June 12, 1945. R. A. HILFERTY 2,378,298

COMPOSITE-MODULATION RADIO SERVICE SYSTEM

Filed March 12, 1943 3 Sheets-Sheet 1

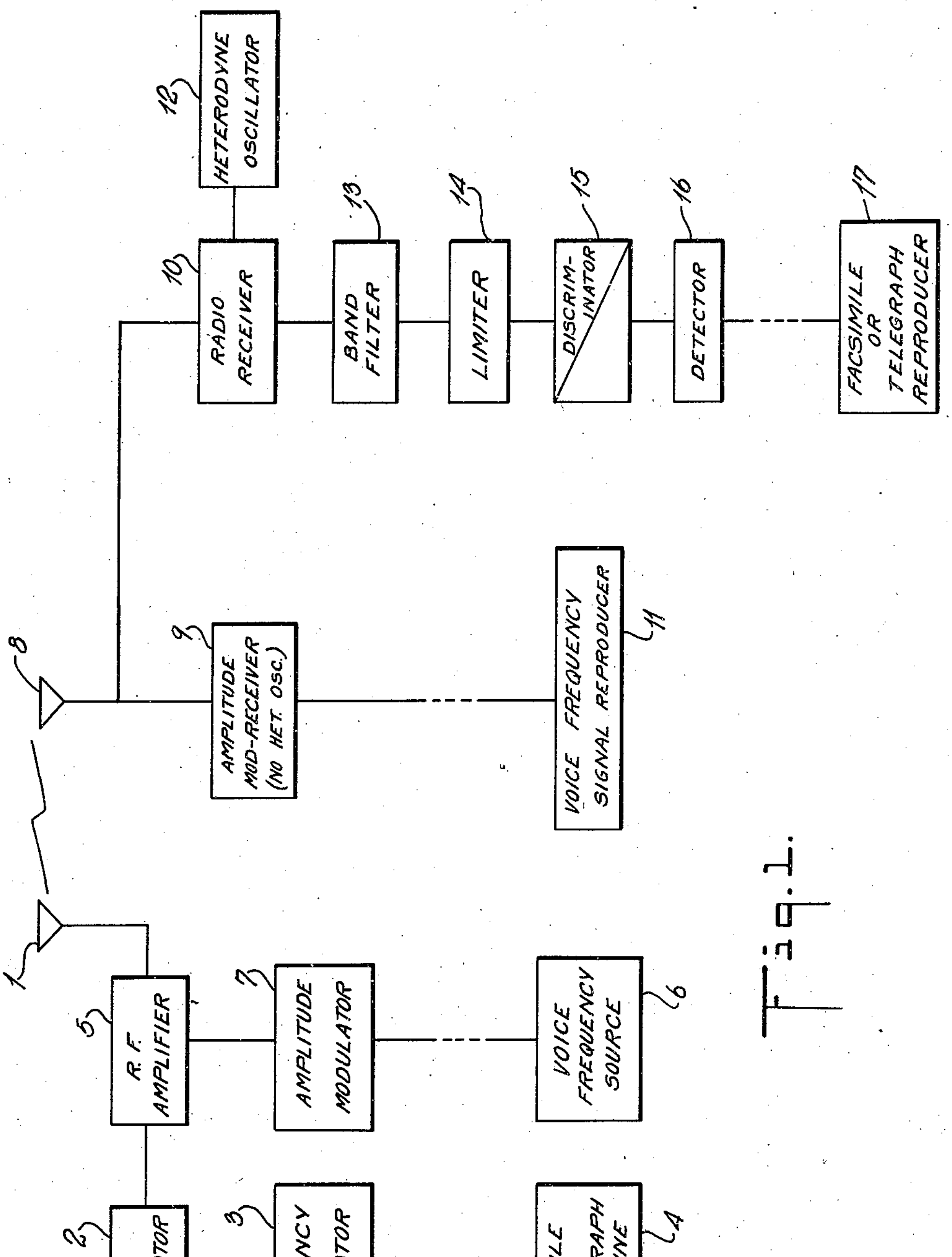

Fig. 1.

