Aug. 31, 1948. M. SILVER ET AL 2,448,055

WOBBLED FREQUENCY CARRIER WAVE COMMUNICATION SYSTEM

Filed Feb. 21, 1944 5 Sheets-Sheet 1

Fig. 1.

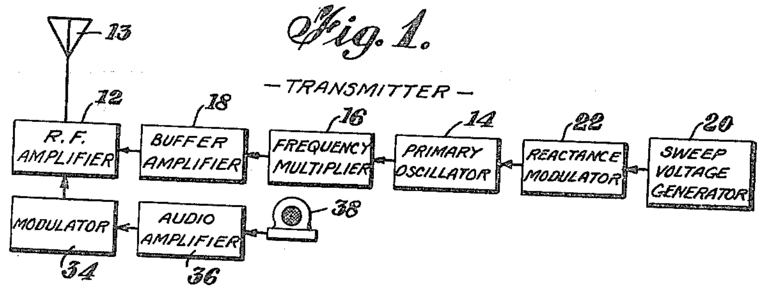

Fig. 2.

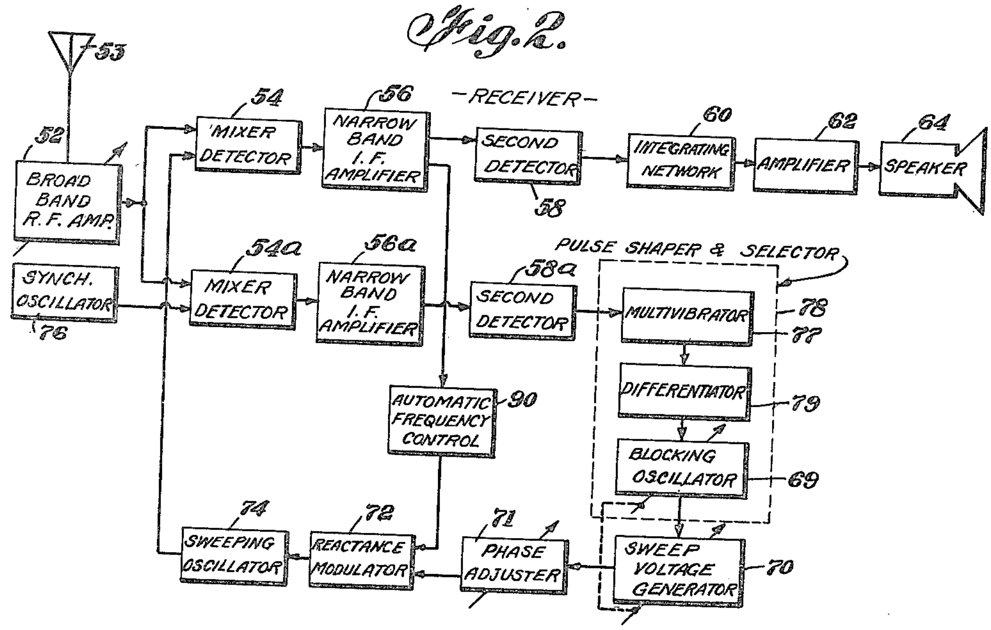

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Fig. 3.

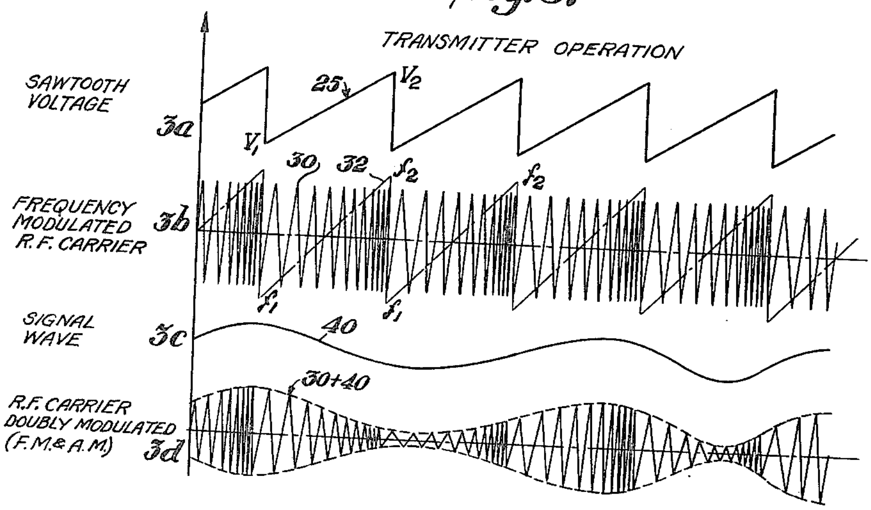
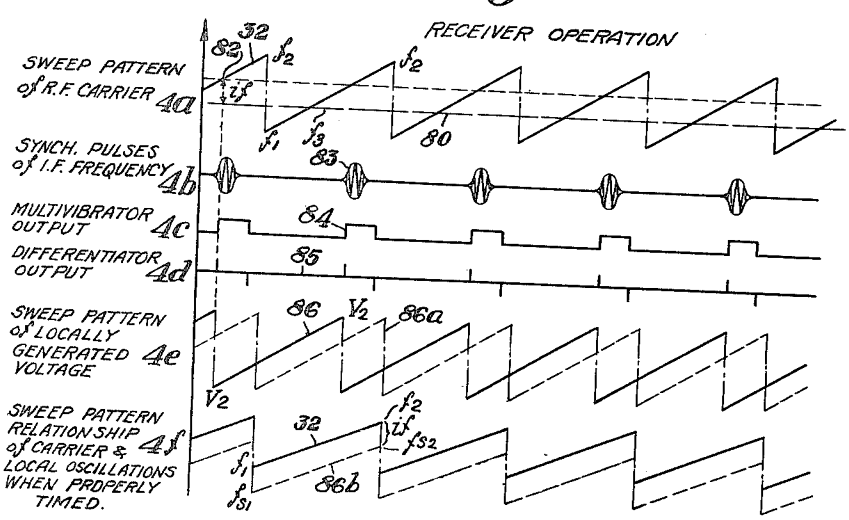


Fig. 4.



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5 Sheets-Sheet 3

Fig. 5.

