March 2, 1943. C. W. HANSELL 2,312,835

SHORT WAVE RADIO SYSTEM

Filed March 4, 1941 2 Sheets-Sheet 1

Fig. 1.

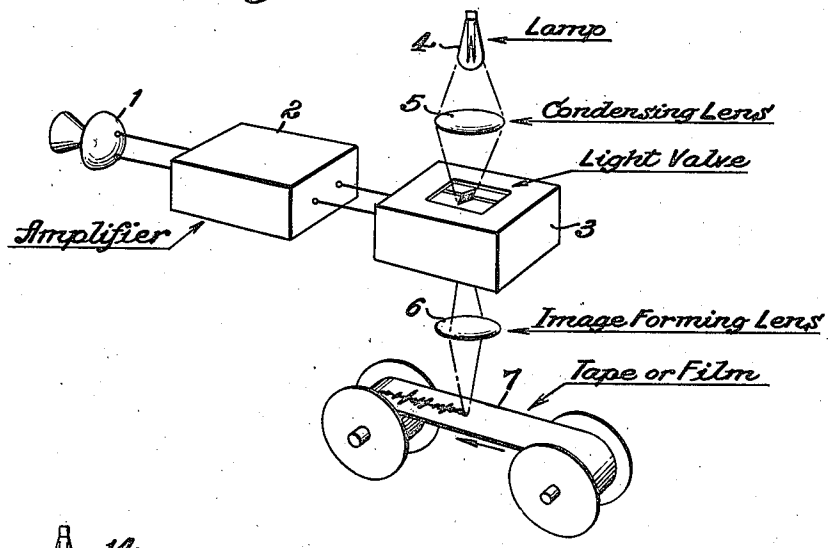
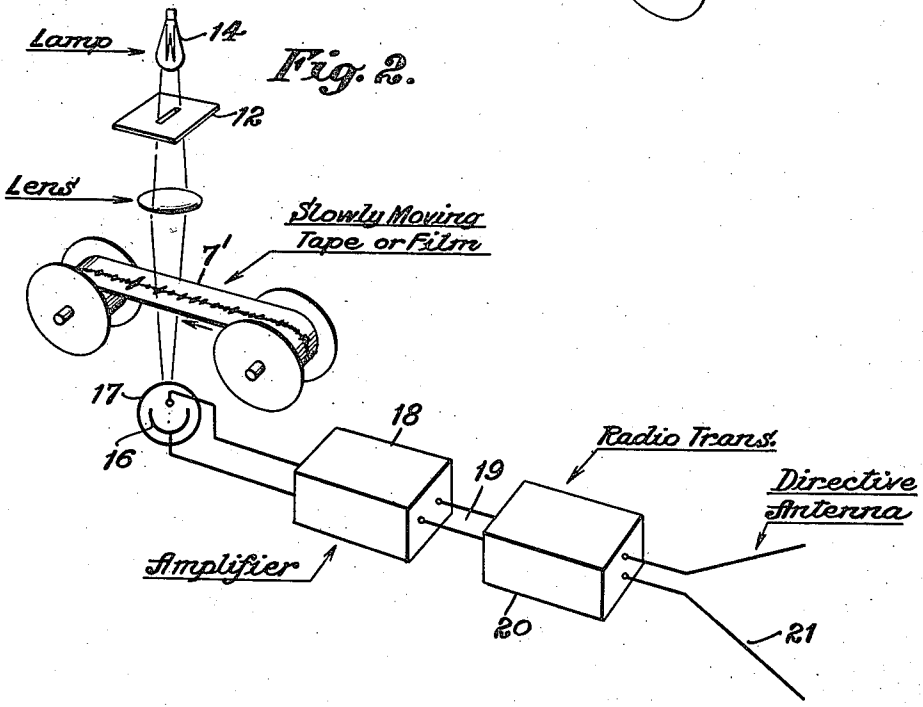


Fig. 2.