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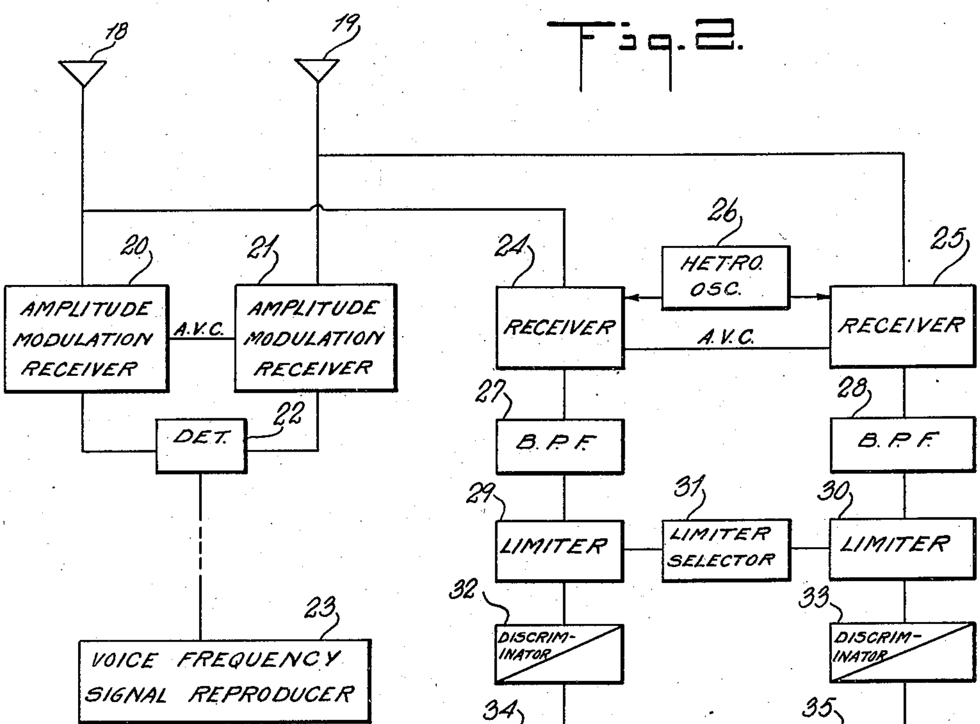
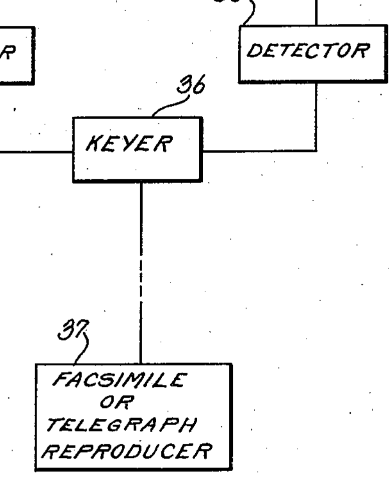
Fig. 2.

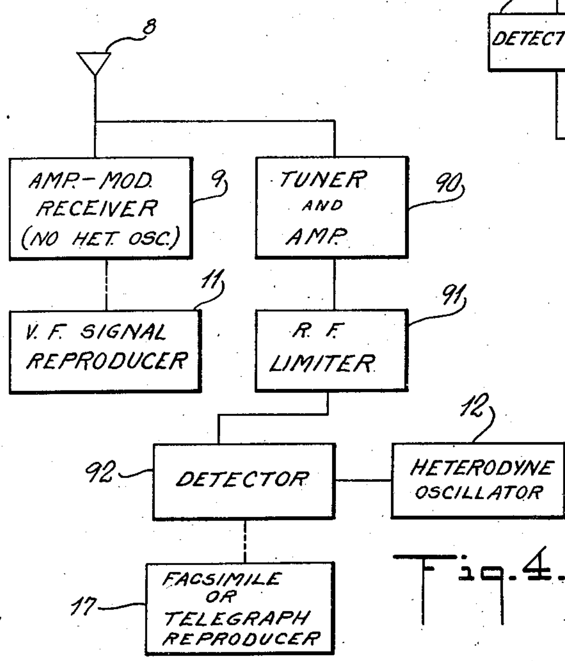


Fig. 4.

