the power received over different space circuit paths will change frequency at different times and in a succession which is in inverse order with respect to the effective space path lengths. During the transition period at the receiver, power of both transmitter frequencies will be present simultaneously and give rise to two resultant currents at two frequencies. By continuing the marking and spacing frequencies momentarily past their normal steady values at the transmitter in accordance with the invention, I am able to raise the average beat frequency at the receiver caused by the two currents of different frequencies arriving over the various space paths during the transient period, and thus reduce the resultant distortions between the beat and signalling frequencies. This is because the average frequency of the beats is increased, according to the invention, preferably until it is above the normal required frequency, which makes it easier to eliminate and discriminate against the beats with less deleterious effects than heretofore.

The features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the drawings in which Fig. 1 shows the rectangular wave form of frequency shift sent out by a known type of frequency shift transmitter; Figs. 2 and 3 show possible wave forms of the received signal before detection when a wave form such as Fig. 1 is transmitted; Fig. 4 shows the distorted wave form of the signal transmitted in accordance with the present invention; Fig. 5 shows the wave form of the received distorted signal before detection; Figs. 6a and 6b show alternative wave distorting circuits which can be used to produce the wave form of Fig. 4 from a source of keyed direct current potentials; Figs. 7a and 7b show alternative wave distorting circuits which can be used to produce the wave form of Fig. 4 from a source of keyed alternating current; Figs. 8a and 8b show two receivers delivering direct current output and which can be used in accordance with the invention, to counteract the distortion produced at the transmitter and to restore the signals to the desired rectangular wave form; Figs. 9a and 9b show two receivers delivering alternating current output and which can be used in accordance with the invention to counteract the distortion produced at the transmit-

ter and restore the received signals to the desired rectangular wave form; and Fig. 10 shows in more detail than Figs. 8a to 9b, inclusive, the elements of a receiver, given by way of example, to counteract the distortion produced at the transmitter and restore the received signals to the desired rectangular wave form.

Referring to Fig. 1, there is shown the rectangular wave form of a well known telegraph signal employing one frequency, let us say 14.999 megacycles, for the space, and another frequency, let us say 15.001 megacycles, for the mark. In order to transmit signals of this character, the carrier frequency is changed more or less suddenly from one value, let us say 14.999 megacycles, to the other value, let us say 15.001 megacycles. Although the wave form has been shown in the drawing as being purely rectangular for the sake of simplicity, in practice the wave form will be slightly rounded. Because of the multipath phenomena, there exists a plurality of space paths between the transmitter and the receiver over which the signal will travel. If we are to assume, as an example, that there is a main path and a secondary path between the transmitter and receiver, it will be evident that the signal transmitted over the main path will arrive at the receiver a short interval of time ahead of the secondary path signal, and that after the frequency has been shifted at the transmitter, currents of both the spacing and marking frequencies will arrive simultaneously during a transient period.

Fig. 2 illustrates a possible wave form of the signal arriving at the receiver when one of the space paths, let us say the main path, delivers the strongest current to the receiver. It will be noted that during the time l corresponding to the interval of the time the transients occur at the receiver, which is equal to the difference in time of travel over the longest and the shortest space paths, there will occur phase modulation or beats of the two currents at the receiver. These phase modulation beats are equivalent to variations or modulations in frequency of the received current.

Fig. 3 shows the wave form of the signal at the receiver, if we assume that the signal arriving over the longer path delivers the strongest current. Here again l indicates the interval of time the transients occur, which interval is equal to the difference in time of travel over the longest and shortest space paths. It should be noted that in Fig. 3 the beats or the phase modulation due to the currents of two frequencies arriving simultaneously at the receiver occurs at the end of the marking and spacing frequencies, whereas in Fig. 2 the beats occur at the beginning of the marking and spacing frequencies.