INVENTOR
Clarence W. Hansell
BY H. R. Grove
ATTORNEY

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Filed March 4, 1941 2 Sheets-Sheet 2

Fig. 3.

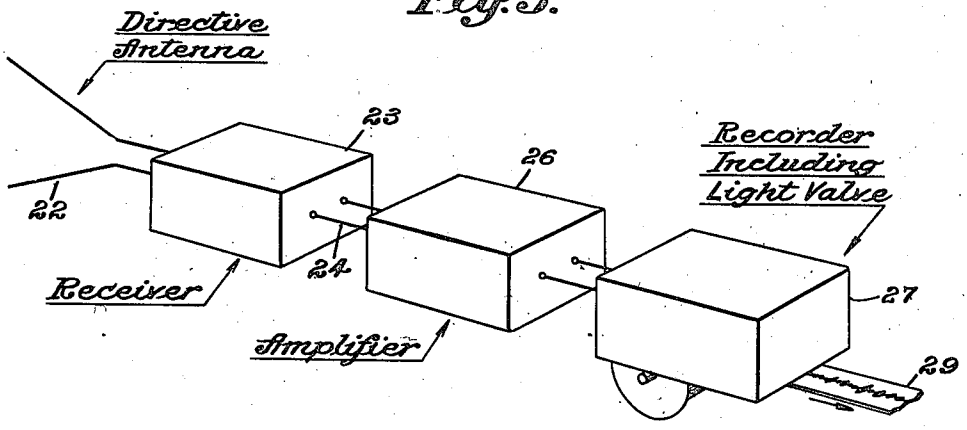
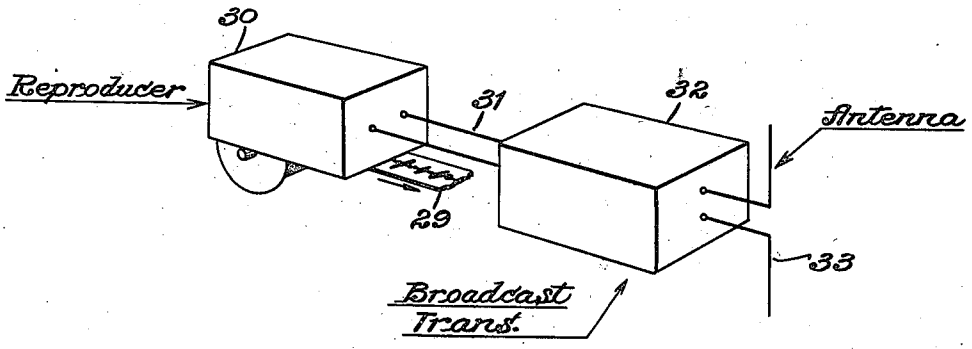


Fig. 4.



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

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UNITED STATES PATENT OFFICE

2,312,835

SHORT WAVE RADIO SYSTEM

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

Application March 4, 1941, Serial No. 381,605

12 Claims. (Cl. 250—6)

The present invention relates to communication over long distances by means of short radio waves in the range from 10 to 200 meters.

In radio communication over long distances, as between America and Europe, signal distortion is almost always present due largely to the multipath phenomenon. By the term "multi-path phenomenon" is meant the existence of several paths of different lengths and different time delays taken by the radio wave signals in their travel between the transmitting and receiving stations. These paths constantly change as the radio waves pass through the ionosphere. The distortion referred to, which has been apparent to all who listen to programs rebroadcast from overseas, renders it virtually impossible with present radio systems for fine musical programs to be sent over long distances with short waves and reproduced with any satisfactory degree of quality. Since radio circuits provide the only available means to send programs across the oceans, aside from physical transportation of records by airplanes or ships, it will be apparent that, before this invention, no means for sending high quality programs across the ocean has been available.

For publications describing this multipath phenomenon, reference may be made to radio and scientific papers; particularly those appearing under the subject of "Ionosphere, Echo Signals" in Proceedings of the Institute of Radio Engineers. See, for example, papers in the Proceedings for April and December, 1927; May, June and October, 1928; May and September, 1929; January, 1930.