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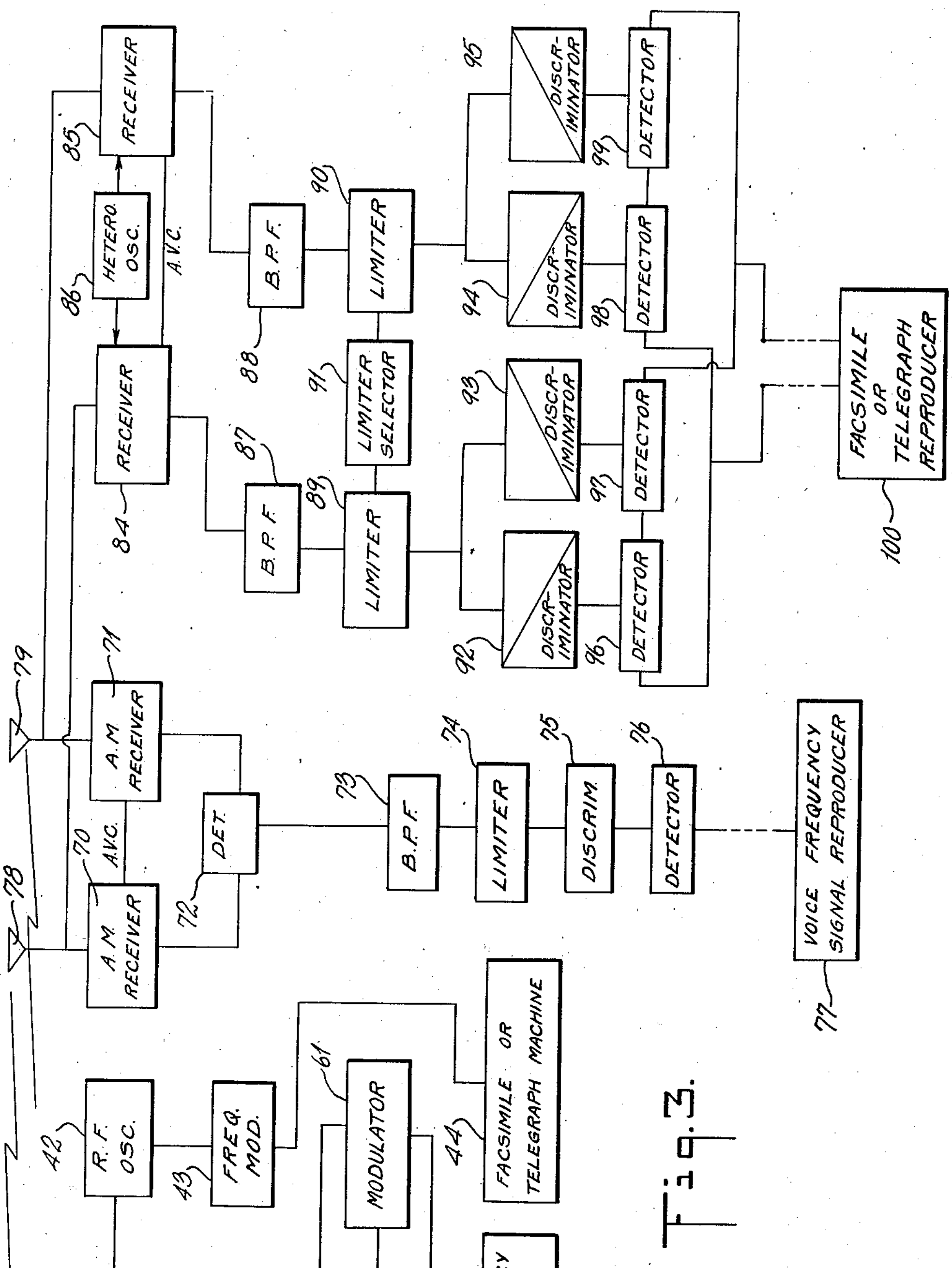

Fig. 3.

