

Dec. 15, 1942.

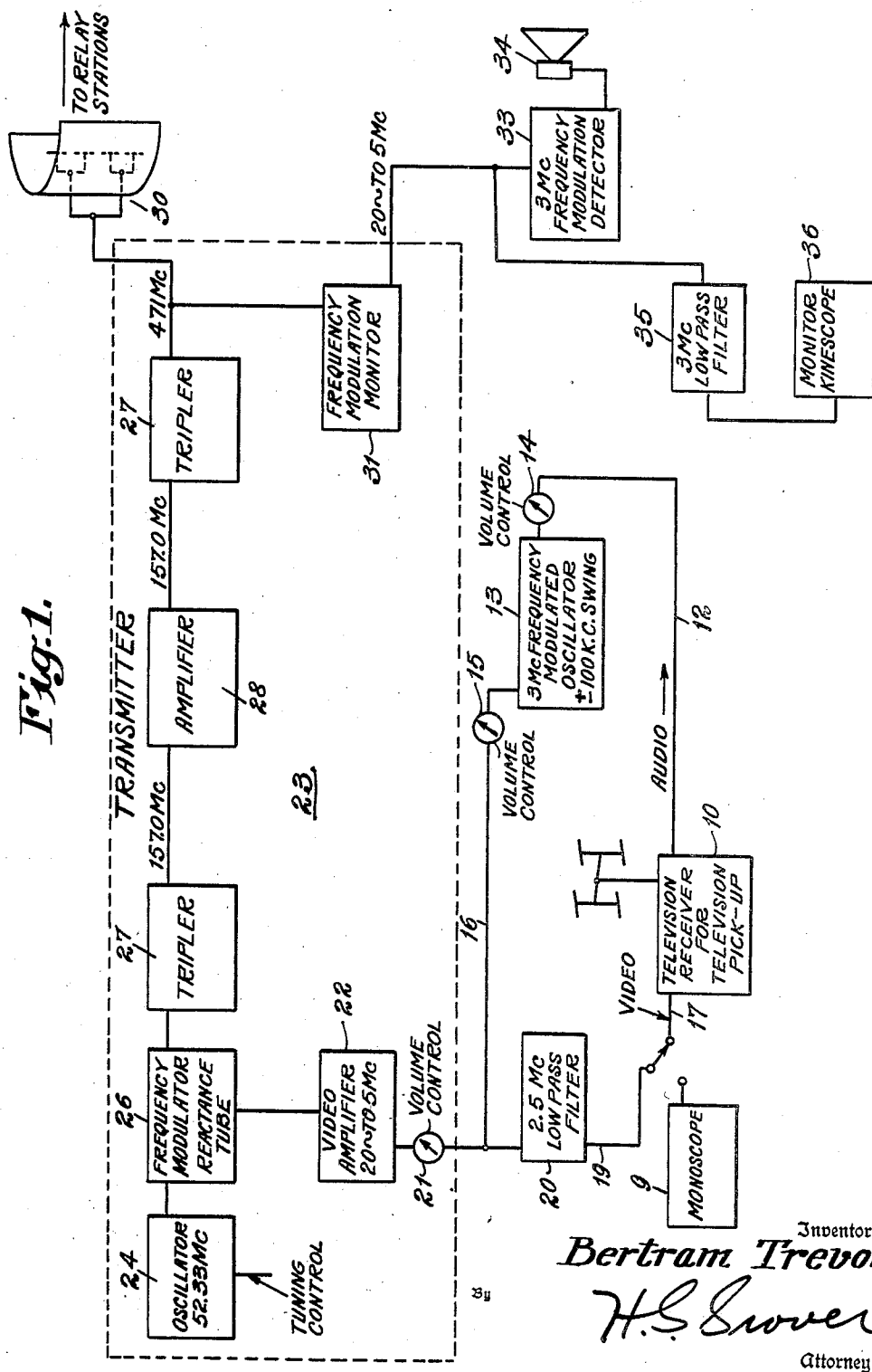
B. TREVOR

2,304,969

MULTIPLEX SYSTEM

Filed July 31, 1940

4 Sheets-Sheet 1