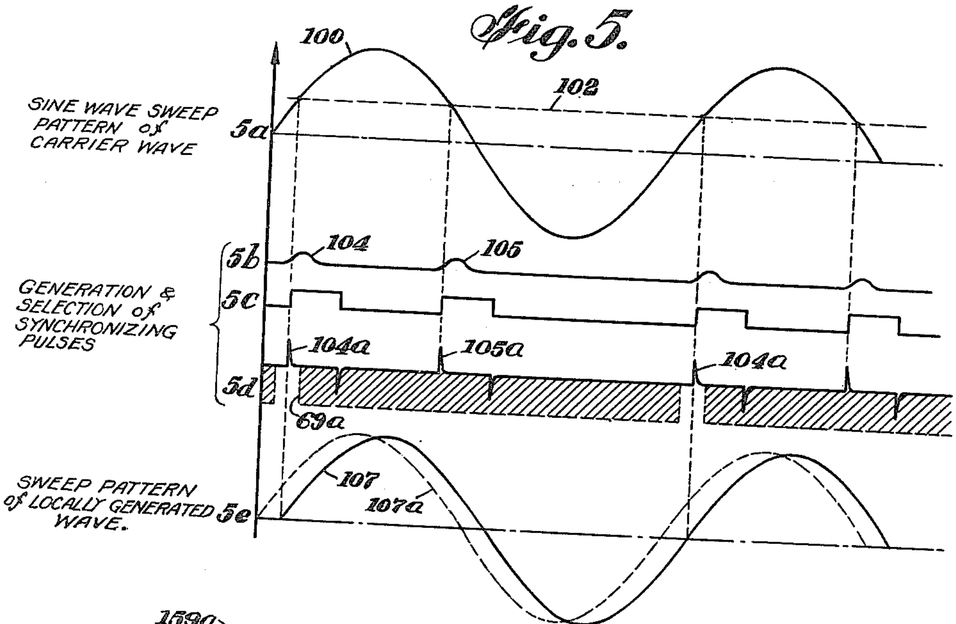

Fig. 8.

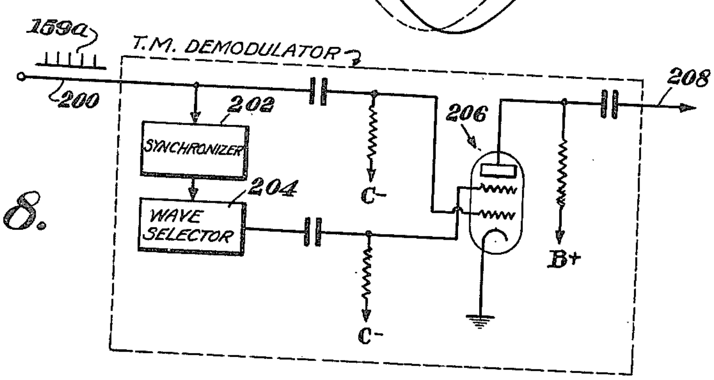

Fig. 9.

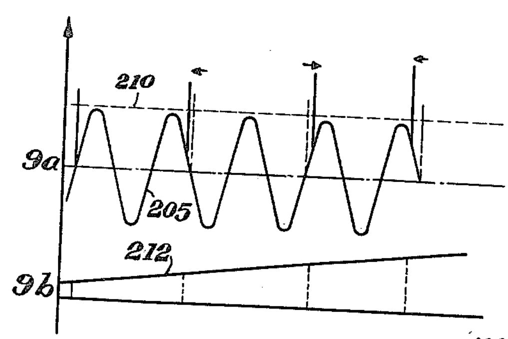

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Fig. 6.

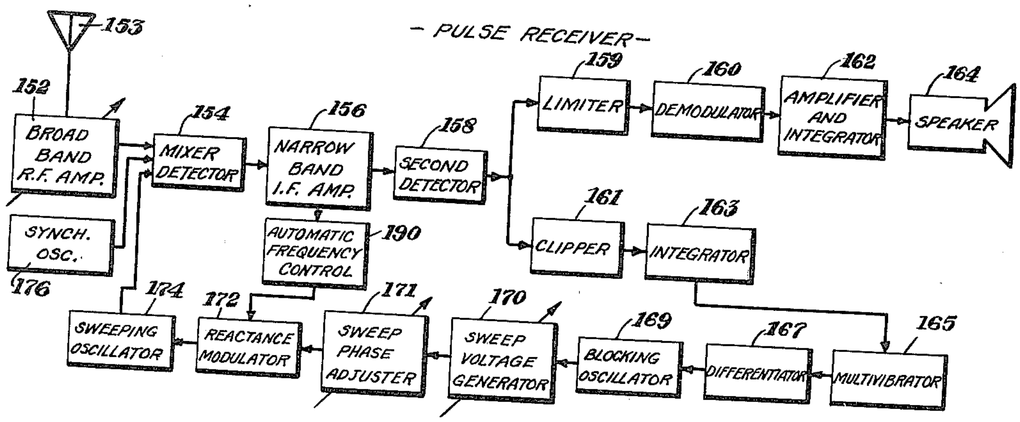
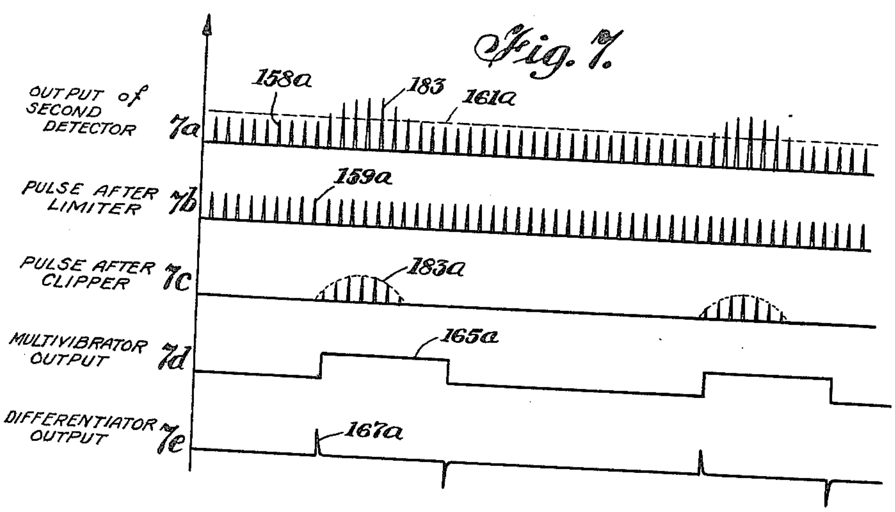


Fig. 7.



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2,448,055

5 Sheets-Sheet 5

Fig. 10.

