June 3, 1947. L. E. THOMPSON 2,421,727

MULTIPLEX SYSTEM HAVING CHANNELS ADDED AT A RELAY STATION

Filed April 9, 1945 2 Sheets-Sheet 1

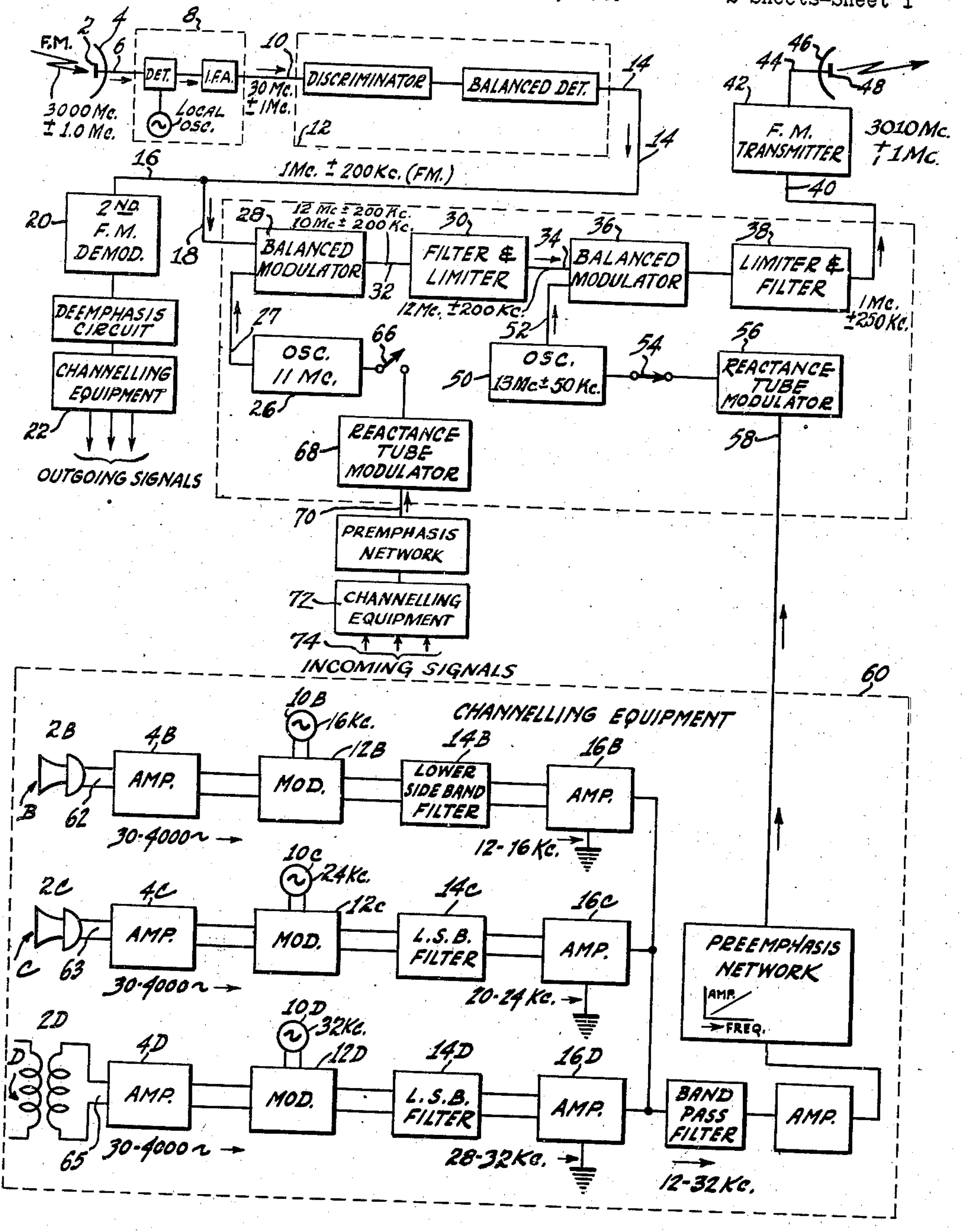

Fig. 1.