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UNITED STATES PATENT OFFICE

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COMPOSITE-MODULATION RADIO SERVICE SYSTEM

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Application March 12, 1943, Serial No. 478,854

2 Claims. (Cl. 250—9)

This invention relates to radio transmission systems and more particularly to systems wherein two different signal conditions or forms of intelligence can be transmitted simultaneously over the same radio channel.

A principal object is to provide an improved multiplex radio transmission system wherein, simultaneously, two separate signals can be transmitted by frequency modulation and amplitude modulation over the same radio channel.

Another object is to provide an improved arrangement whereby existing radio frequency channels of the amplitude modulation type can be simultaneously used to transmit and receive signals by frequency modulation without undesirable mutual interference.

A feature of the invention relates to a radio transmission system wherein a given channel can be used to transmit such signals as voice frequencies by amplitude modulation of a carrier, and other signals such as telegraph or facsimile signals by frequency modulation without introducing "key clicks" or the like from the telegraph transmission into the voice frequency transmission.

Another feature relates to an improved form of diversity transmitting and receiving arrangement using the simultaneous frequency and amplitude modulation features of the invention.

A further feature relates to a system of simultaneous reception of frequency modulated and amplitude modulated emissions from a single radio transmitter on the same mean carrier frequency without mutual interference, while at the same time providing signalling circuits of good quality and flexibility for the simultaneous handling of telephone, facsimile, and telegraphic communications in any combinations desired.

Other features and advantages not specifically enumerated will be apparent after a consideration of the following detailed descriptions and the appended claims.

Inasmuch as the invention is concerned primarily with methods and general arrangements for simultaneous transmission of amplitude modulations and frequency modulations of the same mean carrier frequency, and since certain parts of the equipment are well-known in the art, for purposes of simplicity in explanation, block diagrams are used throughout the drawings. It will be understood of course, that the various parts incorporated within the block portions can be of any well-known construction so long as they are modified or adjusted as disclosed herein for the purpose of achieving the inventive objects. Accordingly, in the drawings,

Fig. 1 is a schematic block diagram of a radio system embodying features of the invention.

Fig. 2 shows the invention as embodied in a diversity-type radio system.

Fig. 3 is a modification of Fig. 2 using subcarrier transmission.

Fig. 4 is a further modification.

Referring to Fig. 1, there is shown a radiating antenna 1 of any known type, which is adapted to be excited at a radiating frequency under control of the output of the R. F. oscillator 2. Oscillator 2 is controlled by any well-known frequency modulation arrangement 3 which in turn is controlled by a signal generator 4 which may be a facsimile machine, a telegraph machine or the like. By well-known principles, the signals from device 4 act through device 3 to vary the frequency of the oscillator 2. In accordance with the present invention, the device 4 is adjusted so that the telegraph or facsimile signals impressed upon the modulator 3 are free from square, or substantially square wave fronts or square trailing edges. For example, if the device 4 is a telegraph keyer, it should be arranged and provided with known wave shaping networks or other devices so that the keyed impulses are shaped to a quasi-sinusoidal form or to impulses having curved or smooth leading and trailing edges. I have found that this is extremely important if mutual interference is to be avoided between the two types of intelligence that are to be simultaneously transmitted from the antenna 1. Preferably, modulator 3 is adjusted to vary the carrier from source 2 over a frequency range of 500 C. P. S. For example, if the mean carrier frequency from source 2 is 5000 k. c., the modulator 3 will vary this frequency between 4999.75 k. c. and 5000.25 k. c.