Another difficulty experienced in the reception of long distance broadcast signals with the use of present day systems lies in the ease with which accidental interference from other transmitters and deliberate inteference, sometimes known as "jamming," can be produced. This deliberate interference often occurs during war when an enemy nation attempts to interfere with the reception of signals broadcast from another country and in both war and peace time may occur when stations in one country attempt to crowd out stations in another country, in order to obtain a channel for their own use or to prevent the reception of propaganda or prejudicial information.

A further objection to international programs resides in the difference in time in the different countries. As an illustration, programs from Europe are broadcast there five or six hours later in the day than the time in New York, and eight or nine hours later than the time in San Francisco, California. Consequently, a program given in England at eight o'clock in the evening when the largest number of Englishmen can listen, will arrive at from noon to 3 p. m. in various parts of the United States, when most people are at work, and relatively few persons have the time to listen.

One of the objects of the present invention is to reduce multipath distortions present on long distance radio circuits wherein communication is carried out by means of waves passing through the ionosphere.

Another object is to reduce noise and interference in radio waves caused either by natural causes or by man-made noises originating outside the receiving equipment. The natural causes may be lightning, corona, thermal agitation, etc., while the man-made noises may be from internal combustion engines, ignition, sparking contacts, diathermy, industrial high frequency equipment and jamming.

A further object is to obtain a certain amount of secrecy in the transmission of long distance short wave telephony signals.

The present invention achieves the foregoing objects and overcomes the difficulties mentioned in present day long distance communication by transmitting the programs at the originating station, recording or storing them at the station or country of origin, and then retransmitting them at an opportune time. Thus, programs given in Europe at eight o'clock in the evening could be rebroadcast in the United States five to eight hours later so that the people in America could hear them at about the same time (by the sun) as the Europeans. The essential feature of the present invention resides in the concept of transmitting the recorded or stored programs at reduced speed, such as one-tenth of the normal speed of transmission, by phase or frequency modulation but preferably by means of frequency modulations of a carrier wave current, in order to overcome or reduce the effects of distortion and noise.

It has been found through studies of the long distance propagation of modulated short waves that the fading and distortion have greater effect upon the higher modulation frequencies than upon the low modulation frequencies, which is a natural consequence of the presence of multiple paths with unequal time delay. Thus, it is possible to transmit modulations in the band from zero to 500 cycles with far less selective fading and distortion than the transmission of modulations in the band from zero to 5000

cycles. This increased fading and distortion at the higher modulation frequencies is caused by the fact that the time delay between the shortest and the longest paths extending from the transmitting to the receiving station becomes larger compared to one-half cycle of the modulation frequency as the frequency is increased. It is common for time difference of arrival of waves over longest and shortest paths to range up to 3 milliseconds even over the best circuits, an amount of time equal to a half cycle of modulation at modulation frequencies down to 167 cycles. However, since time differences as great as this exist usually only when there are a number of more significant components arriving with lesser time delays, it has been found that generally the highest frequency modulation which does not suffer considerable selective fading and distortion ranges from about 500 to 100 cycles per second, depending upon conditions.

According to the invention, it is proposed to store or obtain a program record of the message to be transmitted over long distances, and then reproduce it at say 10% of the normal speed, upon which the recorded sound frequencies will all be reduced in the ratio of 10 to 1, and the total modulation frequency band required will also be reduced by ten to one. This reduction of ten to one occurs because the frequency is dependent upon the speed of reproduction of the wave form of the sound. By transmitting the program at 10% of the normal speed, it is therefore possible to greatly reduce the distortion caused by multipath transmission and selective fading. By employing directive antennas at the transmitting and receiving stations, and also the diversity receiving principle and more selectivity at the receiver, together with amplitude limiting made possible by employing phase or frequency modulation, it is possible to further reduce noise and minimize the effects of jamming.