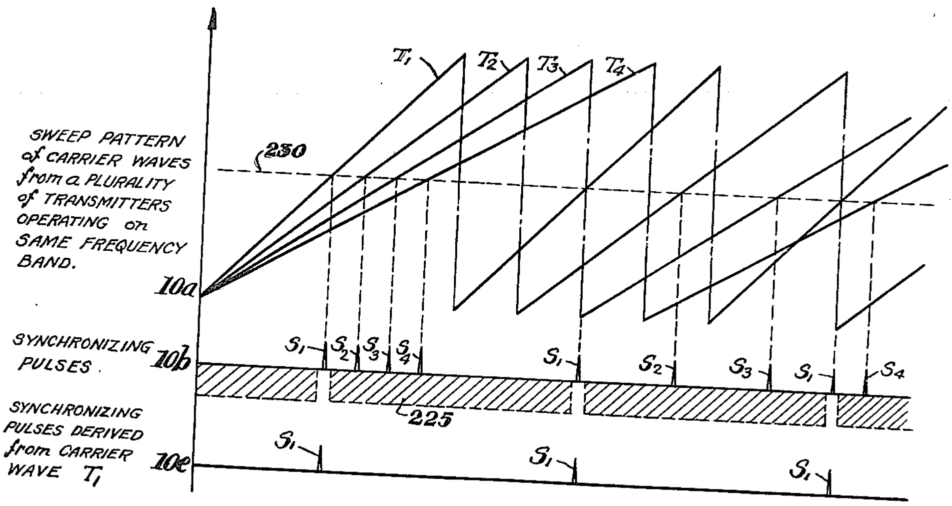
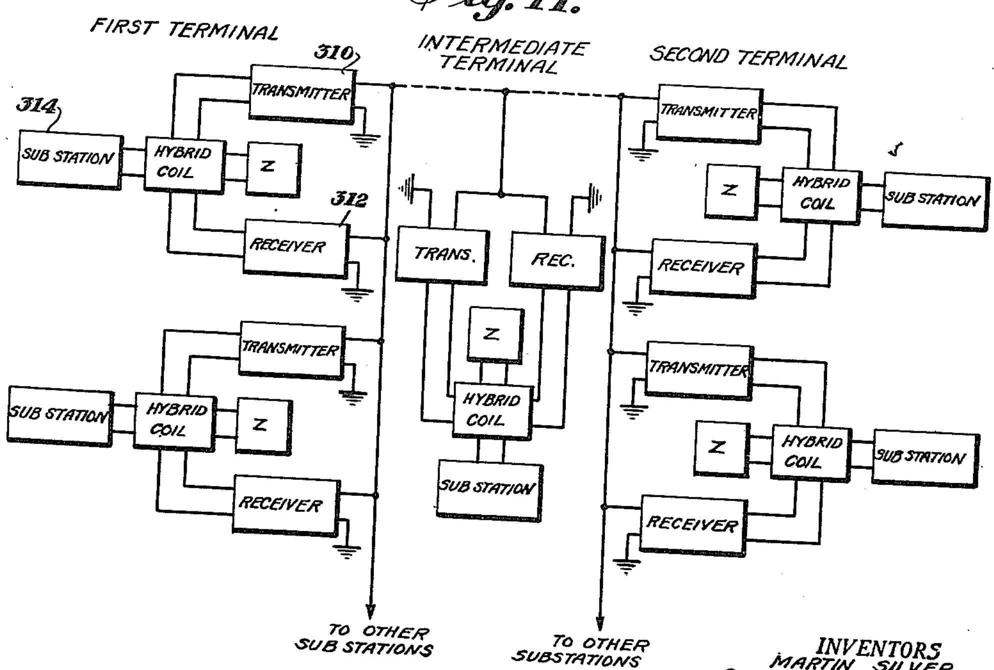


Fig. 11.



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Patented Aug. 31, 1948

2,448,055

UNITED STATES PATENT OFFICE

2,448,055

WOBBLED FREQUENCY CARRIER WAVE COMMUNICATION SYSTEM

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Application February 21, 1944, Serial No. 523,194

26 Claims. (Cl. 250—6)

1

This invention relates to radio communicating systems, and more particularly to methods and means for private communication of intelligence of a character not easily affected by jamming attempts.

It has been proposed, heretofore, to transmit intelligence by means of a carrier wave the frequency of which is varied periodically between two predetermined limits according to a given pattern. This varying or "wobbling" carrier is amplitude modulated with intelligence. To receive the wobbling carrier and to detect the intelligence conveyed thereby, the tuning of the receiver is wobbled synchronously with the received carrier. This synchronism is effected according to the systems heretofore proposed by periodic transmission of a synchronizing signal or by a separate communicating or synchronizing channel.

It is one of the objects of our invention to provide, for use in private communicating systems wherein the carrier wave used is caused to wobble in frequency over a given frequency band according to a given pattern, a method and means for receiving the transmitted carrier without requiring periodic transmission of synchronizing signals or the provision of a separate communicating or synchronizing channel.

Still another object of the invention is to provide a multiplex or radio communicating system for transmission of a plurality of carrier waves wobbling over the one or more frequency bands and receivers capable of selective reception from the transmitters.

A further object of the invention is to provide an improved method and means for synchronizing a locally produced cyclic sweeping electromotive force with another cyclic sweeping electromotive force produced at some remote point.

The synchronizing feature, according to the principles of our invention, includes the local generation of oscillations at a selected constant frequency. This constant frequency is selected so that the oscillations produce, when mixed with a carrier wave varying periodically over a given R. F. frequency band, a pulse envelope at a selected I. F. frequency at least once during each sweep cycle of the carrier. The receiver is provided with a narrow band I. F. amplifier which passes only the I. F. frequency of the pulse envelope which is thereafter used to control the local generation of a cyclic sweeping voltage. The cycle of the sweeping voltage is adjusted in time and rate of sweep to the sweep cycle and rate of the received carrier. This locally generated sweeping voltage is used for frequency modulation of radio frequency oscillations which produces a constant I. F. frequency wave when mixed with the oscillations of the received carrier wave. This constant I. F. frequency wave is a facsimile of the original carrier except first, the characteristic of frequency variation is removed and second, the I. F. frequency is equal to the difference between the R. F. frequency of the carrier and the frequency of the locally generated frequency modulated oscillations. To insure accurate phasing of the locally generated sweeping oscillations with the received carrier, and thereby avoid any drift from synchronism, an automatic frequency control is used to control the local sweeping oscillator.

2

It will thus be clear that where a receiver is arranged for broad band reception equal to or greater than the frequency band of a particular wobbling carrier wave, synchronous reception may be had by simulating the pattern of the wobble cycle and by adjusting the cyclic phase of the locally generated sweeping oscillations to the cyclic phase of the carrier wave. This is all performed at the receiver without the aid of specially transmitted periodically synchronizing signals or a separate communication or synchronizing channel.