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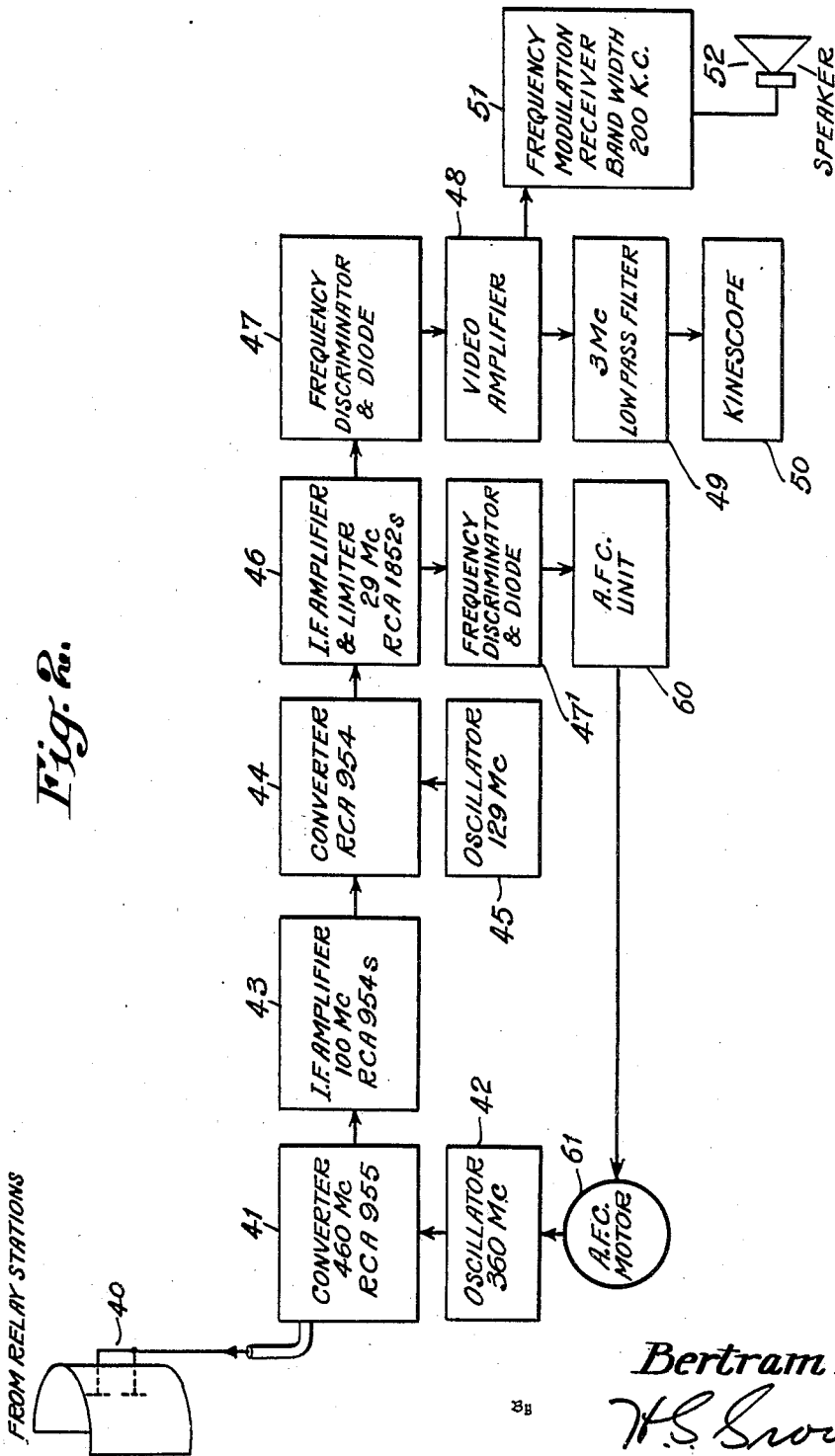
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Fig. 3.

