

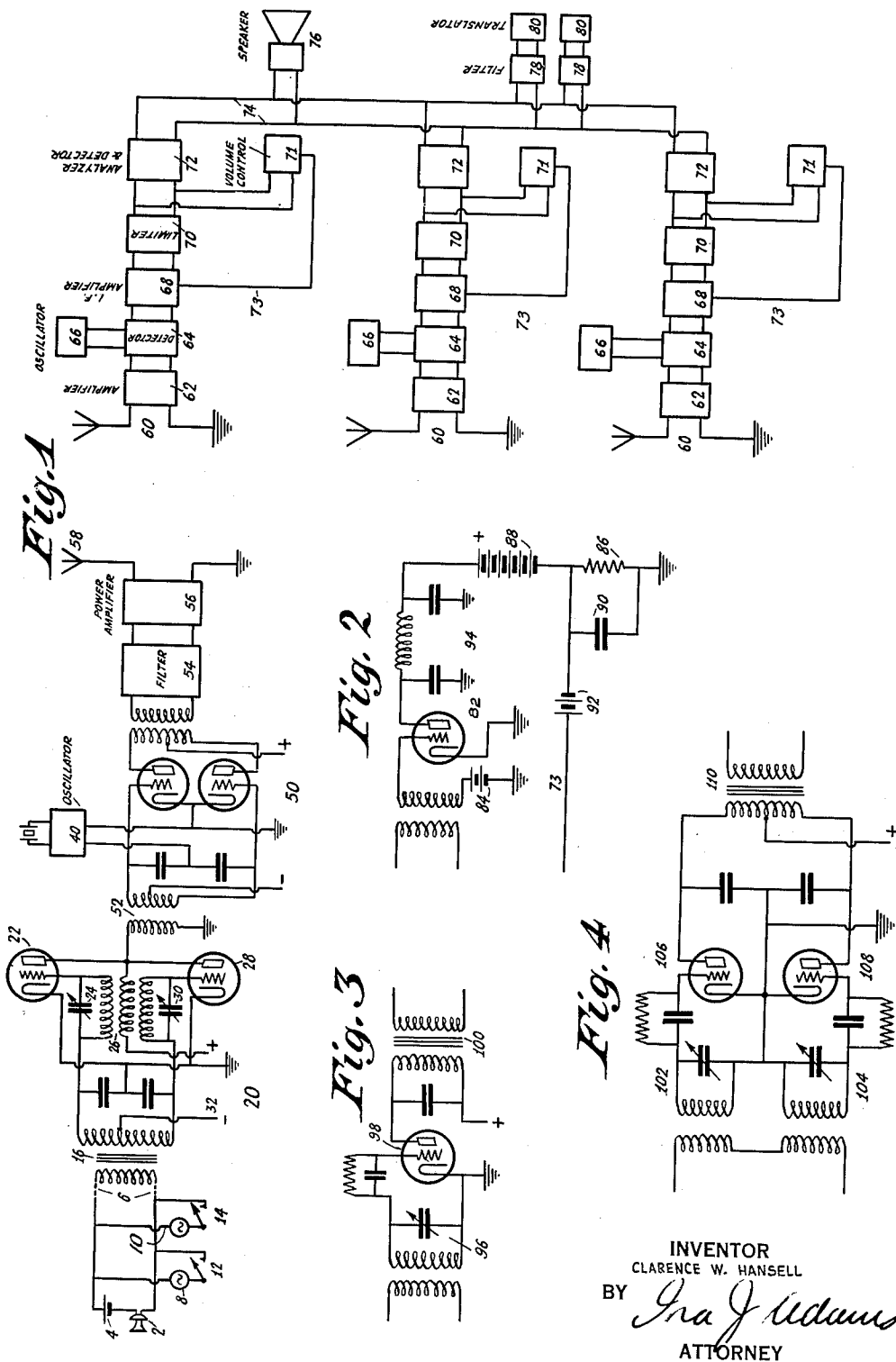
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SIGNALING

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SIGNALING

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This invention relates to signaling, and more particularly to the elimination of the effect of fading of speech or speech-simulating signals transmitted on high frequency carriers.

Short wave signals are subject to fading which varies both in frequency and degree in an unpredictable manner. Inasmuch as the fading at any instant may differ very widely at geographically spaced points, it has been suggested that a receiving station be equipped with a number of spaced antennae the energies collected by which are fed to a single signal responsive means.

Experience has shown that high frequency energy fluctuates not only in intensity but also in phase, and that there may be considerable relative phase fluctuation at spaced points. This phenomenon makes it impossible to directly combine the radio frequency energies for the energies may as often be in phase opposition as in like phase. To overcome this difficulty it has been suggested to equip each of the antennae with a separate receiver, and to combine the energies only after rectification, and this, in the case of code signals, has proven an apt solution.