Fig. 4 illustrates a distorted wave form which is produced at the transmitter in accordance with the invention. To achieve this wave form, each frequency swing at the transmitter is made to go momentarily beyond the steady state value and then come back to the steady state value with a time constant which is made to approximate the signal elongation at the receiver due to the multipath phenomenon. In the particular distorted wave form of Fig. 4, I overswing the marking frequency from its steady state value of 15.001 megacycles to say 15.0015 megacycles, and overswing the steady state value of the 14.999 megacycle spacing frequency to 14.9985 megacycles. Putting it in other words, I intentionally introduce at the transmitter, in accord-

ance with the invention, an overswing of both the marking and spacing frequencies in order to produce a signal distortion, whereby there is obtained a wave form such as shown in Fig. 4 instead of the normal wave form shown in Fig. 1. This overswing occurs momentarily so that the transmitter frequency comes back to its steady value after a time approximating the signal elongation due to the multipath. This signal elongation time may be defined as the difference in time of arrival, at the receiver, of waves over the shortest and longest important paths, which waves left the transmitter at the same time. It will now be evident that by virtue of this overswing the beat frequency on the receiver will now be 2500 cycles maximum (the difference between 14.999 and 15.0015 or between 15.001 and 14.985 megacycles) during the time both frequencies are being simultaneously received at the receiver due to the multipath phenomena; whereas previously, in the case of Fig. 1, without the overswing, the beat frequency was 2000 cycles at the receiver (the difference between 14.999 and 15.001 megacycles). I have thus been able to increase the average frequency of the beats at the receiver further above the normal maximum signalling frequency required, which may correspond to say 600 dots per second.

Fig. 5 illustrates the wave form of the received signal at the receiver. It should be noted that the multipath beats at each frequency change from space to mark and vice versa, increase to maximum amplitude and then die out again in a time period which corresponds to a little more than the maximum multipath time difference. The beats thus start with maximum frequency and then decrease to a value equal to the steady state frequency shift.

Because of the wave form distortion intentionally introduced at the transmitter in accordance with the invention, I am now able (at the receiver by means of low pass filters) to filter out the received signal with less deleterious effects from the beats than heretofore. Previously, in accordance with known practice, as illustrated by the case of Fig. 1, the beat frequencies occurring between 14.999 and 15.001 megacycles were all concentrated at 2000 cycles, a condition which required the signalling frequencies to be considerably below 2000 cycles in order to obtain a cut-off frequency between the signalling and beat frequencies. By raising the average beat frequency in accordance with the invention so that the beat is concentrated mainly above 2000 cycles, up to 2500 cycles, the signalling frequencies may be increased somewhat and, in any event, even if not increased, the relative deleterious distortion of signalling modulation, due to the beats, is much less than before. Because of the increase in the average frequency of the beats further above the normal signalling frequency required, the beats are more easily eliminated or discriminated against, and have less distorting effect. The signalling may now be carried to a higher speed before the frequency components of the signalling are extended too far up into the beat frequency region. I have thus been able, by means of the invention, to increase the ratio of signal to multipath distortion of the received signal.

In order to restore the purposely distorted transmitted signal arriving at the receiver to the desired rectangular wave form, it is necessary to introduce an opposite type of distortion, sometimes called a counterdistortion. This counter-

distortion, or signal wave form correction may often be accomplished by the simple expedient of employing as much frequency selectivity as possible at the receiver, or by employing counter distorting circuits. However, it is not absolutely essential to introduce this counter distortion in order to be able to read the transmitted distorted signal as received at the receiver.

Fig. 6a illustrates one form of distorting circuit between the terminals *a* and *b* which can be used to produce the desired wave form of Fig. 4. In this figure, numeral 1 represents any suitable source of keyed direct current potential, 2 represents a network consisting of a condenser and a parallel connected resistance having a time constant approximating the signal elongation due to the multipath, 3 represents a frequency shift keyed transmitter whose output is radiated over an antenna 4. The internal impedance of the input circuit of the transmitter 3 is represented by a resistance 5. The network 2 between terminals *a* and *b* of Figs. 6a can be replaced, if desired, by the network shown in Fig. 6b, which is an alternative and produces the same distorting effect upon the output from a source of keyed direct current potential. In Fig. 6b an inductance *L* in series with a resistance *R* is connected across the two sides of the network.