The above and other objects and features of the invention will become more apparent upon consideration of the following detailed description to be read in connection with the accompanying drawings, in which:

Fig. 1 is a schematic block diagram of a transmitter for transmitting a carrier wave, amplitude modulated by intelligence, and periodically varied in frequency according to a given sweep pattern between limits of a given frequency band;

Fig. 2 is a schematic block diagram of a receiver capable of synchronously receiving and demodulating the carrier wave transmitted by the transmitter of Fig. 1;

Figs. 3 and 4 are graphical illustrations used for explaining the transmitting and receiving operations of the transmitter and receiver systems of Figs. 1 and 2 respectively;

Fig. 5 is a graphical illustration indicating the operation of the receiver of Fig. 2 for a sinusoidal sweep pattern;

Fig. 6 is a schematic block diagram of a receiver capable of receiving a pulse modulated carrier which is wobbled between two limits of a given frequency band;

Fig. 7 is a graphical illustration used for explaining the operation of the receiver of Fig. 6;

Figs. 8 and 9 are schematic and graphical diagrams used for explaining the TM demodulation features that may be included in the receiver of Fig. 6;

Fig. 10 is a graphical illustration of the selective synchronizing of a receiver to one of a plurality of carrier waves wobbling in the same frequency band; and

Fig. 11 is a schematic block diagram of a multiplex signalling system according to our invention.

Referring to Fig. 1, the transmitter is of the character adapted to transmit a carrier wave which varies in frequency according to a given pattern such as a saw-tooth, sine wave, etc., whichever is preferred, the variation being between limits of a given frequency band, for example, ±5% of a mean frequency. The transmitter circuit includes the usual R. F. oscillator **12** with antenna system **13**, a primary oscillator **14**, frequency multiplier **16** and buffer amplifier **18**. These elements of the circuit produce a carrier wave of a given mean frequency. This wave is frequency modulated by a sweep voltage or electromotive force which varies cyclically according to a desired sweep pattern. A sweep voltage generator **20** is provided for this purpose, and, if desired, may be adjustable to any desired sweep frequency and deviation. This varying voltage is applied to a reactance modulator **22** which controls the frequency of the primary oscillator **14** causing the oscillations produced thereby to vary according to the sweep characteristics of the varying voltage.

Assume, for purposes of illustration, that the sweeping electromotive force produced by the generator **20** varies according to a saw-tooth wave between voltages V_1 and V_2 as indicated by the voltage wave **25** of curve **3a**, Fig. 3. The sweep pattern of the varying voltage, however, may comprise other shaped patterns such as a sine wave, triangular wave, etc., as may be desired. When the oscillations are modulated by the sweep voltage of wave **25**, the carrier wave is frequency modulated between two frequency limits f_1 and f_2 as indicated by the wave **30** and the frequency curve **32** of curve **3b**.

Intelligence may be conveyed by the carrier wave according to different types of modulation such as amplitude modulation, frequency modulation, phase modulation and various forms of pulse modulation. In the latter case, the modulation may include amplitude and/or time modulation of the pulses, modulation of pulse repetition rate or cadence frequency, pulse width modulation, etc.

In Fig. 1, the intelligence may be regarded by way of example as being applied to the carrier wave by a known form of amplitude modulating circuit **34** associated with the R. F. amplifier **12**, the signal wave being applied thereto through an audio amplifier **36** from a microphone **38**.

Curve **3c** of Fig. 3 indicates a modulating signal wave **40** such as may be applied from the microphone to the modulator **34**. Curve **3d** illustrates the carrier wave **30** amplitude modulated with the signal wave **40**. It will be noted that the frequency modulation of the oscillations produced by the sweep voltage from generator **20** is independent of the envelope definition of the wave corresponding to the signal wave **40**. The wave **30** thus conveys intelligence while, at the same time, it is frequency modulated over a wide band of frequencies, thereby rendering it difficult for unauthorized persons to receive the intelligence by means of the usual receiver or even by a wide band receiver without the provision of special synchronizing means.

The receiver of Fig. 2 for receiving the wobbling carrier of curve **3d**, Fig. 3, utilizes the heterodyne principle and includes a broad band R. F. amplifier **52** to which receiving antenna **53** is coupled. The R. F. amplifier has a wide R. F. band pass approximately equal to or slightly larger than the frequency band through which the carrier wave sweeps. The output of the R. F. amplifier is fed to two mixer detectors **54** and **54a**. The mixer **54** converts the R. F. carrier into a corresponding wave of constant intermediate frequency which is fed through a narrow band, high gain I. F. amplifier **56** to a detector **58** for demodulation of the I. F. wave. The output of the demodulator **58** is fed to the usual integrating network **60** and thence through audio amplifier **62** to a speaker **64**.

In order to remove the wobble variation from the carrier and provide the constant I. F. wave for the duration of the cyclic sweeps of the carrier wave, a varying electromotive force is generated by a sweep voltage generator **70** substantially identical to the sweep pattern of the carrier wave. The generator is controlled by selected synchronizing pulses from a blocking oscillator **69**, the selective feature of which is described in detail hereinafter.

The generator **70** is adjustable for a rate of sweep corresponding to the sweep rate or pattern of the generator **20** at the transmitter. This varying voltage of the generator **70** is adjusted by phase or time adjuster **71** to agree substantially with the timing of the sweep pattern of the received carrier. The voltage output of adjuster **71** is applied to a reactance modulator or other suitable modulator **72** to modulate the oscillations generated by a sweep oscillator **74**. This produces a frequency varying train of oscillations which when mixed with the carrier wave at detector **54**, the pattern of the sweeping oscillator being timed to the pattern of the carrier wave, a wave of constant intermediate frequency is produced which bears a facsimile of the modulation of the carrier wave. By detecting the I. F. wave at **58**, a signal wave corresponding to the transmitted intelligence is reproduced for the speaker **64**.

Synchronization of the sweeping oscillations of the oscillator **74** is effected by applying to the mixer detector **54a** oscillations generated by a synchronizing oscillator **76** at a selected frequency such, when mixed with the carrier wave, produces a pulse envelope of the I. F. frequency of the narrow band, I. F. amplifier **56a**, each time the received carrier wave sweeps across the frequency band of the amplifier. The I. F. pulse envelope is detected at **58a** to remove the intermediate frequency leaving pulse envelopes used for synchronizing purposes. These synchronizing pulses are sharpened by pulse shaper and selector **78**, the sharpened pulses being used to control the voltage sweep cycles produced by the generator **70**.

The two series of elements **54**, **56**, **58** and **54a**, **56a**, **58a** separate the reception of intelligence signals from the generation of synchronizing pulses. These two functions, however, may be combined in the same elements, such as elements **54**, **56** and **58**, and the beating of the oscillations of oscillator **76** and the carrier wave distinguished by suitable filter means from the intelligence wave produced by the beating of the carrier with the sweep oscillations produced by oscillator 74. The filtering of the synchronizing pulses from the intelligence wave is insured in such case by selecting the frequency of the sweep pattern repetition either higher or lower than the frequency range of the signal intelligence. A specific example of this feature is given hereinafter.