However, I have found that in the case of speech telephony, or other speech-simulating signals, where the transmission energy is radiated in the form of a carrier and side bands, there is a relative difference in the phase fluctuations of closely adjacent frequencies, such as side band and carrier frequencies, even at one geographic point, just as there is between carriers of like frequency at different geographic points. This causes similar phase fluctuations in the beat of the carrier and side bands, for if of two beating waves one is kept constant in phase, while the other is shifted in phase, their beat is equally shifted in phase.

This may readily be understood by visualizing two beating radio frequency waves of slightly different frequency, which have an envelope which is a maximum where the waves are cophasal, and which gradually drops off to a minimum where the waves are in phase opposition. Now if the phase of one of these waves is kept constant while the

phase of the other is shifted 180 degrees the waves will be in phase opposition where before they were cophasal, so that the envelope will be a minimum where before it was a maximum, and where the waves were in phase opposition they now will be cophasal, so that the envelope will be a maximum where before it was a minimum, and, therefore, in effect the envelope too has been shifted 180 degrees in phase.

Because of the foregoing considerations it follows that although the carrier and side band energies experience only radio frequency difference in phase, these differences are transferred to the detected or audio frequency energies, so that it is as impossible to combine the detected energies as it is to directly combine the originally collected radio frequency energies.

The primary object of my invention is to overcome this difficulty, making possible the application of diversity reception to overcome fading of speech-simulating signals, and for this purpose I use in combination with the diversity reception receiver a frequency modulation transmitter. By modulating the frequency and not the amplitude of the radiated carrier, and at the receiver analyzing the received carrier in accordance with the changes in frequency rather than the changes in amplitude, there is no appreciable variation in the phase of the audio frequency energies, because the different possible paths taken by the energies collected at the spaced antennae do not differ by so great a length as to be equivalent to an appreciable change in audio frequency phase.

High frequency energy may sometimes experience fading which is only partial in depth but which occurs at so rapid a frequency as to itself constitute an audio frequency. To obviate the effect of this type of fading is a further object of my invention, which I am able to accomplish by the same process of employing frequency modulation rather than amplitude modulation at the transmitter, and limiting the received energy at the receiver, so as to eliminate all amplitude variations above a minimum desired value. Instead of, or in addition to limiting, volume control may

be employed, and in the case of either or both methods of eliminating the effect of partial fading, there is a peculiar advantage residing in their use in cooperation with the frequency modulated wave already provided, inasmuch as this wave, ideally, should have no amplitude modulation whatever, and therefore by making the limiter, or the volume control detector, or both, equally responsive to the entire range of frequencies involved, these devices will operate practically as though they were being applied to a perfectly unmodulated continuous wave carrier, which is, of course, the ideal condition for their best operation.

A further object of my invention is to provide for multiplexing, which I do by separately signaling on a plurality of different relatively low frequency energies, combining the signal energies, and frequency modulating a high frequency carrier in accordance with the combined signal wave. Even if the signals are code signals the combined wave is a complex signal wave which, if employed for amplitude modulation, would result in carrier and side band frequencies. This complex wave may, for the purpose of this invention, be considered as equivalent to a speech wave, and is included within the meaning of what I shall term a "speech-simulating wave". Of course, the relatively low frequency energies could be modulated, rather than keyed, and in every case, the modulation may be in accordance with light intensity, as well as sound intensity. At the receiver the detected wave is separated into its constituent signal energies, and these are separately translated to obtain the desired signals.

The invention is more fully described in the following specification, which is accompanied by a drawing in which

Figure 1 is a wiring diagram for a communication system arranged in accordance with my invention;

Figure 2 is a detail of the volume control;

Figure 3 is a detail of one form of analyzer and detector; and

Figure 4 is an alternative and preferred form of analyzer and detector.