Fig. 7a illustrates a circuit at the transmitter for introducing the desired distortion when there is provided a source of keyed alternating current labeled 1' whose output feeds the frequency shift keyed transmitter 3. In this case the distorting network 2' is provided with a resistor *R*' serially placed in one side of the network, and a series circuit of a condenser *C* and inductance *L* and another resistor *R*'' placed across the two sides of the network. Condenser *C* and inductance *L* are here tuned to the alternating current frequency of the source of keyed signals emanating from 1'.

Fig. 7b shows an alternative form of wave distorting circuit which can be substituted for 2' in Fig. 7a, between the terminals *a* and *b*. The time constant of the wave distorting circuits of Figs. 7a and 7b are suitably chosen in the same way as the wave distorting networks of Figs. 6a and 6b, to approximate the signal elongation time due to the multipath.

Figs. 8a and 8b illustrate alternative receiving circuits for receiving the distorted signals transmitted by the circuits of Figs. 6a, 6b, 7a and 7b, and for counteracting the distortion in the signalling wave form produced at the transmitter. In Figs. 8a and 8b the signals are received on antenna 6 and impressed on a superheterodyne receiving circuit 7, from which signals are then impressed upon networks 8 and 8' respectively prior to utilization by the device 9. In Figs. 8a and 8b the superheterodyne receiver circuit 7 and 7' delivers a direct current output corresponding to the signal. These receivers each employs an amplitude limiter stage which feeds a frequency modulation detector, whose audio frequency output is rectified. In Fig. 8a the inductance 10 slows up the rate of change of the current supplied to the utilization device 9, thus counteracting the transmitter distortion produced by the transmitter 6 of Figs. 6a to 7a, inclusive. In Fig. 8b the condenser 11 tends momentarily to short circuit the signal applied to the utilization device 9, so that it takes time for the signal to build up, thus also counteracting the distortion produced in the signal originally transmitted. Obviously, the counteracting dis-

torting networks of Figs. 8a and 8b have suitable time constants to produce the proper counter-distortion.

If it is desired to deliver an alternating current output from the superheterodyne receiver to the utilization device, we can use either of the circuits illustrated in Figs. 9a and 9b. Here again, the signal is received by antenna 6 and supplied to a superheterodyne receiver now labeled 12, from which an alternating current tone output is supplied to a suitable counterdistortion network before being supplied to the utilization device 9. The superheterodyne receivers 12, 12 of Figs. 9a and 9b are similar to the superheterodyne receivers 7, 7 of Figs. 8a and 8b, except that the receivers 12 omit the final rectifier present in receiver 7 and thus supply a tone output to the counterdistortion circuit. This final rectifier which is omitted from the receivers 12 may be the third detector or the audio frequency detector. It should be understood, however, that receivers 12, like receivers 7, each employ an amplitude limiter for the superaudible high frequencies which is followed by a frequency modulation detector. In Fig. 9a the parallel tuned circuit 13 is tuned to the tone output frequency from receiver 12. Since it takes time to build up an alternating current potential across the tuned circuit 13, it will be understood that during this time interval the overswing which was introduced at the transmitter will be counteracted or cancelled out. In Fig. 9b the condenser 14 and the inductance 15 tend to act as an open circuit for a short interval of time, thus introducing a time delay for the tone signal from the superheterodyne receiver 12 to reach the utilization device 9.

In all the receiver circuits of Figs. 8a, 8b, 9a and 9b, the resistor 16 represents the internal impedance of the utilization device.