One advantage of the present invention lies in the fact that there is obtained a certain degree of secrecy by reducing the speed of the transmitted programs previously stored or recorded at the transmitter end. This reduction of speed in transmission makes it extremely difficult if not impossible for a listener equipped only with an ordinary receiver to understand the transmitted message.

In the practice of the present invention, it is essential that the signals be transmitted at reduced speed from a phase or frequency modulation transmitter, and received by a phase or frequency modulation receiver. In this way it is possible to use a large ratio of frequency deviation to modulating frequency. Then so long as the desired carrier frequency current is received at a strength greater than an interfering carrier current and at a strength greater than the peak values of noise, practically all effect of interference and noise may be substantially eliminated. I am thus able to obtain all the advantages of a wide band frequency modulation system; first, because of the use of lower modulation frequencies, and secondly, because of the increase in the ratio of maximum frequency deviation to maximum modulating frequency (known as the modulation index).

This suppression of noise and interference, through the use of my invention, is similar to the elimination of noise through employing an increased transmission band width but has this significant difference, namely that I reduce the modulation frequency band by taking greater time for transmission, in order to obtain a greater ratio of frequency deviation to modulation frequency within any fixed transmission band. This permits me to operate in existing channels and allows greater frequency selectivity before detection at the receiver so that I can work through higher noise levels.

By means of adequate transmitter power, great transmitting and receiving directivity, proper choice of transmitting frequency, use of diversity reception as taught in my Patent 1,803,504, and in my Patent 2,249,425, choice of transmitting period, repetition of transmission and other known expedients, it will generally be possible to get programs through with carrier strength greater than interference and noise and thereby to obtain a nearly perfect result for rebroadcast service so long as the present invention is used but, without the invention, years of experience have shown that a nearly perfect result is practically never obtained.

A more detailed description of the invention follows in conjunction with a drawing, wherein:

Fig. 1 shows, by way of example only, a system for recording at the transmitting station a program or message which is to be later transmitted over the radio circuit to a distant receiving station;

Fig. 2 illustrates a system for transmitting at reduced speed the message or program previously recorded in accordance with the apparatus of Fig. 1;

Fig. 3 illustrates a receiver for receiving the slow speed signals transmitted by the system of Fig. 2; and

Fig. 4 illustrates a system for restoring to normal speed the received slow speed signals and for rebroadcasting these signals.

Referring to Fig. 1, the system for recording the message or program comprises a microphone 1, a suitable sound amplifier 2 coupled thereto, a light valve 3 coupled to the output of the amplifier 2, and associated equipment comprising a lamp 4 and lenses 5 and 6 for producing on a photographic tape or film 7 the signal to be recorded. The light valve 3 may consist of any well known apparatus having a suitable slit or aperture and a vibrating gate or ribbon arrangement whose displacement is proportional to the current applied thereto by the amplifier. Sound currents from the microphone 1 and amplifier 2 flow in a suitable coil in the light valve causing the light from lamp 4 focussed on the valve by condensing lens 5 to appear on the traveling film 7 as a line at right angles to the direction of film travel. As the valve aperture is modulated by sound currents, the film 7 receives a varying exposure and a sound record is made thereon either of the variable area or variable density type, dependent upon the kind of light recording equipment employed. I prefer the variable area constant density type of recording using equipment and methods which have been developed for the recording of sound on film in the moving picture industry. The direction of movement of the film as it advances from one reel to the other is shown by the arrow.