Referring to the drawing, there is a microphone 2 in series with a battery 4, connected to a land line 6. If code signaling, rather than or in addition to speech telephony, is to be employed, there are a plurality of sources of relatively low frequency energy 8 and 10, each keyed by keying means 12 and 14. The resulting speech-simulating wave is transferred over the land line 6 to the input transformer 16 of a frequency modulation generator 20. This comprises an upper and a lower oscillator, the former consisting of the electron emission tube 22, the resonant circuit 24, and a regenerative anode circuit coil 26, while the latter comprises an electron emission tube 28, the resonant circuit 30, and the

common anode circuit coil 26. Because of the common coil 26 both oscillators are forced to oscillate at a common frequency. However, the circuit 24 is tuned to one extreme frequency of the desired frequency range, while the circuit 30 is tuned to the other extreme frequency of the desired frequency range, so that the common oscillation frequency is a compromise frequency lying between the two resonant frequencies. The magnitude of this common frequency depends upon the relative strength of oscillation in the two oscillators, which in turn depends upon the relative potential applied to the control electrodes of the oscillator tubes. The mean value of this control electrode potential is determined by a biasing source connected to the lead 32, while the relative value is varied by the secondary of the input transformer 16, which is connected in series with the control electrodes, so that the frequency of the energy generated in the circuit 20 is varied in accordance with the speech-simulating wave applied to the transformer 16.

This frequency modulated energy may be radiated directly, but in order to keep the mean frequency constant I prefer to use the circuit 20 to generate a frequency modulated wave of intermediate frequency, and to modulate energy of high frequency from a constant frequency source by means of the intermediate frequency energy. For this purpose carrier energy is supplied from a crystal controlled high frequency oscillator 40, which is coupled to feed the tubes of the carrier suppression modulator 50 in parallel while the energy of intermediate frequency is supplied through a transformer 52 to the control electrodes of the modulator tubes in series. Of the two resulting side bands one is selected and the other rejected by the filter 54, and the resulting frequency modulated energy of high frequency may be amplified in a power amplifier 56, and radiated from a suitable antenna 58. For a more detailed description of this transmitter reference may be made to my copending application Serial Number 264,101, filed March 23, 1928.

The radiated energy is collected at a plurality of antennae 60, each of which is provided with a receiver. This preferably includes a radio frequency amplifier 62, a heterodyne detector 64 in which the received energy is heterodyned with energy from a local oscillator 66 and thus reduced to energy of intermediate frequency. This is amplified in an intermediate frequency amplifier 68, and limited in a limiter 70. It should be understood that either or both of the amplifiers 62 and 68 may be so operated as to have a limiting action, and so make the use of a separate limiter 70 unnecessary.

The limited energy is fed to an analyzer and detector 72, the analyzer comprising merely a resonant circuit tuned to one side

of the working range of frequency so that it responds to the applied frequencies unequally, and thereby changes the frequency modulation to amplitude modulation, which, after detection, results in the speech-simulating wave of energy. Details of this receiver may be found in my copending application Serial Number 212,192, filed Aug. 11, 1927.

It has already been pointed out that volume control may be used instead of or in addition to limiting. This is indicated by the volume control device 71, which is connected in parallel with the analyzing detector 72 so that a portion of the output of the intermediate amplifier 68 is fed to the volume control. The volume control serves to change the normal bias on the control electrodes of the tubes in the intermediate amplifier 68 through a lead 73. The bias, and consequently the gain of the amplifier, is varied in such a direction that the output tends to remain constant. There is some advantage in using the volume control even in addition to the limiter because the amplifier may be given increased amplification when the signal level falls below that to which the limiter is adjusted.

The speech-simulating energies from the different antennae are combined together in a line 74, which feeds an appropriate translating device, such as the speaker 76, in case of speech reception or rebroadcasting, or a photo-recorder, in case of pictures, and so on. In the case of multiplex signals the combined energy is fed to a group of filters 78, which separate the combined energy into its constituent signal energies, and each of these is translated in a translating device 80.

Figure 2 is a wiring diagram for one form of the volume control indicated by the rectangle 71 in Figure 1. It comprises a detector tube 82, given a rectifying action by means of a bias battery 84, and having in its anode circuit a resistance 86, which is connected between the anode battery 88 and ground in order to keep it at a low potential. A condenser 90 is connected in parallel with resistance 86 to determine the time constant of the response of the volume control. The lead 73 is connected to the upper terminal of the resistance 86, as shown, and includes a C battery 92 which fixes the normal bias of the amplifier. A filter section 94 is provided to separate the radio frequency and direct current components of the anode current. Upon variation in the strength of the carrier the direct current component also is varied, which changes the potential drop across the resistance 86, and so varies the bias, and consequently the gain, of the amplifier. For further details concerning a suitable volume control reference may be made, for example, to the copending application of T. A. Smith filed October 5, 1928, Serial Number 310,497.

A simple form of analyzing detector is indicated in Figure 3, and comprises a resonant circuit 96, which is tuned to a frequency lying to one side of the operating range of frequencies, so that it responds unequally thereto, and so changes frequency modulation to amplitude modulation. The amplitude modulated wave is fed to a detector tube 98, and the low frequency component of the detected wave is taken out by means of the transformer 100.