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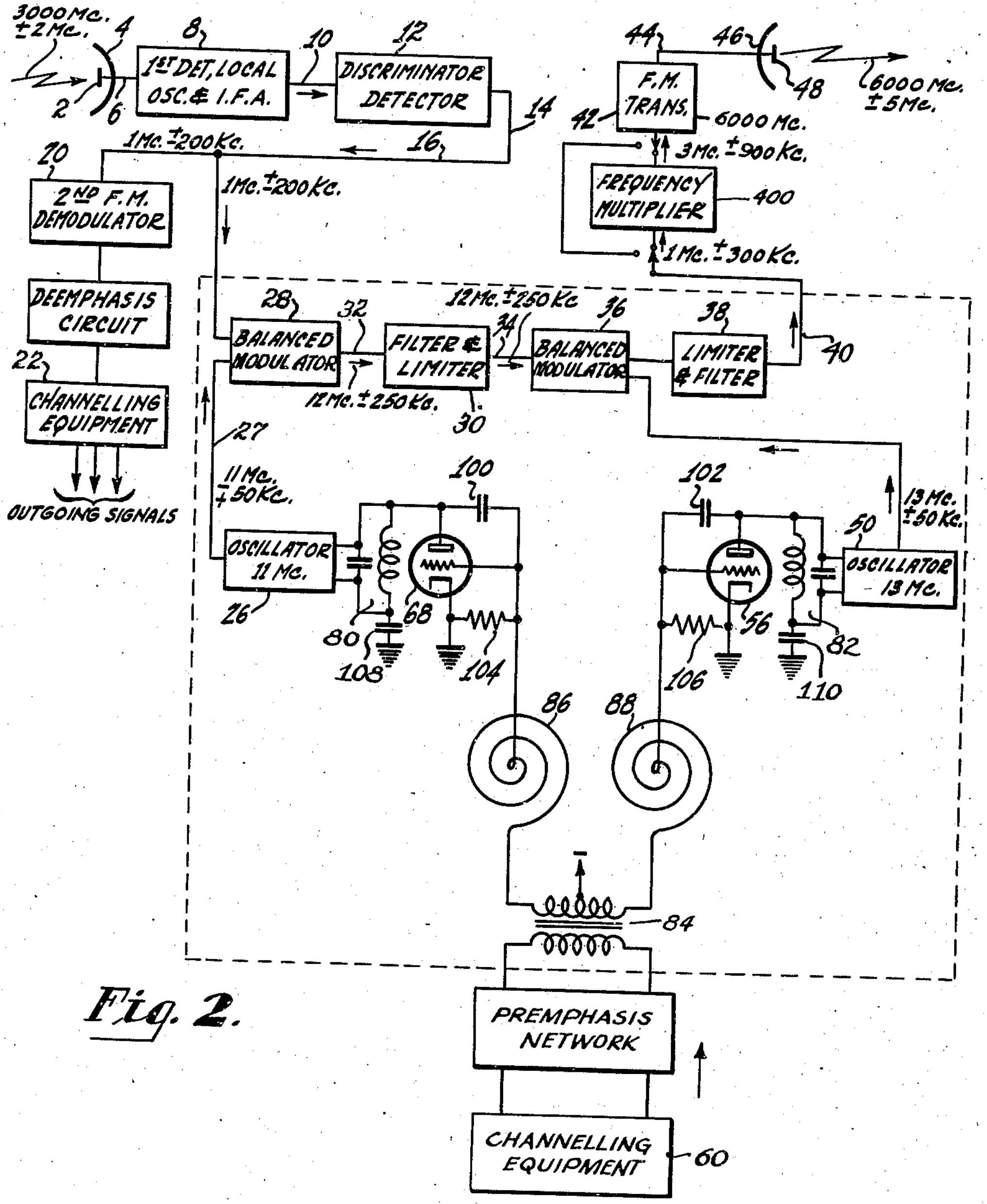

Fig. 2.

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MULTIPLEX SYSTEM HAVING CHANNELS ADDED AT A RELAY STATION

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Application April 9, 1945, Serial No. 587,250

20 Claims. (Cl. 179—15)

My present invention relates to a multi-channel radio relaying system such as described in my co-pending application Serial Number 576,453, filed February 6, 1945.