The method of transmitting the message or program recorded on film 7 will now be described in connection with Fig. 2. The film 7 after development will be put on appropriate reels and other apparatus well known in the talking motion picture and film phonograph art. Light from lamp 14 will be condensed by lens

15 and slot member 12 onto the developed film 7'. The light passing through this film will be projected onto the cathode 16 of the photo-electric cell 17. The photographic tape or film 7' is arranged to advance slowly at say one-tenth of the normal speed at which the message was originally recorded. The quantity of light passing through the film 7' will vary depending upon the overall translucency of the area of the line scanned by the condensed light, and will produce a definite current flow into the input circuit of the vacuum tube amplifier 18, caused by the electron flow between the cathode 16 and the anode of the photo-cell 17. This electron current after amplification will pass into the transmission line or radio relaying circuit 19 which carries the slow speed modulation (sound or otherwise) to the radio transmitter 20 from which it will be radiated by means of the directive antenna 21. This directive antenna may be of any well known type, although it is preferred to be of the V kind constructed in accordance with the principles set forth in United States Patent No. 1,974,387, granted to Philip S. Carter, which type of antenna I believe gives greatest directivity per unit of cost.

In the transmission of signals from the radio transmitter 20 of Fig. 2, it is preferred that there be employed short waves in the range from ten to 200 meters, which depend for their usefulness upon refraction from the ionosphere. This radio transmitter is of the phase or frequency modulation type, now well known in the art. Examples of such transmitters and features employed in them are described in my Patents 1,751,584, 1,787,979, 1,878,308, 2,032,208, 2,190,782. I may also employ in the transmitter the features described in my Patent 2,179,182 and in my application Serial No. 297,777, filed September 28, 1939.

In those cases where the noise to be encountered frequently reaches peak values equal to or greater than the carrier wave, it is preferred that a minimum band width be employed. Where, however, the strength of the carrier current is almost continuously considerably greater than the peak value of the noise, it is preferred to use a wider deviation to occupy the same frequency band as though slow speed transmission were not employed, or to use the maximum band width permitted by the frequency band assigned to use by the particular transmitter 20. Using wider frequency bands increases the initial noise admitted to the frequency modulation detector but, up to the point where the noise peaks approach equality with or exceed the carrier strength, the use of a high ratio of frequency deviation to modulation frequency suppresses or greatly reduces the noise appearing in the output from the detector.

Fig. 3 illustrates diagrammatically a suitable receiving arrangement for receiving and recording the slow speed signals transmitted from the distant transmitter of Fig. 2. In Fig. 3, the received signals are collected by a suitable directive antenna 22 and impressed upon a frequency modulation receiver 23, the latter being a complete receiving arrangement which reproduces the slow speed modulation (sound or otherwise) originally applied to the distant transmitter. Many detail arrangements of frequency modulation receivers are already well known in the art, including the receiver of my Patents 1,813,922, 2,205,762, 2,207,544, and my application Serial No. 398,391, filed June 17, 1941. The slow speed modulation frequencies from the output of the receiver 23 are impressed upon line or radio relaying circuit 24 and amplified in 26, after which the amplified modulation frequencies are applied to a suitable recorder 27 for recording the received slow speed signals on a moving photographic tape or film 29. The recording apparatus 27 may include a suitable light valve of the type shown in Fig. 1, except that it operates slowly since it is desired to record the desired slow speed modulation. The direction of the arrow indicates the direction of travel of the continuously advancing film 29.

Fig. 4 indicates diagrammatically a method of and apparatus for broadcasting signals at normal speed from the message programs recorded at the receiver on tape 29. The tape 29 of Fig. 3, after development, may be placed on suitable reels and caused to pass through reproducing apparatus 30 at a more rapid rate than the speed of travel through the recorder 27 of Fig. 3. This more rapid rate of travel of the film 29 through the reproducer 30 is required in order to reproduce the modulations at normal speed. The reproducing apparatus 30 may be any suitable apparatus for reproducing sound from film or tape as used in the motion picture industry. The output of the reproducer will apply to line 31 modulation frequencies at the same speed or frequency range as is present in the input to the microphone of Fig. 1, and these modulation frequencies are then applied to any suitable broadcasting transmitter 32 for radiating over antenna 33 the signals to be received in the usual home receivers. The antenna 33 is preferably of the omnidirectional type so as to radiate signals with equal strength in all directions for the listeners at the receiving end.