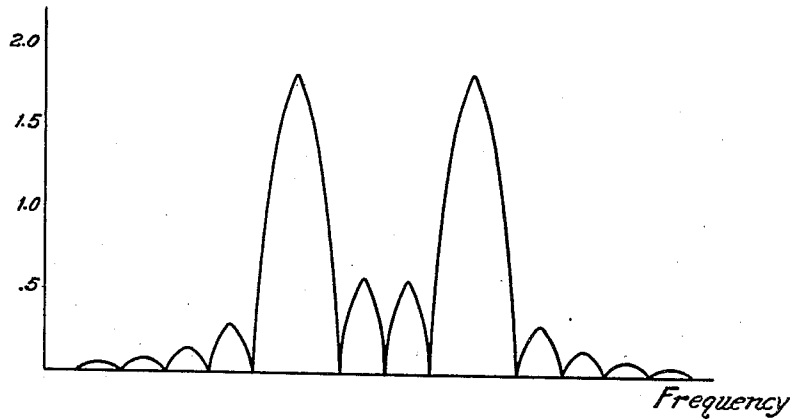


Fig. 3A.

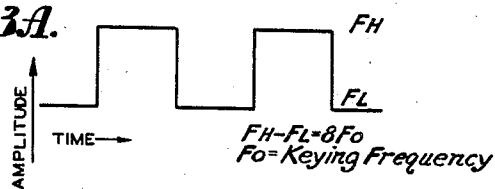


Fig. 4.

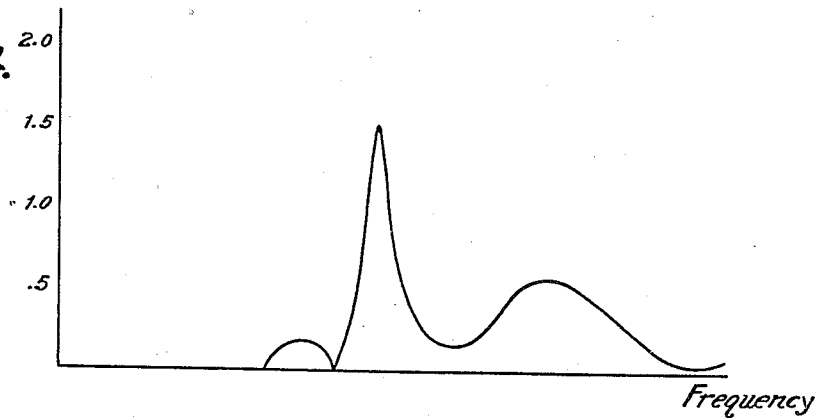
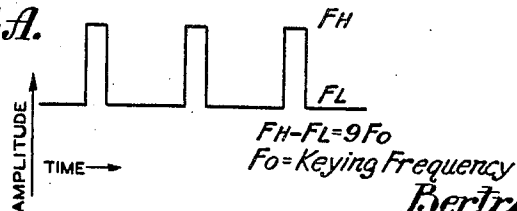


Fig. 4A.