As described in my co-pending application, several different signaling channels are used to independently amplitude modulate separate, relatively low frequency, sub-sub carriers. The lower side bands of the modulated sub-sub carriers are filtered out, amplified, combined and used to angle, or more specifically, frequency modulate a common sub-carrier wave having a mean frequency of, for example, one megacycle. By way of example, also, six different channels may be used to produce a maximum frequency swing of approximately plus and minus 200 kilocycles in the common, frequency modulated sub-carrier. The frequency modulated sub-carrier, having a mean frequency of one megacycle and a maximum frequency swing of plus and minus 200 kilocycles, is used to frequency or angle modulate the radiated carrier. The latter may have a mean frequency of, for example, 3000 megacycles. The 3000 megacycle radiated carrier may be swung or frequency modulated a maximum amount of, for example, plus and minus one megacycle by the frequency modulated sub-carrier.

The 3000 megacycle carrier is directively radiated to a distant relaying point for retransmission to a receiving terminal or to still another relaying point. The frequency of retransmission takes place at a frequency different than that received such as, for example, 3010 megacycles.

To effect this frequency transformation at a relaying point or station, the received high frequency carrier having an unmodulated frequency of, say, 3000 megacycles, is heterodyned down to some convenient intermediate frequency such as 30 megacycles. The latter is amplified, limited and subjected to a frequency demodulation, i. e., to discriminator-detector action, in order to reproduce the common frequency modulated sub-carrier. This frequency modulated sub-carrier is further limited and amplified and then used to frequency modulate a new, locally generated, carrier having a frequency of, for example, 3010 megacycles. The new carrier is directively radiated on to the next point in the relay system.

In such a multi-channel radio relay system, it is desirable, in some cases, to tap in at a relay station in order to add one or more signaling channels for transmittal, along with the channels already present, on to the next point in the system. One way of accomplishing this is to subject the common frequency modulated sub-carrier to a second frequency demodulation process so as to reproduce the combined single side band channels originally transmitted. The new channel or intelligence band may then be combined with the output of the second demodulator and the paralleled channels may be used to frequency modulate a newly generated, common sub-carrier and the latter may be employed to frequency modulate a newly generated radio frequency carrier. This method is objectionable, for unless elaborate and costly equipment in used to increase linearity of the second frequency demodulator and immediately following modulators, an undesirable amount of cross modulation will be introduced, especially in the event that the process is repeated at a number of repeater or relaying stations.

It is, therefore, an object of my present invention to provide an improved method and improved arrangement of instrumentalities for adding one or more intelligence channels to a "through" wave at a high frequency relay or repeater station without introducing objectionable distortion or cross modulation.

A further object of my present invention is to provide simplified equipment at relaying points enabling the addition of one or more channels to "through" waves already carrying one or more intelligence frequency bands.

In accordance with one form of my present invention wherein one or more intelligence bands or signals are added at a high frequency relaying station, such as described in my co-pending application Serial Number 576,453, filed February 6, 1945, a multiply modulated wave is subjected, at the relaying station, to a single demodulation. Waves derived from the demodulation are then heterodyned with an oscillation which has been modulated with one or more signals which are to be added at the relaying point. Waves derived from the heterodyning process are then employed to modulate a locally generated high frequency carrier which is to be transmitted on to the next point in the system.

My present invention will be described more specifically with the aid of the accompanying drawing wherein Fig. 1 illustrates a radio relaying station for relaying a doubly frequency modulated wave and wherein one or more signaling channels may be added at the relaying station with a minimum of distortion and cross talk, and Fig. 2 is a block diagram of a modified form of a relaying station such as shown in Fig. 1.

Fig. 1 is a radio relaying station especially adapted for relaying a multi-channel doubly frequency modulated wave such as emitted by the transmitting station of Fig. 1 of my co-pending application Serial Number 576,453, filed February 6, 1945. It differs over the relaying system shown in Fig. 2 of that application in that Fig. 1 herein describes an arrangement in which one or more signaling channels may be added at the relaying point with a minimum of cross modulation and distortion.