If desired, the adjustment of the phase adjuster 71 may be fixed and other vernier adjustment made by adjusting the frequency of the oscillations produced by the synchronizing oscillator 76. Such oscillator adjustment varies the timing of the synchronizing pulses. Should it be desirable to make the synchronizing oscillator fixed, this adjustment of the timing of the sweep pattern would then be performed by adjusting the phase adjuster 71.

The receiver operation is graphically illustrated in Fig. 4, wherein the curves have the same time base. Curve 4a indicates by saw-tooth wave 32 the sweep pattern of a frequency wobbling carrier wave. The broken line 80 represents the synchronizing oscillations of oscillator 76 at a selected frequency f_s. According to the heterodyning principle of the receiver, the frequency difference between f_s and the carrier wave at a given frequency level 82 in its sweep will produce an I. F. frequency which corresponds to the I. F. frequency band of the amplifier 56a. Thus, each time the carrier wave traverses the level 82 a pulse envelope 83, curve 4b, of this particular I. F. frequency is produced. It will be understood that there is but one synchronizing pulse produced for each sweep since the fly-back of the saw-tooth sweep is instantaneous and no beat effect occurs during that portion of the sweep pattern. Curves 4c and 4d represent the pulse shaping operation at 78, the wave 84 representing the rectangular wave output of the multivibrator 77 of the "flip-flop" type, and wave 85 representing the sharp pulses produced by differentiation of the wave 84 by differentiator 79. The positive pulses may be segregated by the blocking oscillator 69 from the negative pulses of the wave or the wave may be applied, in the absence of positive synchronizing pulses produced by other carrier waves, directly to generator 70 to control the timing of the sweep pattern of the voltage 86, curve, 4e, generated thereby. The broken line wave 86a represents the timing of the voltage sweep 86 after passing through the phase adjuster 71. The saw-tooth wave 32 of curve 4f is a reproduction of the carrier wave pattern 32 of curve 4a for comparison with the locally generated sweep pattern 86b produced by oscillator 74. The sweep of the locally produced oscillations occurs between limits f_{s1} and f_{s2} at substantially the same rate as the carrier between frequency limits f_1 and f_2 so that the difference between the two for the duration of the sweep results in a substantially constant I. F. frequency. It will thus be clear that this I. F. frequency output of the mixer 54 will be constant for the duration of the sweep thereby enabling the second detector 58 to demodulate the entire intelligence conveyed by the carrier wave.

In order to insure exact synchronism of the two sweeping patterns, an automatic frequency control 90 is provided between the I. F. amplifier 56 and the reactance modulator 72. This circuit responds to any tendency of the I. F. frequency, passing through amplifier 56, to vary from a constant value and applies a positive or negative voltage, as the case may be, to the reactance modulator 72 to counteract such variation. Thus, the control 90 counters any tendency of the sweep patterns of the oscillations generated at 74 and the received carrier to drift apart. Automatic frequency controls of this character are known and used for controlling the local oscillator of FM receivers.

The operation of the receiver according to a sinusoidal sweep pattern is illustrated in Fig. 5. The wave 100 of curve 5a represents the sinusoidal sweep pattern of the wobbling carrier wave. The broken line 102 represents the level at which the beat operation takes place between the carrier and the oscillations from the synchronizing oscillator 76. As shown, this beat level is crossed twice by the sweep pattern for each cycle thereof as distinguished by once for each saw-tooth sweep. This produces two synchronizing pulses 104 and 105 for each cycle of the sweep pattern. The multivibrator 77 will accordingly produce a rectangular wave portion for each of these pulses as indicated by curve 5c. Upon differentiation of wave 5c, a positive and a negative pulse is produced for each square pulse produced by the multivibrator. The blocking oscillator 69, however, provides a blocking potential 69a which effectively blocks out all the pulses except the periodic positive pulse 104a. Thus, the second pulse 105a of each cycle may be eliminated so that only the pulses 104a will be permitted to control the voltage generator 70. The voltage generator 70 will, in this case, be adjusted to provide a sinusoidal sweep voltage of a period and amplitude which conforms to the sinusoidal pattern of the carrier wave. This sweep voltage is indicated by wave 107 on curve 5e. The broken line wave 107a represents the timing of the sweep after adjustment by the device 71. Thus, the sweep pattern 107a is timed to the sweep pattern 100 of the carrier so that the resulting locally produced oscillations will beat with the carrier to produce a constant I. F. frequency wave.

Where the carrier wave is pulse modulated, such as where the pulses are displaced from given timing positions, or the width of the pulses is varied, or the cadence frequency of the pulses is varied, according to the instantaneous values of a modulating signal, the receiver may take the general arrangement shown in Fig. 6. This embodiment of the invention will be described, by way of example, for reception of TM (time modulation), the modulation of the pulses being of the "push-pull" character where the successive pulses are displaced toward and away from each other in push-pull according to the instantaneous value of the modulating signal.

The R. F. amplifier 152, the mixer detector 154, the narrow band I. F. amplifier 156 and the second detector 158 correspond to the elements similarly numbered in Fig. 2. The generation of the synchronizing pulses, however, takes place in the mixer detector 154, I. F. amplifier 156 and detector 158 simultaneously with the conversion of the intelligence portion of the carrier wave. Both the outputs of the synchronizing oscillator 176 and the sweeping oscillator 174 are applied to the mixer detector 154. The double beating effect produced by the two locally produced oscillations on the carrier wave results in a train of pulses 158a, curve 7a, Fig. 7. Short groups of these pulses are of greater amplitude as indicated at 183. These groups 183 include the synchronizing pulse envelope components. By limiting the pulses 158a by limiter 159, the pulses are all reduced to a constant amplitude as indicated by curve 7b. By threshold clipping the pulses of curve 7a at a level 161d corresponding approximately to the limiting level of a limiter 159, the pulse groups 183a, curve 7c, are obtained. By integrating the pulse groups 183a at 163, the pulse envelope is obtained which may be applied to a multivibrator 165 to produce rectangular wave 165a, curve 7d, which by differentiation at 167, produces sharp positive pulses 167a which in turn may be used to control the sweeps of the voltage generator 170.

Where more than one carrier wave is present on the same R. F. frequency band, it will be desirable to eliminate undesirable pulses generated in a similar manner. This is done by means of a blocking oscillator 169 or other pulse dividing circuit similarly as hereinbefore described for Fig. 2.

The sweeping voltage of the generator 170 is corrected for phase by adjuster 171 and then applied to the reactance modulator 171 which in turn controls the sweeping oscillator 174. As hereinbefore described, the frequency of the locally generated oscillations is controlled by the automatic frequency control 190 which counters any tendency of the carrier wave and the local sweeping oscillations to drift out of synchronism.