The frequency modulated carrier in device 2 is then passed through any well-known R. F. amplifier 5. Amplifier 5 is also connected so as to have the amplitude of its output waves modulated under control of a source of voice-frequency signals such as a telephone transmitter or the like, which controls an amplitude-modulator 7 whereby the amplitude of the carrier waves impressed on antenna 1 is varied. I have found that while a very high percentage of amplitude modulation can be employed, for example 90%, it should not closely approach 100% amplitude modulation. Consequently, there is impressed upon antenna 1, a carrier wave whose mean frequency varies over a range of 500 C. P. S. i. e., 250 C. P. S. above and 250 C. P. S. below the said mean carrier frequency. At the same time, this carrier is amplitude-modulated in accordance with the voice frequency signals from source 6.

The receiving antenna 8 is connected to two separate radio receivers 9, 10. Receiver 9 is a radio receiver of the amplitude demodulation type such as a tuned R. F. receiver, a superheterodyne receiver or the like, but in no case should this receiver have a beating or heterodyne oscillator at the final detector stage, in order to insure that the receiver responds fundamentally only to the amplitude modulations originating at the device 6. I have also found that it is necessary that the response of receiver 9 be flat over a 500 C. P. S. range in variation of the carrier, so that no amplitude variations will be produced in the output of receiver 9 by the changing transmitter frequency. The demodulated signals from receiver 9 can then be applied to any suitable form of voice frequency signal recorder 11.

The radio receiver 10 may be of the frequency-modulation type which is tuned in the well-known manner to the assumed transmitter mean frequency of 5000 k. c. Receiver 10 may also be of the type which employs a local beating oscillator to produce an audible beat output, e. g. between 1000 and 1500 C. P. S. For example, it may be an ordinary communications receiver such as ordinarily used for AM and CW reception. It responds, in this case, to FM only by virtue of its beat oscillations. The frequency modulation receiver should be so adjusted that the local beating oscillator produces at least six times the current in the R. F. detector as is produced by incoming signal. This is so because of the requisite clear heterodyne beat note which must be relatively unaffected by amplitude modulations received on the same carrier frequency. Consequently, as the transmitter frequency is varied over its 500 C. P. S. range as above noted, the audible heterodyne frequency at the audio output receiver 10 will rise and fall in unison with the transmitter frequency. This heterodyne beat of varying frequency is applied to a suitable band-pass filter 13 designed so that it will transmit faithfully the range of tone to be studied or recorded, namely 1000–1500 C. P. S. Preferably, the receiver 10 with its oscillator is so adjusted that the signals impressed upon filter 13 are in such a frequency range that the frequency of the uppermost useful limit is less than the second harmonic of the lowermost useful frequency limit, and thus the band of subsequent demodulation frequencies contains only the original intelligence and excludes undesirable harmonics and noises.

The varying frequency signals from filter 13 are then impressed on a level limiter 14 whereby all the input components are reduced to a common amplitude level, thereby removing any amplitude modulations which may be accidentally present in the signals as they emerge from filter 13. The remainder of the system associated with receiver 10 is adjusted and designed so that it will not respond to amplitude variations having a modulation factor less than unity. The demodulation is effected by means which is responsive to frequency variations such as network 15 which acts as a frequency discriminator to produce a variable output in proportion to the frequency of the impressed waves. Preferably, the discriminator is of the wide-band type such as disclosed in detail in application Serial No. 457,709, filed September 9, 1942. Preferably also, the discriminator 15 is of the uni-lateral type such that frequencies on one side of the midpoint of the input frequency range produce an increased output while those on the other side of the said midpoint produce a decreased output. The discriminator 15 therefore acts to convert the frequency modulations into amplitude variations. These amplitude variations are then impressed upon a detector 16, such as a rectifier, so as to produce direct current signals which vary in the same manner as the original variations from device 4. These rectified signals may then be used to operate such devices as undulators, relays, lamps, or other signalling devices for recording the intelligence embodied in the original frequency-modulated wave transmitted from antenna 1.