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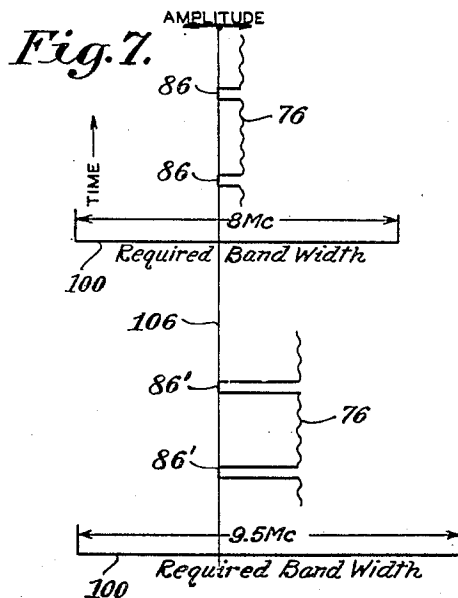
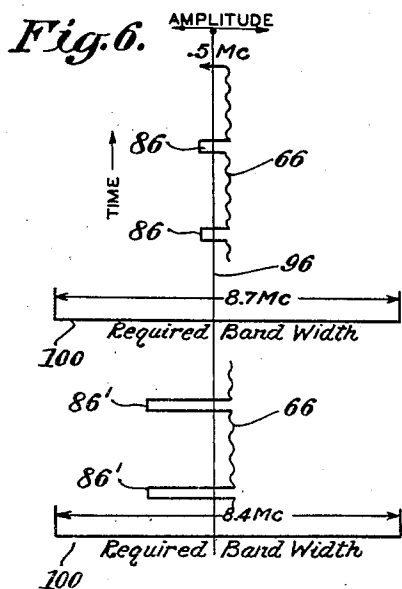
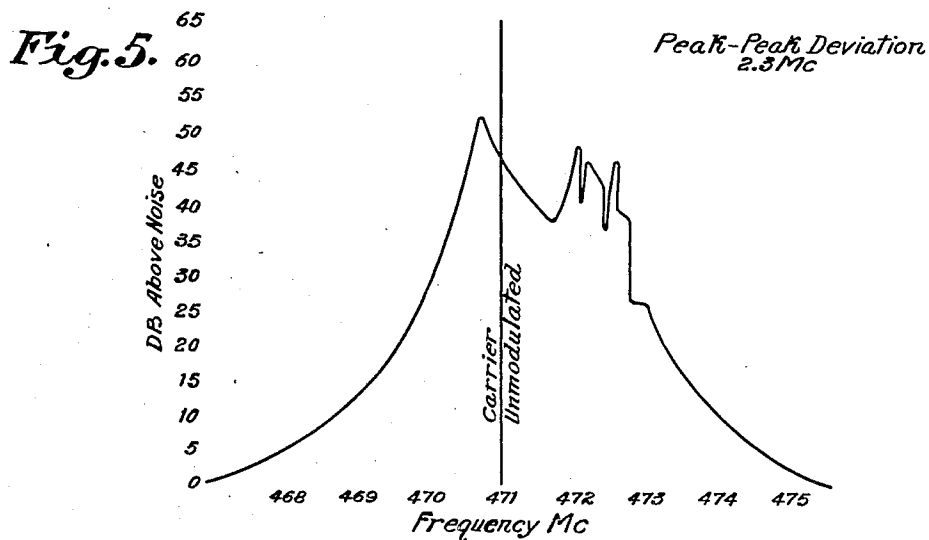
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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,304,969

MULTIPLEX SYSTEM

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Application July 31, 1940, Serial No. 348,779

6 Claims. (Cl. 250—9)

The present invention relates to a multiplex communication system and, more particularly, to a multiplex radio relay system for television programs.

An object of the present invention is to provide a radio relay system for transmitting on a single main carrier a plurality of separate and independent communications.

A further object is the provision of a radio relay system for transmitting video and audio signals of a television program simultaneously on the same carrier frequency.

Still a further object is the provision of a system, as aforesaid, in which the separate signals modulate the instantaneous frequency or wavelength of the carrier.

Still a further object is the provision of a system, as aforesaid, in which the audio signals are used to modulate the instantaneous frequency or wavelength of a sub-carrier and the sub-carrier used to modulate the wavelength of the main carrier simultaneously with the modulation by the video signals.

Another object is the provision of a system, as aforesaid, in which a side band of the main carrier is at least partially suppressed.

Still another object is the provision of a radio relay system which is economical in its frequency spectrum requirements.

The foregoing objects, and others which may appear from the following description, are obtained in accordance with the present invention by modulating the instantaneous frequency or the wavelength of a sub-carrier which may, for example, be of the order of 3 megacycles with the audio portion of a television program and then simultaneously modulating the instantaneous frequency or the wavelength of the main carrier which may be an ultra high frequency wave of the order of 400 or 500 megacycles by the video portion of the television program and the sub-carrier.

The doubly modulated main carrier is then transmitted over a chain of relay stations to desired locations where the modulations are extracted and may be used to modulate a broadcast carrier for radiation in the customary manner and/or they may be used to actuate a "Kinescope" and loudspeaker as in a conventional television receiver.