Fig. 10 is believed to be self-explanatory in giving in more detail the elements of one embodiment which the receiver of the invention may take.

What is claimed is:

1. The method of reducing the effects in a receiver of multiple signalling paths in radio telegraph communication, which comprises alternately shifting the signalling frequency at the transmitting station between two frequencies and introducing a transient overswing in the frequency shift toward and through both of said two signalling frequencies, which overswing is a substantial percentage of the difference between said two frequencies.

2. The method of reducing the effects of multiple signalling paths in radio telegraph communication which comprises alternately changing the signalling frequency at the transmitting station, introducing for a predetermined period of time an overswing in the frequency change toward and through both of said two signalling frequencies, receiving the transmitted waves, limiting the amplitude of the received waves at superaudible high frequencies, changing the variations in frequency of the amplitude limited high frequency waves to corresponding variations in amplitude, and removing the effects produced upon the wave form of the signal by the introduced overswing.

3. The method of reducing the effects of multiple signalling paths in radio communication utilizing marking and spacing frequencies, which comprises distorting the wave form of the transmitted wave by continuing the shift toward

marking and spacing frequencies past their respective normal steady values for a time interval approximating the signal elongation due to the multipath phenomenon.

4. The method of reducing the effects of multiple signalling paths in radio communication utilizing marking and spacing frequencies, which comprises distorting the wave form of the modulating wave by continuing the frequency shifts toward marking and spacing frequencies past their respective normal steady values for a time interval approximating the signal elongation due to the multipath phenomenon, receiving the transmitted waves, limiting the amplitude of the received waves at superaudible high frequencies, changing the variations in frequency of the amplitude limited high frequency waves to corresponding variations in amplitude, and introducing a counterdistortion prior to utilization.

5. The method of reducing the effects of multiple signalling paths in radio telegraph communication which comprises alternately shifting the signalling frequency at the transmitting station, introducing for a predetermined period of time an overswing in the frequency shift toward both of said signalling frequencies, receiving the transmitted waves, heterodyning the signal currents to lower frequency currents, limiting the amplitude of the lower frequency currents to a substantially constant value, utilizing the variations in frequency of the lower frequency current to produce a response in output current, and removing the effects produced upon the wave form of the signal by the introduced overswing.

6. In a system for reducing the effects of multiple signalling paths in radio communication, in combination, a spacing wave or frequency change transmitter for transmitting different marking and spacing frequencies, means at said transmitter for distorting the normal wave form of frequency shift so as to reduce multipath effects, a frequency modulation receiver for receiving the transmitted waves, said receiver including means

for limiting the amplitude of the received waves, a frequency modulation detector designed to respond down to and including zero modulating frequencies, and means in the output of said detector for correcting for the distortions produced at said transmitter.

7. In a radio telegraph system having a transmitter for alternately changing the signalling frequency, and a frequency modulation receiver, the method of operation which includes employing a frequency shift at the transmitter which is greater than the modulation band width required to adequately reproduce the signal at the receiver, and producing a substantial overswing in the normal signalling frequencies over a predetermined time interval.

8. The method of reducing the effects in a receiver of multiple signalling paths in radio telegraph communication, which comprises alternately shifting the signalling frequency at the transmitting station between two frequencies and introducing a transient overswing in the frequency shift toward and through both of said two signalling frequencies, for a time interval substantially equal to the signal elongation due to the multipath phenomenon.

9. In a system for reducing the effects of multiple signalling paths in radio communication, in combination, a spacing wave or frequency change transmitter for transmitting different marking and spacing frequencies, means at said transmitter for distorting for a predetermined period of time the normal wave form of frequency shift so as to reduce multipath effects, a frequency modulation receiver for receiving the transmitted waves, said receiver including means for limiting the amplitude of the received waves, a frequency modulation detector designed to respond down to and including zero modulating frequencies, and means in the output of said detector for correcting for the distortions produced at said transmitter.

CLARENCE W. HANSELL.