The time modulated pulses 159a of curve 7b are demodulated at 160 after which the energy may be amplified and integrated at 162 and applied to speaker 164. The demodulator 160 may comprise any known form of translator capable of translating the time displacements into amplitude displacements. One form of demodulator is shown in Fig. 3. The TM pulses received, at input 200, drive a synchronizer 202 to produce a wave having a frequency corresponding to the pulse period, that is, the time interval between alternate pulses. A wave selector 204 selects a desired harmonic 205, curve 9a, of the wave energy produced at 202, preferably an odd harmonic, for demodulation purposes. The harmonic wave 205 and the TM pulses 159a are mixed in a suitably biased mixer 206, whereby the output energy at 208 varies in amplitude in proportion to the amount the grid potential of the mixer 206 exceeds a given threshold level 210, curve 9a. By integrating the output of the mixer 206, the intelligence wave with which the pulses 159a are modulated will be obtained. Wave 212 of curve 9b represents the envelope of the intelligence, such as where the pulses of curve 9a are modulated with increasing displacements according to a linearly increasing signal, the push-pull modulation being indicated by the arrows on curve 9a.

To tune the receivers of Figs. 2 and 6 to a particular transmitting station, it is first necessary to set the sweep oscillator 74 or 174, as the case may be, to the mid I. F. frequency corresponding to the mid frequency of the R. F. frequency band of the carrier, it being asumed that the R. F. amplifier is adjusted to cover the spectrum of the R. F. frequency band. The next adjustment is that of controlling the sweep rate which, as shown in Fig. 2, is effected by adjusting the sweep rate of the voltage generator 70. This in turn controls through a ganged connection 215 the adjustment of the blocking oscillator 69. This is particularly important where there are a plurality of transmitter stations operating on the same R. F. frequency band but at different sweep rates or patterns. The phase of the locally generated sweeps is controlled by adjusting phase shifter 71. With these three adjustments

made, the receiver is tuned to receive the desired carrier.

It will be clear from the foregoing that our invention contemplates the provision of a plurality of transmitters for wobbling operation in the same broad R. F. band. These transmitters will differ in rate of sweep or some other characteristic of the sweep pattern such as limits of sweep or shape of the sweep pattern. Assuming that a saw-tooth sweep pattern is used for four different transmitters, the sweeps thereof may be represented by the waves T_1, T_2, T_3 and T_4, curve 10a, Fig. 10. Assuming that the synchronizing oscillator beats with the carrier waves of these transmitters at a level 220, four series of synchronizing pulses S_1, S_2, S_3 and S_4 will be generated, one series each for each carrier wave. In order to select the synchronizing pulses corresponding to a particular transmitter, it is necessary that the blocking oscillator 69 (Fig. 2) be adjusted in ganged relation with the sweep voltage generator 70 as indicated by connection 215. The blocking signals are represented by the shaded areas 225 of curve 10b. As soon as a synchronizing pulse is selected, automatically a corresponding local sweep pattern is produced. Thus, the sweep pattern of the locally produced oscillations will be caused to sweep at a chosen rate and be timed according to the synchronizing pulses S_1. Likewise, if the signals of a different transmitter are desired, the corresponding adjustment of the elements 69 and 70 of Fig. 2 will block out the undesired synchronizing pulses and provide a sweep rate corresponding to the synchronizing pulses selected.

It will be readily seen from the foregoing description that each transmitter may have two identifying numbers. First, a number corresponding to the mid frequency of the R. F. band in which it operates and second, a number representing the sweep rate. For example, the identifying numbers 27.5–20 would indicate a transmitter operating at a mid frequency of 27.5 megacycles, the R. F. carrier of which swings between limits of 25 and 30 megacycles and at a sweep rate of 20,000 times per second. If many transmitters are needed for a particular locality, another band can be used, for example, 20 to 25 megacycles in which the transmitters operate at different sweep rates.

In regard to the secretive feature of the invention, it should be noted that while a conventional wide band receiver might detect the carriers of a plurality of transmitters, it would not be able to segregate the carriers one from the other. Consequently, the reception would be garbled by many simultaneous messages.

As regards the counterjamming feature of the invention, it should be noted that the receiver is sensitive to only a narrow band of frequencies at any given instant, while, on the other hand, communication fills up a broad R. F. frequency band. The ratio of the R. F. to the I. F. band width is representative of the counter effect with respect to jamming attempts. Attempts to jam the communication with a constant carrier frequency transmitter would have to fill a considerable portion of the band width with noise at a level equal to the narrow band signal. This obviously would require an enormous amount of power making the jamming operation impractical. Should a jamming attempt provide pulses that would interfere with the synchronizing pulse generation by the transmission of a constant frequency carrier, this would result in the generation of pulses similarly as produced by the synchronizing oscillator 76 of Fig. 2. Such a jamming signal, however, may be substantially avoided by changing the frequency of the oscillator 76 to a clear portion of the carrier band, a corresponding adjustment being made by the time adjuster 71. It will also be clear that most of such interfering pulses may be eliminated by the blocking oscillator 69.

Besides radio communication, our invention is also applicable to multiplex signalling, whether wire, coaxial cable or the ether is used as the common transmitting medium. Fig. 11 shows diagrammatically one form of multiplexing arrangement that may be provided in accordance with the principles of our invention. The system includes first and second terminals and, if desired, one or more intermediate terminals. Each terminal includes a plurality of sub-stations each of which is a complete unit. Fig. 1, for example, includes a transmitter 310, a receiver 312, a hybrid coil connection 313 with balancing impedance Z and a sub-station 314 such as commonly used for selectively switching in telephone lines for two-way conversation. The transmitter 310 may be constructed similarly as described in connection with Fig. 1. The receiver may take any of the forms described in connection with Figs. 2 and 6.

As indicated in Fig. 10, the carrier waves of the several transmitters of the multiplex system may be caused to sweep continuously between limits of a given frequency band according to one or more sweep patterns. In such a system it is preferred, however, that a given sweep pattern be used and that the sweep pattern of the different carrier waves differ according to some selected characteristic of the pattern such, for example, as the sweep rate.

Where there are a very large number of channels different frequency bands may be used. By way of example, each terminal may have a separate frequency band for the transmitters thereof with the receivers adjustable to any one of the bands.

While we have described above the principles of our invention in connection with specific apparatus, and particular modifications thereof, it is to be clearly understood that this description is made only by way of example and not as a limitation on our invention and the scope of the accompanying claims.

We claim:

1. A method of receiving intelligence conveyed by a carrier wave periodically varied in frequency, in addition to intelligence modulation, according to a given sweep pattern between limits of a given frequency band, comprising producing substantially regularly recurring synchronizing pulses timed to at least certain of the successive sweep patterns of said carrier wave, producing oscillations varying in frequency according to said given sweep pattern, using the synchronizing pulses thus produced for synchronizing the sweep patterns of said oscillations with the successive sweep patterns of said carrier waves, mixing said oscillations with the carrier wave to produce a wave of substantially constant intermediate frequency equal to the frequency difference between said carrier wave and said oscillations, and detecting said intermediate frequency wave to obtain a signal wave according to said intelligence.