As shown in Fig. 1 herein a wave such as transmitted by the transmitter of my co-pending application or as transmitted by the transmitting antenna of any one of the relaying stations of my co-pending application, is received upon antenna **2** provided with a parabolic reflector **4** in order to enhance directive reception. The received waves, which may have a mean frequency of 3000 megacycles, are fed through line **6** to apparatus **8** which may include a local oscillator, a first detector, an intermediate frequency amplifier and a limiter. Apparatus **8** corresponds to converter **202**, beating oscillator **204** and intermediate frequency amplifier **206** of my co-pending application. The heterodyned output of apparatus **8** may be, for example, an intermediate frequency wave having a mean frequency of 30 megacycles and a deviation of plus and minus one megacycle.

This wave output is fed through line **10** to a first frequency demodulator or discriminator-detector **12** corresponding to **208** of Fig. 2 of my co-pending application. The output of apparatus **12** may be a wave having a mean frequency of one megacycle and frequency modulated or swung plus and minus 200 kilocycles by the signaling channels when all of them are instantaneously of such phase as to produce additive frequency modulations in the common one megacycle sub-carrier appearing in line **14**.

Part of the output of the first demodulator **12** appearing in line **14** is fed through line **16** to a second demodulator **20** and then to channeling equipment or filters **22** for reproducing one or more of the original signaling currents. The second demodulator **20** corresponds to the second discriminator-detector **312** of Fig. 3 of my co-pending application and the channeling equipment **22** corresponds to and includes one or more of the filters **56**—**64** and their corresponding converters **66**—**74**, oscillators **67**—**75** and filters **76** to **84** of Fig. 3 of my co-pending application.

Another portion of the output of the first demodulator **12** is fed through lines **14** and **18** to a balanced mixer or detector **28**. Waves derived from a local oscillator **26** operating at, for example, **11** megacycles are also fed through line **27** to the balanced mixer **28**. The sum frequency output of mixer **28** appearing in line **32** is passed by filter and limiter **30** and appears in line **34** as a wave having a mean frequency of 12 megacycles and having all of the frequency modulation characteristics of the original one megacycle frequency modulated wave appearing in line **14**.

The 12 megacycle wave having, for example, a maximum swing of plus and minus 200 kilocycles and appearing in line **34** is fed into a second balanced mixer or detector **36** along with oscillations derived from a second local oscillator **50** which may be operating, for example, at a frequency of 13 megacycles per second.

Switched to oscillator **50** by means of switch **54** is a reactance tube modulator **56** fed with one or more signaling channels from channeling equipment **60** and line **58**. Thus three separate voice signals may be fed to the channeling equipment **60** through lines **62**, **63** and **65**. This channeling equipment may correspond, for example, to the channeling equipment associated with channels B, C and D of Fig. 1 of my co-pending application, provided these channels are not used on the incoming sub-carrier in line **14**. In other words, the input in **62**, **63** and **65** separately modulate local oscillators such as **10B**, **10C**, and **10D** of Fig. 1 of my co-pending application operating at different frequencies. Side bands of the resulting modulation are filtered off by filters such as **14B**, **14C** and **14D** of said Fig. 1 and combined and fed into line **58** of Fig. 1 herein. Obviously, of course, one of the channels such as **62** of Fig. 1 may be fed through directly to the reactance tube modulator **56** as was done in channel A of Fig. 1 of my co-pending application, providing this channel is not already in use on the incoming sub-carrier in line **14**.

As a result, the output of oscillator **50** is frequency modulated by the output of the channel equipment **60** and the frequency modulated wave which appears in line **52** is combined with the frequency modulated wave appearing in line **34** in the mixer or detector **36**. Of the resulting waves filter **38** may be designed so as to pass the difference frequency and, assuming a maximum frequency deviation of 50 kilocycles imparted to oscillator **50** by the signals in line **58**, the output of **38**, which may, of course, include a vacuum tube limiter if desired, will be a wave having a mean frequency of one megacycle and a maximum frequency swing or frequency modulation of plus and minus 250 kilocycles. The latter will truly represent all of the signaling channels appearing in line **14** and also the additional channels injected by line **58** carrying signal channels on bands derived from channeling equipment **60**.