Although, in Fig. 3, I have indicated only one receiver and receiving antenna for detecting and reproducing frequency currents, it should be understood that in practice I may employ a plurality of antennas and receivers to provide a common output in accordance with the teachings of my Patent 1,803,504 and my Patent 2,249,425.

It will thus be seen that I have described a system for recording signals at a normal speed, transmitting them slowly at a much reduced speed, receiving them at a distant location and rerecording them at the slow or reproduced speed and then transcribing them at an increased speed equivalent to the normal speed at which they were originally recorded at the distant transmitting station. In addition, I have described means for employing this slowed down transmission with phase or frequency modulated waves transmitted over radio circuits by way of the ionosphere. By these means it becomes possible to remove the previously existing barrier to transmission of high quality programs across the oceans.

Where it is desired to save time in the transmission of the slow speed signals over the long distance circuit (ionosphere), then the signals stored at the transmitter may have different portions thereof transmitted over different channels at the same time (at the same reduced speed) and reproduced at the receiver in proper sequence.

Although the invention has been described with particular reference to a frequency modulation system, the invention is not limited thereto since, if desired, a phase modulation system may also be employed, for (as will be apparent

from the material in my Patent 2,179,182 and my application Serial No. 297,777, filed October 4, 1939) phase and frequency modulation are similar in nature and in the systems described the modulation characteristics used may actually be some compromise between or mixture of phase and frequency modulation.

Obviously, where wire lines are employed to transfer the message waves of reduced speeds from a central location to distant apparatus, either at the transmitting end or at the receiving end, as may be the case where line 19 (Fig. 2) is of a relatively long length, or the directive antenna 22 is remotely located with respect to the receiver of Fig. 3, a direct current type of circuit, or at any rate one capable of responding down to very low frequencies, is required which should be capable of faithfully reproducing the reduced frequency band. In these cases of wire line program transfer, it may be desirable to heterodyne down the incoming radio signals received over antenna 22 (Fig. 3) to a suitable intermediate frequency, and employ this intermediate frequency for transfer over the wire line or radio relay circuit 14 to the amplifier 26. Likewise, at the transmitting end, the modulations may be transferred over lines or radio relay circuits from some central office of origin to the radio transmitter by means of amplitude, phase or frequency modulated carrier currents. Such arrangements would be particularly practical in a frequency modulation system.

Although photographic recording on film has been described, it will be obvious that any suitable form of recording may be used, whether it is film, paper, magnetic tape, or any other type, so long as the method of recording is suitable for storing the signal and for reproducing the program or message waves at the required speeds. It will thus be apparent that the invention contemplates the use of any suitable storage means for achieving the desired recording and rerecording, and for then transcribing the signals at the desired speed.

The term "angular velocity" employed in the appended claims refers to apparatus capable of transmitting or receiving either frequency or phase modulated waves.

What is claimed is:

1. In a long distance radio communication system employing short waves in the range substantially from 10 to 200 meters, the method of overcoming multipath distortions in signaling between the transmitter and the remote receiver which comprises first storing the signals at the transmitter end, then transmitting the signals over the radio circuit at appreciably reduced speed with frequency modulated waves, receiving the frequency modulated signal waves at the receiving end and storing the same at the said reduced speed, and then translating the stored signals at the receiver end at an increased speed approximating the speed at which the original signals were stored at the transmitter end.

2. In a long distance radio communication system, means for recording speech and musical waves, an angular velocity modulation transmitter for radiating said recorded speech waves at a speed appreciably lower than the speed at which they were recorded and as modulations of radio waves in the range substantially from 10 to 200 meters, a remotely located angular velocity modulation receiver for receiving the transmitted waves and having means for recording the received waves at the same reduced speed at which they were received, and means for transmitting the recorded received waves at an increased speed of the order of the speed at which the original waves were recorded at the transmitter end of the system.