Throughout this specification and the appended claims, wherever a reference is made to a modulation of the instantaneous frequency or the wavelength of a carrier wave, it is to be distinctly understood that the terms are intended to be

generic to frequency modulation and phase modulation of the carrier by an intelligence bearing signal wave.

The following detailed description is accompanied by drawings in which Figure 1 represents a transmitter at a point of origin of a relay system, Figure 2 represents the terminal receiver of the relay system, while Figures 3 to 7 are curves illustrating features of the invention.

In Figure 1, reference character 10 indicates a television receiver which is used for pick-up of television signals as broadcast from a conventional television broadcast system. Obviously, of course, if desired, the television receiver 10 could be substituted by the output lines from a television studio since the only requirement here involved is that separate video and audio signals be obtained from some source. The audio signals from the television receiver 10 are transmitted by way of conductor 12 to a frequency modulated oscillator 13. In the example shown, the oscillator generates a 3 megacycle wave which may be modulated over a frequency swing of 100 kilocycles. The amplitude of the audio wave is adjusted to a suitable value by a volume control 14. The frequency modulated 3 megacycle wave from oscillator 13 has its amplitude controlled by volume control 15 in transmission channel 16.

Similarly, the video signals appearing in channel 17 are applied through conductor 19 to a low pass filter 20. The low pass filter removes any frequency components above 2.5 megacycles to avoid interference with the 3 megacycle frequency modulated wave from oscillator 13. For monitor purposes a "Monoscope" 9 may be switched on to conductor 19 instead of the video signals appearing in channel 17. A "Monoscope" is an "Iconoscope" having a fixed pattern plate substituted for the photo-sensitive plate so that a picture signal of constant and predetermined characteristics may be obtained for that purpose. From the low pass filter 20 the video signals from 17 or 9 are combined with the 3 megacycle wave from oscillator 13 and applied through a volume control 21 to a video amplifier 22. Video amplifier 22 amplifies with substantial uniformity a band of frequencies from 20 cycles to 5 megacycles.

In the transmitter proper, generally denoted by reference character 23, is a master oscillator 24 which, in the example shown, generates a frequency of 52.33 megacycles. A tuning control is provided for this oscillator so that the oscil-

lator frequency may be changed over a small range as desired.

In the frequency modulator 26 the 52.33 megacycle wave from oscillator 24 is modulated by the amplified signals from amplifier 22 in order to obtain a frequency modulated wave having a mean frequency of 52.33 megacycles. The frequency modulator is of the reactance tube type more fully described in an M. G. Crosby application entitled Frequency modulator #136,578, filed April 13, 1937, to which reference may be had for a more complete description. The modulator is not more completely described here since it forms no part of the present invention. The frequency modulated 52.33 megacycle wave is then applied to a chain of frequency triplers and amplifiers 27 and 28, thus obtaining at the output of the chain a 471 megacycle frequency modulated main carrier which is applied to a radiating system 30.

If the transmitter shown in Figure 1 forms a part of a radio relay system the radiating system 30 will preferably be a highly directional antenna directed toward the next station of the relay chain. If desired, a broadcast antenna could be used to radiate the signals with substantially uniform intensity in all directions. Also connected to the output of the transmitter is a frequency modulation monitor 31 for demodulating the 471 megacycle carrier to obtain a signal similar to the original signal in the output of amplifier 22 and which may include frequencies within a band covering 20 cycles to 5 megacycles. The output of monitor 31 is applied to a second frequency modulation detector 33 tuned to 3 megacycles. The output of this detector is applied to a loudspeaker 34 for monitoring the audio signals. Simultaneously, through a low pass filter 35 which does not admit any of the 3 megacycle waves utilized by detector 33, the remainder of the output of the monitor 31 is applied to a monitor "Kinescope" 36. The quality of the transmitted picture may thus be observed.