2. A method according to claim 1 wherein the synchronizing pulse producing operation includes the generation of oscillations at a given frequency, and mixing the oscillations of given frequency with said carrier wave to produce at least one pulse of a given intermediate frequency during each sweep pattern of the carrier wave.

3. A method according to claim 1 wherein the synchronizing pulse producing operation includes controlling the recurrence rate of the synchronizing pulses so that such rate is outside the audible frequency range of said intelligence.

4. A method according to claim 1 wherein the carrier wave is pulse modulated, and the synchronizing pulses are produced by mixing locally generated oscillations with the carrier for beating operation with the carrier to produce pulse envelopes of a given intermediate frequency each of which includes at least one of the pulses with which the carrier is modulated, and threshold clipping said pulse envelopes to obtain the synchronizing pulse components thereof.

5. A method of synchronizing a locally produced cyclic sweeping electromotive force with a remotely generated electric wave periodically varied in frequency according to a given sweep pattern having a regularly repeated linear portion between limits of a given frequency band, comprising producing substantially regularly recurring synchronizing pulses derived from frequencies of said given frequency band and timed to at least certain of the successive linear portions of the sweep pattern of said wave, producing a varying electromotive force having a cyclic sweeping characteristic substantially the same as the sweep pattern of said wave, and using said synchronizing pulses to time the sweep patterns of said varying electromotive force to the timing of the successive sweep patterns of said electric wave.

6. A method according to claim 5 wherein the synchronizing pulse producing operation includes the generation of oscillations at a given frequency, and mixing said oscillations with said electric wave to produce at least one synchronized pulse of a given intermediate frequency during each sweep pattern of the carrier wave, using said synchronizing pulse to control the local generation of a cyclic sweeping voltage and adjusting the cycle of said sweeping voltage in time and rate of sweep to the sweep cycle and rate of the carrier wave.

7. A method according to claim 5 wherein the sweep pattern of said electric wave comprises a steadily increasing change in frequency from one to the other of said limits and then repeating the sweep, and the synchronizing pulse producing operation includes the generation of oscillations at a given frequency, and mixing said oscillations with said electric wave to produce a synchronizing pulse of a given intermediate frequency for each sweep pattern of the electric wave.

8. A communication receiving system for reception of intelligence conveyed by a carrier wave periodically varied in frequency, in addition to intelligence modulation, according to a given sweep pattern between the limits of a given frequency band, comprising means for receiving said carrier wave throughout the spectrum of said frequency band, means for producing substantially regularly recurring synchronizing pulses from the successive sweep patterns of said carrier wave, means to produce oscillations varying in frequency according to said given sweep pattern, means controlled by said synchronizing pulses to synchronize the sweep patterns of said oscillations with the successive sweep patterns of

said carrier wave, means for mixing said oscillations with said carrier wave to produce a wave of substantially constant intermediate frequency, detector means for said intermediate frequency, and means to integrate the output of said detector means to obtain a signal wave according to said intelligence.

9. A system according to claim 8 wherein the means for producing said synchronizing pulses includes means to generate oscillations at a given frequency, means for applying said oscillations to said mixing means for mixing with said carrier wave to produce at least one pulse envelope of a given intermediate frequency during each sweep of the carrier wave, and means associated with said detector means for segregating the synchronizing pulse components from said pulse envelopes.

10. A system according to claim 8 wherein the means for producing synchronizing pulses includes means to generate oscillations at a given frequency, means separate from said mixing means for mixing said oscillations of given frequency with said carrier wave to produce at least one pulse envelope of a given intermediate frequency for each sweep cycle of said carrier, and detector means for the pulse envelopes.

11. A system according to claim 8 wherein the carrier wave is pulse modulated, and the means for producing synchronizing pulses includes means to generate oscillations at a given frequency, means causing said oscillations of given frequency to mix and beat with said carrier wave to produce pulse envelopes of a given intermediate frequency including at least one of the pulses with which the carrier is modulated, and means to obtain the synchronizing pulse components of said envelopes.

12. A communication receiving system for reception of intelligence conveyed by a carrier wave periodically varied in frequency, in addition to intelligence modulation, according to a given sweep pattern between the limits of a given frequency band, comprising means for receiving said carrier wave throughout the spectrum of said frequency band, means for producing substantially regularly recurring synchronizing pulses from the successive sweep patterns of said carrier wave including means for deriving said synchronizing pulses from frequencies of said frequency band, means controlled by said synchronizing pulses to produce a varying electromotive force having a cyclic sweeping characteristic substantially the same as the sweep pattern of said carrier wave, means for producing oscillations, means for frequency modulating said oscillations according to said varying electromotive force, means for adjusting the timing of the sweep pattern of said oscillations to the timing of the sweep pattern of said carrier wave, means for mixing said oscillations with said carrier wave to produce a wave of substantially constant intermediate frequency, detector means for said intermediate frequency, and means to integrate the output of said detector means to obtain a signal wave according to said intelligence.

13. A system according to claim 12 in combination with an automatic frequency control responsive to variations in said intermediate frequency wave to vary the instantaneous value of the electromotive force, thereby offsetting any tendency of the sweep patterns of the carrier wave and the electromotive force to vary one from the other.

14. A system according to claim 12 wherein the

sweep pattern of said carrier wave follows a saw-tooth by a steadily increasing change from one to the other of said limits and then repeating, and the means for producing a varying electromotive force includes a voltage generator whereby a varying electromotive force is produced which has a saw-tooth pattern substantially the same as the sweep pattern of said carrier wave.

15. A system according to claim 12 wherein the sweep pattern of said carrier wave varies in a sinusoidal manner between said limits thereby producing two synchronizing pulses per cycle, and the means for producing said varying electromotive force includes a sine wave voltage generator and a blocking oscillator whereby alternate synchronizing pulses only are passed by said blocking oscillator for synchronizing of said sine wave voltage generator.

16. A communication receiving system for reception of intelligence conveyed by a carrier wave periodically varied in frequency, in addition to intelligence modulation, according to a given sweep pattern between the limits of a given frequency band, comprising a mixer detector, means for receiving and applying said carrier wave throughout the spectrum of said frequency band to said detector, means to generate oscillations at a selected frequency, means to apply said oscillations to said detector to mix with said carrier wave to produce at least one pulse envelope of a given intermediate frequency for each sweep of the carrier wave, means to produce oscillations varying in frequency according to said given sweep pattern, means controlled by energy of said pulse envelopes to synchronize the sweep patterns of said varying oscillations with the sweep patterns of said carrier wave, means to retard the timing of the sweep pattern of said oscillations a given amount, means for changing the selected frequency of said oscillator to adjust the timing of the synchronizing pulse envelopes, means for mixing said varying oscillations with said carrier wave to produce a wave of substantially constant intermediate frequency, detector means for said intermediate frequency, and means to integrate the output of said detector means to obtain a signal wave according to said intelligence.