3. In a long distance radio communication system, means for recording speech waves, an angular velocity modulation transmitter for transmitting said recorded speech waves at a speed appreciably lower than the speed at which they were recorded and at frequencies corresponding to waves in the range substantially from 10 to 200 meters, said transmitter having a directive antenna in circuit therewith, a remotely located angular velocity modulation receiver for receiving the transmitted waves and having means for recording the received waves at the same reduced speed at which they were received, said receiver also having a directive antenna, and means for transmitting the recorded received waves at an increased speed of the order of the speed at which the original waves were recorded at the transmitter end of the system.

4. In a long distance radio communication system, a broadcast transmitter, means for recording the signals broadcast from said transmitter, an angular velocity modulation transmitter for directively radiating the recorded signals at a speed appreciably lower than the speed at which they were recorded and at frequencies corresponding to waves in the range substantially from 10 to 200 meters, a remotely located angular velocity modulation receiver directively arranged to receive the retransmitted waves and having means for recording the received waves at substantially the same speed at which they were received, and a local radio transmitter associated with said receiver for broadcasting the recorded received waves at an increased speed of the order of the speed at which the original waves were first broadcast at the transmitter end prior to recording thereat.

5. In a radio system, the method of transmitting intelligence which comprises making a record of the message to be transmitted, transmitting the message by causing it to modulate the angular velocity of a carrier wave current, at reduced speed, on short waves in the range from 10 to 200 meters, receiving the modulations of the transmitted waves and recording the same at the same reduced speed as received, and transmitting the received recorded signal waves at an increased speed of the order of the speed at which the original message was first recorded at the transmitting end of the system.

6. A system in accordance with claim 2, characterized in this that said angular velocity modulation transmitter and said angular velocity modulation receiver are frequency modulation apparatus.

7. A system in accordance with claim 2, characterized in this that said angular velocity modulation transmitter and said angular velocity modulation receiver are phase modulation apparatus.

8. A system in accordance with claim 2, characterized in this that a diversity receiving system is employed.

9. In a long distance radio communication system employing short waves in the range substantially from 10 to 200 meters, the method of overcoming multipath distortions in trans-

mitting a complete program between the transmitter and the remote receiver which comprises first continuously storing the complete program at the transmitter end, then transmitting the complete program without interruption over the radio circuit at appreciably reduced speed with frequency modulated waves, receiving the transmitted frequency modulated waves at the receiving end and storing the same at the said reduced speed, and then translating the complete stored program at the receiver end at an increased speed approximating the speed at which the original signals were stored at the transmitter end.

10. In a long distance radio communication system, means for recording speech and musical waves, an angular velocity modulation transmitter for radiating said recorded speech waves at a speed appreciably lower than the speed at which they were recorded and at an increased ratio of maximum frequency deviation to maximum modulating frequency and as modulations of radio waves in the range substantially from 10 to 200 meters, a remotely located angular velocity modulation receiver for receiving the transmitted waves and having means for recording the received waves at the same reduced speed at which they were received, and means for transmitting the recorded received waves at an increased speed of the order of the speed at which the original waves were recorded at the transmitter end of the system, whereby undesirable effects of distortion and noise are appreciably reduced.

11. In a long distance radio communication system wherein stored intelligence is transmitted over the ether by means of angular velocity modulated waves and at a speed appreciably lower than the speed at which the intelligence was stored, an angular velocity modulation receiver for receiving the transmitted waves and having means for storing the received waves at the same reduced speed at which they were received, and means for translating the stored received waves at an increased speed of the order of the speed at which the original intelligence was stored at the transmitting end of the system.

12. In a radio system wherein a record is made of the message to be transmitted and the message later caused to modulate the angular velocity of a carrier wave at a speed lower than the speed at which the message was recorded, said carrier being in the range substantially from 10 to 200 meters, an angular velocity modulation receiver for receiving the transmitted waves and having means for recording the received waves at the same reduced speed at which they were received, and means for transmitting the recorded received waves at an increased speed of the order of the speed at which the original waves were recorded at the transmitter end of the system.

CLARENCE W. HANSELL.