Referring to Fig. 2, the invention is shown as applied to a diversity-type radio reception system. In general, Fig. 2 comprises two complete composite-modulation systems at the receiver such as the receiver shown in Fig. 1 and connected in parallel to the common driving load represented by the receiving antennae 18, 19. The diversity receiving antenna 18 is connected in the usual way for diversity reception to two radio receivers 20, 21, of the amplitude demodulation type similar to receiver 9 (Fig. 1). The receivers 20, 21, are provided with A. V. C. circuits which are connected together as indicated and the outputs of the receivers are fed to a common detector 22 whose output is responsive to the particular antenna which delivers the greater driving load, as is well-known in diversity-type receiving systems. The detected output is therefore a counterpart of the original signals from device 6 (Fig. 1) and is used to control a suitable signal reproducer 23.

The two diversity antennae 18 and 19 are also connected in parallel to two radio receivers 24, 25, of the frequency-modulation type, each similar to receiver 10 (Fig. 1), and are heterodyned from a common local heterodyne oscillator 26. The A. V. C. leads of both receivers are tied together in the well-known manner. The receiver outputs are connected through respective band-pass filters 27, 28, similar to filter 13, and through respective limiters similar to limiter 14. By means of the limiter selector 31, the stronger of the two signals from devices 29, 30, is selected as described for example in application of Robert M. Sprague and Richard A. Hilferty, Serial No. 469,501, filed December 18, 1942. The frequency modulations from the selected channel 29 or 30 therefore control the respective frequency discriminator 32 or 33, which in turn controls the respective rectifier detector 34, 35. The particular device 34 or 35, that is effective at any given instant, depending upon which of the two channels 18 or 19 delivers the stronger signal, operates a keyer device 36 which transmits the demodulated F. M. signals over a local circuit to a central office wherein a suitable recorder such as a facsimile or telegraph recorder 37 is located.

Referring to Fig. 3, there is shown a further modification of Fig. 2, wherein the voice frequency signals from source 46 instead of amplitude-modulating the amplified carrier from device 42 directly through the amplitude-modulator 47, are first used to frequency-modulate a subcarrier 60 by means of a subcarrier frequency modulator 61. Thus the voice frequency signals from source 46 are converted through devices 60, 61, into a frequency-modulated subcarrier in the audio frequency band having a frequency-modulation range of 1800 C. P. S. to 3400 C. P. S. In other words the intelligence signals from source 46 are converted into a frequency spectrum e. g. 1800 C. P. S. to 3400 C. P. S., wherein the uppermost useful frequency is less than the second harmonic of the lowermost useful frequency. This varying frequency subcarrier is then used through the amplitude modulator 47 to amplitude-modulate the mean radio carrier from source 42. At the same time the facsimile or telegraph signals from source 44 are used through frequency-modulator 43 to frequency-modulate the mean radio carrier frequency from source **42**, so that the latter has a frequency swing approximately of 250 C. P. S. above and 250 C. P. S. below said mean carrier frequency.

At the receiving end, the two diversity antennae **78**, **79**, are connected to separate radio receivers **70**, **71**, of the amplitude demodulation type, such as receiver **9** (Fig. 1), having their A. V. C. leads tied together in the well-known manner for diversity reception. The detector **72** therefore responds to the channel delivering the greater signal strength. If, in the example assumed, the devices **60** and **61** produce 1800–3400 C. P. S. signals, this frequency spectrum is detected by detector **72** and is applied to a band-pass filter **73** which usefully passes substantially only the said range 1800–3400 C. P. S. This band of frequencies is then passed through a level limiter **74** to eliminate any undesirable amplitude modulations, and the leveled waves are then impressed upon the discriminator **75** to convert the frequency spectrum into amplitude variations corresponding to those from source **46**. These signals after rectification and detection in device **76** are used to control any suitable voice frequency reproducer **77**.