The output of filter and limiter **38** is then fed through line **40** to a transmitter **42** corresponding in design and construction to the frequency modulated oscillator **212** of Fig. 2 of my co-pending application. Transmitter **42** may thus, for example, be operated at a mean frequency of 3010 megacycles and the input fed through line **40** adjusted so as to produce a maximum deviation of plus and minus one megacycle in the wave radiated by radiating antenna **48**. The construction of re-radiating antenna **48** and its reflector **46** together with connecting transmission line **44** may be identical to that shown in Fig. 10 of my co-pending application.

If desired, of course, switch **54** may be opened and channeling equipment **72** corresponding to channeling equipment **60** may be used to frequency modulate the first beating oscillator **26**. In that event switch **66** would be closed, a suitable number of inputs would be provided at **74** and the combined channels in line **70** would be used to operate a reactance tube modulator **68**. Also if desired both switches **66** and **54** may be closed, one or more signals may be impressed upon oscillator **26** and one or more signals concurrently may be impressed upon oscillator **50**.

As shown in Fig. 2 the same resultant modulating voltage may be used to simultaneously frequency modulate both oscillators **26** and **50**. In this case, however, the phase of the resultant voltage applied to the reactance tube modulators **68** and **56** must be opposite so that the total frequency swing of the oscillators is the sum of frequency swings imparted to them.

More specifically, as shown in Fig. 2, oscillator **26** is provided with a frequency controlling parallel tuned circuit **80** and oscillator **50** is provided with a parallel tuned frequency controlling circuit **82**. The output of channeling equipment **60**, through the action of transformer **84** applies the resultant modulating potentials oppositely to the control grids of the reactance tubes **56** and **68** through chokes **86** and **88**. The valves of frequency swing and mean frequency shown on Fig. 2 are illustrative only and are not to be considered in any way as restrictive of the present invention.

As in connection with Fig. 1 rectangle **38** may not only represent a filter network but also a vacuum tube limiter. This is also true of the apparatus represented by rectangle **30**.

It should accordingly be clear that whatever frequency modulation exists in line **14** of either Fig. 1 or Fig. 2 is also completely present in line **40**. In addition, as before explained, line **40** also contains the modulation due to the channels which are locally introduced through equipment **60** provided at the relaying point. Since the modulation appearing in line **14** is not subjected to complete demodulation so as to reproduce the ultimate or elemental signals, cross talk due to unlinearity of discriminators and modulators is not added to the "straight through" channels—that is, those received upon the receiving antenna system **2**, **4** and retransmitted over the retransmitting antenna arrangement **46**, **48**—even though several channels are added to the "through wave" at the relaying point as explained.

My invention is not, of course, restricted to a doubly modulated system such as referred to. For example, the addition of channels to a relay system employing single frequency modulation may be accomplished in a similar way. Thus, for example, assume that the received wave has a mean frequency of 3000 megacycles and has been directly frequency modulated with an audio channel covering a band of frequencies from 16 cycles to 16,000 cycles and so that the maximum deviation in the received 3000 megacycle wave is plus and minus 2.5 megacycles. This wave is received at the relaying point and beat in apparatus **8** to an intermediate frequency of, for example, 30 megacycles ±2.5 megacycles. This 30 megacycle wave may then be beat to a low frequency by oscillator **26** such as, for example, 15 megacycles and then beat back up to a higher frequency such as to 60 megacycles with the second oscillator **50**. In this case either or both oscillators as explained in connection with Figs. 1 and 2 may be frequency modulated with one or more new and different signals introduced at the relaying point.

A frequency multiplier **400** may be inserted in line **40** before transmitter **42** and following filter and limiter **38**. The effect of this multiplier will be to increase the mean frequency of common sub-carrier and also its frequency deviation by the multiplying factor, prior to use for modulation in the frequency modulated oscillator **42**.

The balanced mixers **28** and **36** of Figs. 1 and 2 are preferably of the type shown in Fig. 9 of my co-pending application involving the mixer tubes **904**, **906**, oscillator tube **908** and their associated circuits.

The reactance tubes **56**, **68** may, of course, be four element screen grid tubes or they may be pentode tubes. Condensers **100**, **102** are shown as connected between the plates and control grids and they should, therefore, have relatively high reactance at the operating frequencies of oscillators **26** and **50** respectively. Resistors **104**, **106** are of relatively low value. In this way effective quadrature voltage derived from the tuned circuits **80**, **82** is impressed across the control grids and cathodes of tubes **68**, **56**.