17. A system for synchronizing a locally produced cyclically varying electromotive force with a remotely generated electric wave periodically varied in frequency according to a given sweep pattern between the limits of a given frequency band, comprising means for receiving said electric wave throughout the spectrum of said frequency band, means to produce substantially regularly recurring synchronizing pulses from the cyclic character of the received wave, said synchronizing pulses being timed to at least certain of the successive sweep patterns of the received wave, means controlled by said synchronizing pulses for producing a varying electromotive force having a cyclic sweeping characteristic substantially the same as the sweep pattern of said wave, said synchronizing pulses operating to time the sweep patterns of said varying electromotive force to the timing of the successive sweep patterns of said electric wave.

18. A system according to claim 17 wherein the means for producing synchronizing pulses includes means for generating oscillations at a given frequency, and means for mixing said oscillations with said electric wave to produce at least one synchronizing pulse envelope of a given intermediate frequency for each sweep pattern of said electric wave.

19. A system according to claim 17 wherein the sweep pattern of said electric wave increases steadily in frequency from one to the other of said limits and then repeats in the manner of a saw-tooth variation, and the means for producing synchronizing pulses includes means for generating oscillations at a given frequency, and means for mixing said oscillations with said electric wave to produce a synchronizing pulse envelope of a given intermediate frequency for each sweep pattern of said electric wave.

20. A system according to claim 17 wherein the sweep pattern of said electric wave varies between said limits in a sinusoidal manner, and the means for producing synchronizing pulses includes the generation of oscillations at a given frequency, means for mixing said oscillations for said electric wave to produce a synchronizing pulse envelope of a given intermediate frequency at corresponding points in each half-cycle of the sweep pattern of said electric wave, and means to eliminate alternate pulses to provide one synchronizing pulse only for each sweep pattern of said electric wave.

21. In a communicating system wherein a plurality of channels are transmitted over a common medium, each channel being represented by a carrier wave modulated with intelligence and varying between limits of a given frequency band according to a given pattern, the pattern of each carrier wave differing from the patterns of others in said band according to a given characteristic; a receiver for selectively receiving the carrier wave of any of said channels comprising means for receiving said carrier waves throughout the spectrum of said frequency band, means for producing a separate series of substantially regularly recurring synchronizing pulses from the successive sweep patterns of each of said carrier waves, means to produce oscillations varying in frequency according to said given sweep pattern, means adjustable to select the series of synchronizing pulses corresponding to the carrier wave of a desired channel, means controlled by the selected series of synchronizing pulses to synchronize the sweep patterns of said oscillations with the sweep patterns of the desired carrier wave, means for mixing said oscillations with said carrier waves whereby a wave of substantially constant intermediate frequency is produced by interaction with said desired carrier wave, detector means for said intermediate frequency, and means to integrate the output of said detector means to obtain the intelligence conveyed by the selected channel.

22. A two-way communication system comprising first and second terminals each having a transmitter and a receiver, each transmitter having means for modulating a carrier wave with intelligence, means at the transmitter of the first terminal to vary a first carrier wave between limits of a given frequency band, means at the transmitter of said second terminal to vary a second carrier wave between limits of said given frequency band but differing from said first carrier wave by a given characteristic of the sweep pattern, means to transmit the first and second waves over a common medium between said terminals, the receivers of each terminal having means to produce substantially regularly recurring synchronizing pulses from the successive sweep patterns of the carrier wave transmitted from the other terminal, means controlled by said synchronizing pulses to produce oscillations varying in frequency in a manner similar to the sweep pattern of the carrier waves, means to vary the sweep pattern of said oscillations with respect to said given characteristic until the sweep pattern of said oscillations represents a facsimile of the sweep pattern of the carrier wave received, means for mixing said oscillations with the received carrier wave to produce a wave of substantially constant intermediate frequency, detector means for said intermediate frequency, and means to integrate the output of said detector means to obtain the intelligence of the received carrier wave.

23. A system according to claim 22 wherein the sweep pattern of the carrier waves is a saw-tooth wave and the given characteristic is the sweep rate of the saw-tooth, and the means controlled by said synchronizing pulses for producing oscillations includes a sweep voltage generator, and the means for varying said given characteristic of the pattern of said oscillations includes means for varying the sweep rate of the oscillations between the limits of said frequency band.

24. A multiplex communication system comprising first and second terminals each having a plurality of transmitters and receivers, each transmitter having means for modulating a carrier wave with intelligence, the carrier wave of all the transmitters varying between limits of a given frequency band according to a given type of sweep pattern, the pattern of each carrier wave differing from the patterns of other carrier waves according to a given characteristic thereof, and means to transmit the carrier waves over a common medium between said terminals; and the receivers of each terminal having means to produce a separate series of substantially regularly recurring synchronizing pulses from the successive sweep patterns of the carrier waves, means adjustable to select the series of synchronizing pulses corresponding to a desired carrier wave, means controlled by the selected series of synchronizing pulses to produce oscillations varying in frequency according to said given type of sweep pattern, means adjustable to change said given characteristic of the pattern of said oscillations until the sweep pattern thereof corresponds substantially to the sweep pattern of the desired carrier wave, means for mixing said oscillations with said carrier waves whereby a wave of substantially constant intermediate frequency is produced by interaction of the oscillations with said desired carrier wave, detector means for said intermediate frequency, and means to integrate the output of said detector means to obtain the intelligence of said desired carrier wave.

25. A communication system according to claim 24 wherein the carrier waves of the transmitters of the first terminal are varied between the limits of a given frequency band, the carrier waves of the transmitters of the second terminal are varied between limits of a different wave band, the receivers at the first terminal include means for receiving the carrier waves of said second frequency band and the receivers of said second terminal include means for receiving the carrier waves of said first frequency band.

26. A method of synchronizing a locally produced cyclic sweeping electromotive force with a remotely generated electric wave periodically varied in the frequency in a sinusoidal manner between limits of a given frequency band to provide a sweep pattern comprising generating oscillations at a given frequency, mixing oscillations

with said electric wave to produce a synchronizing pulse of a given intermediate frequency for each half cycle of the sweep pattern of said electric wave, blocking out of said pulses to insure one synchronizing pulse only for each sweep pattern of the electric wave, blocking alternate pulses to insure one synchronizing pulse only for each sweep pattern of the electric wave, producing a varying electromotive force having a cyclic sweeping characteristic substantially the same as the sweep pattern of said wave, and using said synchronizing pulses to time the sweep patterns of said varying electromotive force to the timing of the successive sweep pattern of said electric wave.

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