The analyzing detector is preferably arranged in the form shown in Figure 4, where two circuits 102 and 104, are provided, each tuned to different frequencies lying either side of the operating range of frequency, so that they respond unequally and in opposite sense to the different frequencies supplied thereto. The resulting amplitude modulated energies are fed to the detector tubes 106 and 108, and the outputs of these tubes are combined differentially in a single transformer 110, from which the desired signal energy is taken. For further details concerning this analyzing and detector circuit a copending application of George L. Usselman, Serial Number 216,873, filed Sept 18, 1927, may be consulted.

My invention, employing frequency modulation, possesses all of the advantages concomitant to the use of this type of modulation, such as the possibility of reducing the necessary frequency band for each channel of communication, the inherent reduction of fading owing to the range of frequencies employed, and the use of the transmitter at its maximum output at all times, but no claim is made herein to frequency modulation per se. My invention, insofar as it employs diversity reception, is accompanied by important advantages, such as the reduction in the effect of fading at geographically spaced points, but no claim is made herein to diversity reception per se. However, in combining frequency modulation with diversity reception there results not only the advantages of each, but a new and very important advantage, in the case of speech-simulating signals, in that it makes possible the application of diversity reception to speech-simulating signals in spite of fluctuations in the relative phase of closely adjacent frequencies, such as side band and carrier frequencies, at even a single geographic point, and therefore what I claim is:

1. The method of making possible the application of diversity reception to overcome fading of speech-simulating signals transmitted on a high frequency carrier, in spite of fluctuations in the relative phase of closely adjacent frequencies such as side band and carrier frequencies, which includes the step of frequency modulating the carrier at the transmitter in accordance with the speech-simulating signal.

2. The method of communicating speech-

simulating signals on a high frequency carrier which includes, at the transmitter, frequency modulating the carrier in accordance with the speech-simulating signal, and radiating the frequency modulated carrier, and at the receiver, collecting the radiated energy at a plurality of spaced points, separately analyzing and detecting the collected energies to obtain speech-simulating signal energies, combining the signal energies, and translating the combined energy.

3. The method of communicating speech-simulating signals on a high frequency carrier which includes, at the transmitter, frequency modulating the carrier in accordance with the speech-simulating signal, and radiating the frequency modulated carrier, and at the receiver, collecting the radiated energy at a plurality of spaced points, separately limiting the collected energies to obviate the effect of partial fading, separately analyzing and detecting the limited energies to obtain speech-simulating signal energies, combining the signal energies, and translating the combined energy.

4. The method of communicating speech-simulating signals on a high frequency carrier which includes, at the transmitter, frequency modulating the carrier in accordance with the speech-simulating signal, and radiating the frequency modulated carrier, and at the receiver, collecting the radiated energy at a plurality of spaced points, separately amplifying the collected energies, controlling the gain in the aforesaid step of amplification in response to the volume of the amplified energy to tend to keep the volume constant in order to obviate the effect of partial fading, separately analyzing and detecting the amplified energies to obtain speech-simulating signal energies, combining the energies, and translating the combined energy.

5. The method of multiplexing which includes, at the transmitter, separately signaling on a plurality of different relatively low frequency energies, combining the signal energies to form a speech-simulating signal wave, frequency modulating a high frequency carrier in accordance with the signal wave, and radiating the frequency modulated carrier, and at the receiver, collecting the radiated energy at a plurality of spaced points, separately analyzing and detecting the collected energies to obtain the signal waves, combining the signal waves, separating the combined wave into its constituent signal energies, and separately translating the signal energies.

6. The method of multiplexing which includes, at the transmitter, separately signaling on a plurality of relatively low frequency energies, combining the signal energies to form a speech-simulating signal wave, frequency modulating a high frequency carrier in accordance with the signal wave, and ra-

diating the frequency modulated carrier, and at the receiver, collecting the radiated energy at a plurality of spaced points, separately limiting the collected energies to obviate the effect of partial fading, separately analyzing and detecting the limited energies to obtain the signal waves, combining the signal waves, separating the combined wave into its constituent signal energies, and separately translating the signal energies.

7. The method of multiplexing which includes, at the transmitter, separately signaling on a plurality of relatively low frequency energies, combining the signal energies to form a speech-simulating signal wave, frequency modulating a high frequency carrier in accordance with the signal wave, and radiating the frequency modulated carrier, and at the receiver, collecting the radiated energy at a plurality of spaced points, separately amplifying the collected energies, controlling the gain in the aforesaid step of amplification in response to the volume of the amplified energy to tend to keep the volume constant in order to obviate the effect of partial fading, separately analyzing and detecting the amplified energies to obtain the signaling waves, combining the signaling waves, separating the combined wave into its constituent signal energies, and separately translating the signal energies.