At the far end of the relay chain is established a receiving system such as shown in Figure 2. The frequency modulated wave from the final intermediate relay station is picked up by a directional antenna 40 and applied to a first converter 41. Since, in the example being described, it is considered that there is at least one intervening relay station, the received signal is shown as having a mean frequency of 460 megacycles indicating at least one change in the carrier frequency had been encountered in the relay change. In some cases the received carrier may have the same frequency as that radiated from antenna 30. The converter 41 is supplied with a 360 megacycle wave from oscillator 42. The resultant 100 megacycle output is then applied to a first intermediate frequency amplifier 43. The frequency is again changed in converter 44 by being heterodyned with oscillator 45 operating at 129 megacycles. A 29 megacycle second intermediate frequency is thus obtained which is amplified in a second intermediate frequency amplifier 46. The amplifier 46 is so designed that in normal operation it is overloaded, thus obtaining amplitude limiting of the signals passed therethrough. The output of the second intermediate frequency amplifier 46 is applied to a pair of frequency discriminators and diodes 47 and 47'. These discriminators may be of the type described in Seeley Patent #2,121,103, granted June 21, 1938, or in Crosby Patent #2,154,398, granted April 11, 1939. The output of frequency discriminator 47 is applied through a video amplifier 48 and a

low pass filter 49, which passes none of the 3 megacycle frequency modulated waves, to a receiving Kinescope 50 where the transmitted picture is reproduced. Also, a 3 megacycle frequency modulation receiver 51 is connected to the output of the video amplifier 48. The output of the receiver 51 is reproduced in loudspeaker 52 thus reproducing the transmitted audio frequency program. The band width of the receiver 51 preferably should be of the order of 200 kilocycles since the original 3 megacycle frequency modulated wave was modulated over a 200 kilocycle total swing.

The output of the frequency discriminator 47' is applied to an automatic frequency control unit 60 controlling motor 61 which is connected to a variable tuning control for oscillator 42. The receiving system, as a whole, is thus kept accurately tuned to the mean frequency received on antenna 40.

Before discussing the overall performance of the relay and the various tests conducted, it will be helpful to consider briefly the nature of a television signal and, particularly, to compare frequency modulation with amplitude modulation for this type of modulating signal. Normally, amplitude modulation is studied in one of three forms; namely, the modulation envelope, the sideband configuration or the vector method of representation. For our purpose, the first two forms will be sufficient.

With amplitude modulation, it is well known that the sidebands are symmetrical about the carrier both as to amplitude and phase no matter how unsymmetrical the positive and negative polarities of the modulating wave may be. It is a curious fact that the first tendency of a student, during his early amplitude-modulation studies, is to associate one sideband with one polarity of the modulating wave. While this tendency is definitely incorrect when applied to amplitude modulation it is not so far wrong when the sideband distribution of a frequency modulated wave is considered. Actually, the amplitude of the sideband components are symmetrical about the carrier in frequency modulation only when the polarities of the modulating wave have symmetrical wave shapes. The phases of the sidebands, on the other hand, are never symmetrical about the carrier. This statement is correct even if we include the very special case of sine-wave modulation with a small modulating index, since the even-order components having a 180-degree phase difference still exist although they are usually disregarded due to their small amplitudes.

To illustrate this more clearly, consider Figure 3 which disregards the phase reversals of the even-order sideband components. It will be seen that the amplitudes of the components are symmetrical for the 50—50 square-wave envelope shown in Figure 3a. The sidebands are calculated on the basis that the peak-to-peak frequency deviation $H_F - F_L$ is eight times the keying rate F_0 . A higher value of this ratio would merely move the peak sideband maxima farther apart without destroying symmetry. It will be understood that, theoretically, the sidebands extend from zero to infinity since it has been assumed that the modulating wave produces an instantaneous frequency change in the modulated wave. Now observe Figure 4 where the modulating wave is a 20—80 dot. The wave is shown in Figure 4a. The sideband configuration shows a very pronounced component amplitude

corresponding to the frequency of longest duration of the instantaneous carrier. Further, there is no sideband symmetry about any frequency. In fact, the sidebands are about as unsymmetrical as the polarities of the modulating envelope.