These tubes as connected in Fig. 2 will present a variable capacitive reactance in shunt to the tuned circuits **80**, **82** which may effectively be grounded at their lower terminals for high frequency currents by large bypassing condensers **108**, **110**.

The positions of condensers **100**, **102** and resistors **104**, **106** may be reversed, in which case the resistors should be blocked off from the plates by series connected bypassing condensers of large value so as to prevent the plate voltage from being applied to the grids while allowing A. C. components to reach the grids. Also, in this case the resistors should be large in value and the condensers **100**, **102** when connected between the grids and filaments should be of large capacity or relatively low capacitive reactance. With the latter connections, tubes **66**, **68** then act as variable inductances in shunt to the tuned circuits **80**, **82**.

Having thus described my invention, what I claim is:

1. The method which includes receiving a multiply modulated wave, subjecting the wave to a single demodulation, heterodyning waves derived from the demodulated wave with signal modulated oscillations, filtering waves resulting from the heterodyning process, and transmitting the filtered waves.

2. The method of wave conversion which includes subjecting a doubly frequency modulated wave to a single frequency demodulation, heterodyning waves derived from the demodulated wave with frequency modulated oscillations, and transmitting waves resulting from the heterodyning process.

3. The method which includes subjecting a successively angle modulated wave to an angle demodulation process, heterodyning waves derived from the demodulation with an angle modulated oscillation, and transmitting waves derived from the heterodyning process.

4. The method of adding signal channels to a signal carrying, successively angle modulated wave which includes subjecting the wave to an angle demodulation, generating waves, angle modulating the generated waves with waves representing one or more signal channels, heterodyning waves derived from the demodulation with said waves which have been angle modulated with one or more signal channels which are to be added, and transmitting waves resulting from the heterodyning process.

5. The method of relaying a signal carrying, doubly modulated wave and adding one or more signal channels to the wave to be relayed which includes subjecting the doubly modulated wave to a single demodulation, heterodyning waves derived from the demodulation with a wave which has been modulated with one or more signaling channels to be added, filtering the heterodyned waves, generating a high frequency carrier, and modulating the high frequency carrier with the filtered waves.

6. The method of relaying a signal carrying, doubly angle modulated wave and adding one or more signal channels to the wave to be relayed which includes subjecting the doubly angle modulated wave to a single angle demodulation, heterodyning the waves derived from the angle demodulation with a wave which has been angle modulated with one or more signaling channels to be

added, filtering the heterodyned waves, generating a high frequency carrier, and angle modulating the high frequency carrier with the filtered waves.

7. The method of relaying a signal carrying, doubly frequency modulated wave and adding one or more signal channels to the wave to be relayed which includes subjecting the doubly frequency modulated wave to a single frequency demodulation, heterodyning the waves derived from the frequency demodulation with a wave which has been frequency modulated with one or more signaling channels to be added, filtering the heterodyned waves, generating a high frequency carrier, and frequency modulating the high frequency carrier with the filtered waves.

8. The method of relaying which includes receiving a signal carrying, doubly frequency modulated wave, subjecting the received wave to a single frequency demodulation, heterodyning the demodulated wave to an intermediate frequency, filtering the intermediate frequency wave, heterodyning the filtered wave with an oscillation which has been frequency modulated with bands of frequencies representing one or more signal channels, generating a high frequency carrier, and frequency modulating the high frequency carrier with waves derived from the last-mentioned heterodyning process.

9. The method of relaying which includes receiving a signal carrying, doubly frequency modulated wave; subjecting the received wave to a single frequency demodulation, heterodyning waves derived from the demodulation with an oscillation which has been frequency modulated with one or more signal channels, filtering out a band of waves from the band of heterodyned waves, heterodyning the filtered waves to occupying a different position in the frequency spectrum, generating a high frequency carrier, and frequency modulating the generated carrier with the heterodyned band occupying said different position.

10. The method of relaying which includes receiving a signal carrying, doubly frequency modulated wave; subjecting the received wave to a single frequency demodulation, successively heterodyning the demodulated waves with two locally generated oscillations, oppositely frequency modulating the locally generated oscillations with bands of frequencies representing one or more signaling channels, generating a high frequency carrier, and frequency modulating the high frequency carrier with waves derived from the second heterodyning process.