At the same time, the frequency modulations of the radio carrier wave produced under control of devices **42**, **43**, **44**, are received by the two respective diversity receivers **84**, **85**, of the frequency modulation type with their local heterodyne oscillator **86** similar to elements **24**, **25**, **26**, (Fig. 2). The A. V. C. leads of the two receivers **84**, **85**, are tied together for diversity control. The device **86** is adjusted so that the outputs of receivers **84** and **85** are in the desired frequency range e. g. 1000–1500 C. P S., which frequencies are then applied through respective band-pass filters **87**, **88**, so as to attenuate very greatly any frequencies below 1000 and above 1500 C. P. S. The signals passed by the respective band-pass filters are then applied to the respective level limiters **89**, **90**, which are connected to a common limiter selector **91** which may be of a type such as disclosed in copending application Robert M. Sprague and Richard A. Hilferty, Serial No. 469,501, filed December 18, 1942, whereby one or the other of the limiters takes control in accordance with which one of the diversity channels **78**, **79**, delivers the greater signal strength. Each limiter is connected in parallel to a pair of frequency discriminators **92—93**, **94—95**, and each pair of discriminators **92—93** is connected to a corresponding pair of detectors **96—97**, **98—99**, each pair of detectors being connected in opposition. The purpose of the double discriminators is for obtaining polar current from the output of the discriminators. Each "mark" discriminator (**92** or **94**) puts out a voltage which is, let us say, positive with respect to ground or some similar reference point. Each "space" discriminator (**93** or **95**) then produces a negative voltage. Since the mates are in series, the effective output of a pair is the differential between them. There are two pairs because of the two diversity receiving channels. While the mates are in series, the pairs are in parallel so that, due to fortuitous diversity action, a polar output is obtained so long as one discriminator of each sign receives a signal. At the "center-frequency" all discriminators would give the same output, but, due to opposing relationship, the net output voltage would be zero. The detected output of the particular diversity channel which is effective at any given instant is then applied to control the facsimile or telegraph reproducer unit **100**. It will be understood of course that in the foregoing description, while special forms of frequency demodulators employing level limiters and discriminators are disclosed, any other well-known form of frequency demodulation receiving system may be employed.

Various changes and modifications may be made herein without departing from the spirit and scope of the invention. For example, while in the foregoing embodiments, where a level limiter is disclosed, it is incorporated in an audio frequency part of the system, in certain cases, it is desirable to effect the limiting action at a radio frequency stage. Thus, there is shown in Fig. 4, a receiving system similar to that of Fig. 1, wherein corresponding parts bear the same designation numerals. In this case, the radio receiver for the frequency modulation signals comprises a radio frequency tuner and amplifier **90**, a radio frequency level limiter **91**, and a detector **92**. The detector is also fed with a local heterodyne oscillator **12** so as to convert the detected oscillations into the desired frequency band e. g. 1000–1500 C. P. S. This band is then used to control a facsimile or telegraph reproducer **17**.

In Fig. 4, the radio frequency limiter precedes the final detector in the radio receiver. This is a radio frequency limiter as distinguished from the audio limiters of the preceding embodiments described. The object in using a radio frequency limiter is to operate on the signal wave where the frequency is highest in order to be able to use small components of very small time constant. Thus, instead of limiting at several thousand cycles, the limiting can be done at several hundred kilocycles, as, for example, the intermediate frequency of the receiver. The limited radio frequency is then passed on to a heterodyne detector. The beat frequency due to the difference between signal and local heterodyne oscillator, is then passed through a discriminator and detector before entering the reproducer.

What I claim is:

1. The method of simultaneous transmission of keyed telegraph signals of substantially square-wave shape and of voice frequency signals over the same radio transmitter which comprises, modifying the wave shape of the keyed telegraph signals to convert them into substantially sinusoidal form, generating a radio frequency carrier, shifting the frequency of said carrier between certain limits under control of said modified keyed waves, amplifying the frequency-shifted carrier, amplitude-modulating the amplified carrier under control of the voice frequency signals, and radiating the doubly modulated carrier.

2. The method of simultaneous transmission of keyed telegraph signals having a normal substantially square-wave shape and of voice frequency signals over the same radio transmitter which comprises modifying the wave shape of the keyed telegraph signals to render them quasi-sinusoidal, generating a radio frequency carrier, shifting the frequency of said carrier between certain limits under control of said amplified keyed waves, amplifying the frequency-shifted carrier, amplitude-modulating the frequency-shifted carrier under control of the voice frequency signals and maintaining the said amplitude modulation below 100%.

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