8. The method of multiplexing code signals which includes, at the transmitter separately keying a plurality of different low frequency energies, combining the keyed energies to form a speech-simulating signal wave, frequency modulating a high frequency carrier in accordance with the signal wave, and radiating the frequency modulated carrier, and at the receiver, collecting the radiated energy at a plurality of spaced points, separately analyzing and detecting the collected energies to obtain the signal waves, combining the signal waves, separating the combined wave into its constituent low frequency energies, and separately translating the low frequency energies to obtain the code signals.

9. A diversity communication system for overcoming fading of speech-simulating signals transmitted on a high frequency carrier, in spite of fluctuations in the relative phase of closely adjacent frequencies such as side band and carrier frequencies, comprising the combination of a frequency modulation transmitter with a diversity reception receiver.

10. A communication system for speech-simulating signals including a frequency modulation transmitter comprising a source of carrier energy, means to frequency modulate the carrier in accordance with the speech-simulating signal, and means to radiate the frequency modulated carrier, in combination with a diversity receiver comprising a plu-

ality of spaced antennæ, means to separately analyze and detect the energies collected thereby to obtain speech-simulating signal energies, means to combine the signal energies, and means to translate the combined energy.

11. A communication system for speech-simulating signals including a frequency modulation transmitter comprising a source of high frequency carrier energy, means to frequency modulate the carrier in accordance with the speech-simulating signal, and means to radiate the frequency modulated carrier, in combination with a diversity receiver comprising a plurality of spaced antennæ, means to separately limit the collected energies to obviate the effect of partial fading, means to separately analyze and detect the limited energies, means to combine the detected energies, and means to translate the combined energy.

12. A communication system for speech-simulating signals including a frequency modulation transmitter comprising a source of high frequency carrier energy, means to frequency modulate the carrier in accordance with the speech-simulating signal, and means to radiate the frequency modulated carrier, in combination with a diversity receiver comprising a plurality of spaced antennæ, a plurality of amplifiers for separately amplifying the collected energies, a volume control for controlling the amplification gain of the aforesaid amplifiers to obviate the effect of partial fading, means to separately analyze and detect the amplified energies, means to combine the detected energies, and means to translate the combined energy.

13. A multiplex communication system including a transmitter comprising a plurality of sources of different relatively low frequency energy, means to separately signal on each of the energies, means to combine the signal energies to form a speech-simulating signal wave, a source of high frequency carrier energy, means to frequency modulate the carrier in accordance with the signal wave, and means to radiate the frequency modulated carrier, and a diversity receiver comprising a plurality of spaced antennæ, means to separately analyze and detect the collected energies, means to combine the detected energies, means to separate the combined energy into its constituent signal energies, and means to translate the signal energies.

14. A multiplex communication system including a transmitter comprising a plurality of sources of relatively low frequency energy, means to separately signal on each of the energies, means to combine the signal energies to form a speech-simulating signal wave, a source of high frequency carrier energy, means to frequency modulate the carrier in accordance with the signal wave, and

means to radiate the frequency modulated carrier, and a diversity receiver comprising a plurality of spaced antennæ, means to separately limit the collected energies to obviate the effect of partial fading, means to separately analyze and detect the limited energies, means to combine the detected energies, means to separate the combined energy into its constituent signal energies, and means to translate the signal energies.

15. A multiplex communication system including a transmitter comprising a plurality of sources of low frequency energy, means to separately signal on each of the energies, means to combine the signal energies to form a speech-simulating signal wave, a source of high frequency carrier energy, means to frequency modulate the carrier in accordance with the signal wave, and means to radiate the frequency modulated carrier, and a diversity receiver comprising a plurality of spaced antennæ, a plurality of amplifiers coupled thereto, a volume control for controlling the amplification gain of the aforesaid amplifiers to obviate the effect of partial fading, means to separately analyze and detect the amplified energies, means to combine the detected energies, means to separate the combined wave into its constituent signal energies, and means to translate the signal energies.

16. A multiplex communication system for code signals including a transmitter comprising a plurality of sources of different low frequency energies, means to separately key the low frequency energies, means to combine the keyed energies to form a speech-simulating signal wave, a source of high frequency carrier energy, means to frequency modulate the carrier in accordance with the signal wave, and means to radiate the frequency modulated carrier, and a diversity receiver comprising a plurality of spaced antennæ, means to separately analyze and detect the collected energies, means to combine the detected energies, means to separate the combined energy into its constituent low frequency energies, and means to translate the low frequency energies to obtain the code signals.

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