11. Relaying apparatus comprising means for receiving a signal carrying, doubly frequency modulated wave, a discriminator-detector circuit for subjecting the received waves to a single frequency demodulation, a pair of generators for generating two high frequency oscillations, means for successively heterodyning the demodulated waves with waves from the two generators, circuits for oppositely frequency modulating the two generated oscillations with waves representing one or more signaling channels, means for generating a high frequency carrier, and means for frequency modulating the high frequency carrier with waves derived from the second heterodyning process.

12. Relaying apparatus including means for receiving a signal carrying, doubly frequency modulated wave, a discriminator-detector circuit for subjecting the received wave to a single frequency demodulation, means for heterodyning waves derived from the demodulation with an oscillation which has been frequency modulated with one or more signal channels, a filter for filtering a band of waves from the heterodyned waves, apparatus for heterodyning the filtered band of waves to waves having different mean frequency than said filtered band, a generator for generating a high frequency carrier, and circuits operating to frequency modulate the generated carrier with the heterodyned waves of different mean frequency.

13. Relaying apparatus including means for receiving a signal carrying, doubly frequency modulated wave, a demodulator system for subjecting the received wave to a single frequency demodulation, means for heterodyning the demodulated wave to an intermediate frequency, a filter filtering the intermediate frequency wave, means for heterodyning the filtered wave with an oscillation which has been frequency modulated with waves representing one or more signal channels, means for generating a high frequency carrier, and means for frequency modulating the high frequency carrier with waves derived from the last-mentioned heterodyning process.

14. Means for relaying a signal carrying, doubly frequency modulated wave and adding one or more signal channels to the wave to be relayed which includes means for subjecting the doubly frequency modulated wave to a single frequency demodulation, means for heterodyning the waves derived from the frequency demodulation with a wave which has been frequency modulated with waves representing one or more signaling channels to be added, means for filtering and limiting the heterodyned waves, means for generating a high frequency carrier, and means for frequency modulating the high frequency carrier with the limited and filtered waves.

15. Apparatus for relaying a signal carrying, doubly angle modulated wave and adding one or more signal channels to the wave to be relayed which includes demodulating apparatus operating to subject the doubly angle modulated wave to a single angle demodulation, a mixer for heterodyning the waves derived from the angle demodulation with a wave which has been angle modulated with waves representing one or more signaling channels to be added, a filter filtering the heterodyned waves, an oscillator generating a high frequency carrier, and a modulator for angle modulating the high frequency carrier with the filtered waves.

16. Apparatus for relaying a signal carrying, doubly modulated wave and adding one or more signal channels to the wave to be relayed comprising a demodulator for subjecting the doubly modulated wave to a single demodulation, a mixer for heterodyning the waves derived from the demodulation with a signal modulated wave, a filter for filtering the heterodyned waves, a generator for generating a high frequency carrier, and a circuit for modulating the high frequency carrier with the filtered waves.

17. Apparatus for adding signal channels to a successively angle modulated wave comprising a demodulator for subjecting the wave to an angle demodulation, a mixer for heterodyning waves derived from the demodulation with a wave which has been angle modulated with waves representing one or more signal channels which are to be added, filtering and limiting apparatus to filter and limit the output of said mixer and means for utilizing the filtered and limited waves.

18. In combination, means for subjecting a successively angle modulated wave to an angle demodulation process, means for heterodyning waves derived from the demodulation with an oscillation which has been angle modulated in accordance with the wave output of one or more signal channels, a limiter for limiting the heterodyned waves, and a circuit utilizing waves derived from the heterodyning process.

19. In combination, means for subjecting a doubly frequency modulated wave to a single frequency demodulation, means for heterodyning the demodulated wave with a modulated oscillation, modulated in accordance with waves representing one or more bands of frequencies, and means for utilizing the waves resulting from the heterodyning process.

20. In combination, means for receiving a multiply modulated wave, a demodulator for subjecting the wave to a single demodulation, a mixer for heterodyning the demodulated wave with an oscillation which has been modulated with waves representing one or more bands of frequencies, and a circuit utilizing the wave resulting from the heterodyning process.

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