It will be understood that the present discussion is not an attempt to cover the theory of frequency modulation completely. The intention has been to show some fundamental concepts that were instrumental in determining the type of tests to be conducted. Heuristically, we may reason from the two examples above, that the blanking and synchronizing pulses of a video modulating signal will give sideband dissymmetry. However, the higher frequency components of the video signal, considered as small amplitude sine waves, would tend to submerge this result. Figure 5 showing the measured sidebands of the "Monoscope" composite signal indicates that no great amount of dissymmetry is obtained for a complete picture signal.

In a test of the complete system as just described, the following results were obtained. Using a 3 megacycle sub-carrier frequency modulated with the television sound over a deviation of approximately 70 kilocycles the 470 megacycle main carrier was modulated with deviation of about $\frac{1}{2}$ megacycle by the 3 megacycle sub-carrier. At the same time the video modulation on the 470 megacycle main carrier produced a deviation of about 1 megacycle. At the receiving station a video signal of .31 volt was obtained with a White "Monoscope" picture and the video noise level was about .028 volt, with the sound sub-carrier modulation applied. The video signal-to-noise ratio was therefore 21 db. The sound signal itself produced from full deviation of the 3 megacycle carrier a voltage of 1.6. The sound channel noise level was .072 volt with the video signal on and .018 volt with the video signal off. The sound signal-to-noise ratio was thus 27 db. with the video on and 39 db. with the video off.

Because of the low pass filters used in the system the sound sub-carrier caused no interference in the video channel. The test also showed that the maximum peak-to-peak deviation, or swing, useable for a White "Monoscope" picture transmission in the system as tested was 2.3 megacycles. Modulator overloading began to appear with higher values of swing.

A distinction should be made between A. C. transmission and D. C. transmission of the video signal as applied to a frequency-modulated system. Since the standard video composite signal inherently contains all necessary information as to the picture background level (by maintaining a fixed-peak amplitude and fixed super sync-amplitude), the D. C. component may be restored in the video circuits at the receiving terminal. Insofar as the relay is concerned, the signal to be transmitted may be considered as an A. C. wave only and is shown in Figure 6 as wave 66 having supersync peaks 86 for a black picture and 86' for a white picture. If this is done the radio frequency carrier component indicated by line 96 will not be shifted when modulation is applied. On the other hand, if the D. C. component is transmitted over the relay as in Figure 7, the radio frequency carrier component will vary with the picture background and the frequencies corresponding to the supersync pulses as indicated by line 106 will remain unchanged. Comparison of Figures 6 and 7 indicates the range of radio frequency or I. F. frequency de-

viation with respect to the pass band for the required band width is indicated by the dimension lines 100 across each of the figures.

The previously described system was also operated with a partial suppression of one side band by the following adjustment of the two intermediate frequency amplifiers 43 and 46, shown in Figure 2. The signal carrier was placed at one edge of the band pass characteristic of the 100 megacycle I. F. amplifier 43 and at mid-band in the 29 megacycle amplifier. With the receiver tuned as just described, the discriminator diodes operated under balanced conditions and a satisfactory picture was observed over a total carrier shift of 4 megacycles.

In the system described consisting of a terminal transmitter, a relay station, and a terminal receiver, the band pass circuits at each station are all aligned to give a band pass characteristic to the whole system. Due to the larger number of cascaded band pass circuits a very rapid attenuation occurs at the extremities of the band of frequencies passed. Another test was conducted to make use of this characteristic to partially suppress one set of the signal side bands. This was done by changing, in small steps, the tuning of the oscillator 24 in the terminal transmitter to bring the carrier frequency toward one edge of the band pass characteristic of the system as a whole, including the intermediate relay station amplifiers. In order to maintain balanced operation of the discriminator diodes in the terminal receiver the oscillator 45, Figure 2, was, at each change, retuned to bring the 29 megacycles carrier at midband in the final amplifiers of this receiver.

This shifting of the carrier to the edge of the passed band was permissible since the D. C. component of the "Monoscope" signal is constant. At each point the video-signal polarity was reversed to compare the transmissions for two extremes of background level. In effect, this test also simulated partial sideband transmission as the carrier approached the edge of the pass band. It was observed that the fidelity of transmission remains unchanged until definite sideband clipping of the synchronizing pulses results in poor synchronization. With the carrier shifted toward the edge opposite to the excursions of the supersync pulses, it was found that a somewhat larger peak-to-peak frequency deviation could be employed, or with the same deviation a narrower band pass may be used in the amplifiers of the system than would be required with transmission using both side bands.

While I have shown and particularly described several embodiments of my invention, it is to be distinctly understood that my invention is not limited thereto but that further modifications within the scope of my invention may be made.

I claim:

1. A communication system comprising a main carrier source, a sub-carrier source, means for modulating the instantaneous frequency of said sub-carrier from a first source of signals, means for modulating the instantaneous frequency of said main carrier by said sub-carrier, means for simultaneously modulating the instantaneous frequency of said main carrier from a second source of signals, said signals being unsymmetrical about an axis representing zero amplitude whereby the modulated frequency spectrum is unsymmetrical about the unmodulated frequency of said main carrier, means for radiating said modulated main carrier, means for receiving said

carrier, means for at least partially removing one side band of said modulated main carrier, means for obtaining a wave representative of the modulations of said carrier, means for separating from said wave the components thereof representative of said second signal and means for obtaining from the remainder of said wave a wave representative of said first signal.

2. A method of multiplex communication comprising the steps of modulating the instantaneous frequency of a sub-carrier by one signal, modulating the instantaneous frequency of a main carrier by said sub-carrier, modulating the instantaneous frequency of said main carrier by another signal, said other signal being unsymmetrical about an axis representing zero amplitude whereby the modulated frequency spectrum occupied by said main carrier is unsymmetrical about the frequency of the unmodulated main carrier, removing at least partially one side band of said main carrier, radiating said modulated main carrier at one location, receiving said main carrier at another location, deriving a wave representative of the modulations on said main carrier, separating from said wave the components thereof representative of said other signal and obtaining from the remainder of said wave a wave representative of said one signal.

3. A method of communication which comprises modulating the instantaneous frequency of a carrier by a signal wave which is unsymmetrical about a zero axis to obtain a spectrum of frequencies which is unsymmetrical about the unmodulated frequency of said carrier, filtering said spectrum of frequencies to remove at least a portion thereof at one side of the unmodulated frequency of said carrier, radiating said carrier, receiving said carrier, and deriving from said received carrier a wave representative of said signal wave.

4. A method of transmitting intelligence by a wave representative of said intelligence, said wave being unsymmetrical due to peaked impulses therein being in the same direction comprising the steps of modulating the instantaneous

frequency of a carrier of said wave, the distribution of the spectrum of frequencies due to said modulation being unsymmetrical about the frequency of said unmodulated carrier and discriminating against frequencies outside of a band of frequencies narrower than the extreme limits of said spectrum, the frequency of said unmodulated carrier being placed off the center of said band.

5. A method of transmitting intelligence by a wave representative of said intelligence, said wave being unsymmetrical due to peaked impulses therein being in the same direction comprising the steps of modulating the instantaneous frequency of a carrier of said wave, the distribution of the spectrum of frequencies due to said modulation being unsymmetrical about the frequency of said unmodulated carrier and discriminating against frequencies outside of a band of frequencies narrower than the extreme limits of said spectrum, the frequency of said unmodulated carrier being placed off the center of said band in a direction such that the peaked impulses of said wave are not distorted by said discrimination.

6. A method of television transmission comprising the steps of modulating the instantaneous frequency of a sub-carrier by a signal representative of the audio portion of a television program, modulating the instantaneous frequency of a main carrier by said sub-carrier, modulating the instantaneous frequency of said main carrier by another signal representative of the video portion of said television program, said other signal being unsymmetrical about an axis representing zero amplitude whereby the modulated frequency spectrum occupied by said main carrier is unsymmetrical about the frequency of the unmodulated main carrier and removing at least partially one side band of said main carrier, said video signal and said modulated sub-carrier occupying adjacent non-overlapping portions of the frequency spectrum.

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