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2,404,062

SELECTIVITY BY PHASE QUADRATURE USING TRIPLE SELECTIVITY CIRCUITS

Filed July 19, 1941

3 Sheets-Sheet 1

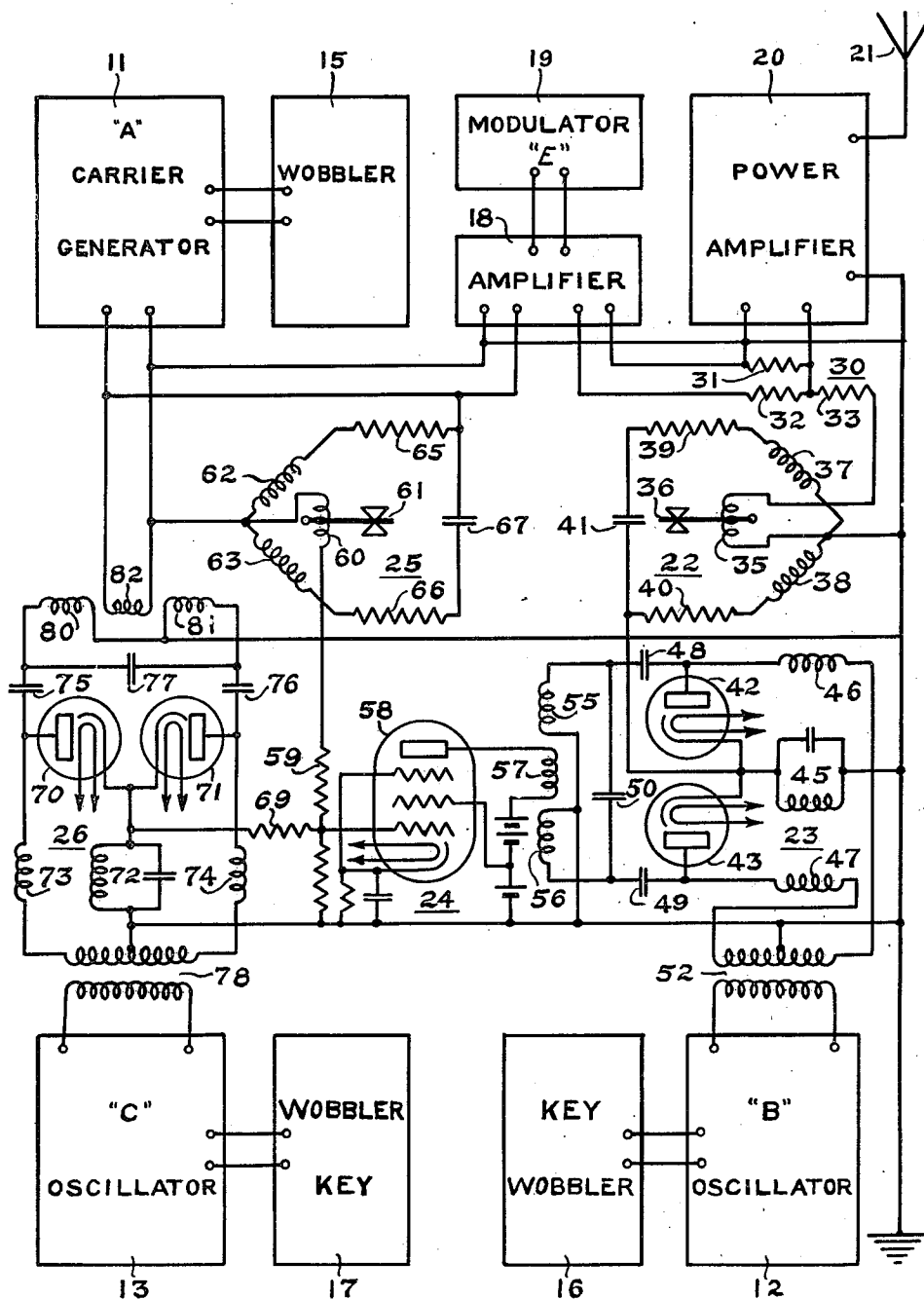


Fig. 1.

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3 Sheets-Sheet 2

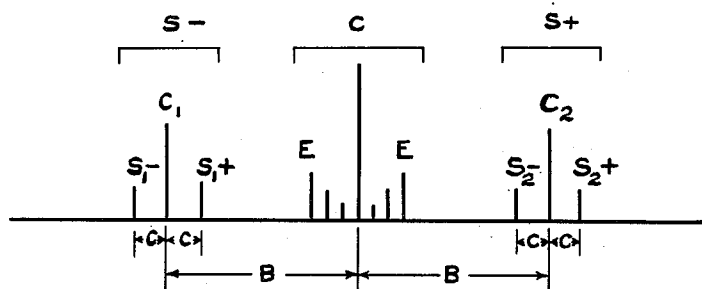


Fig. 2.

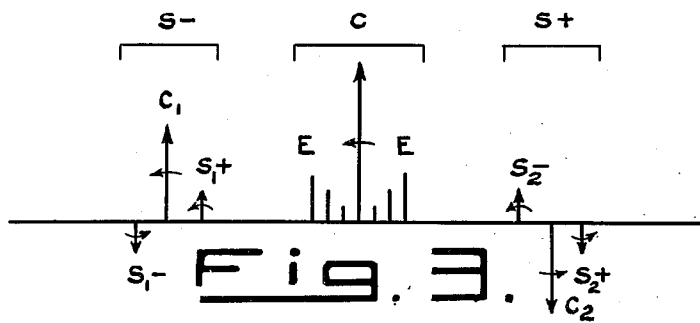


Fig. 3.

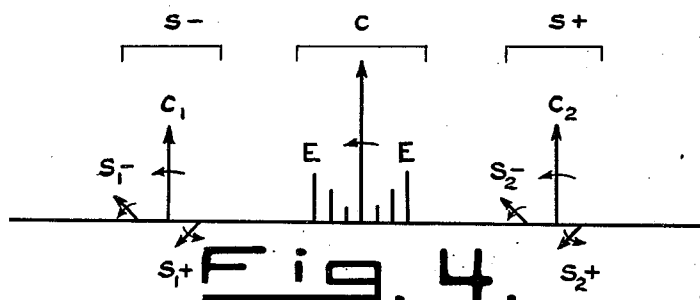


Fig. 4.

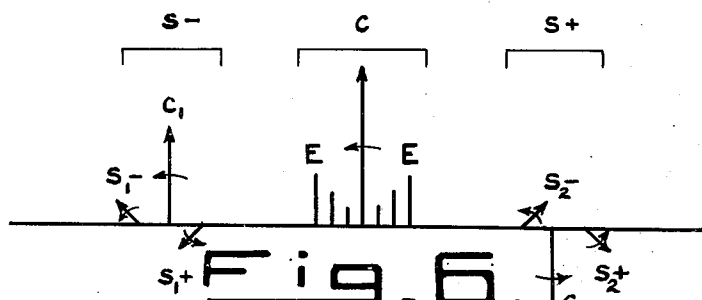


Fig. 6.

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3 Sheets-Sheet 3

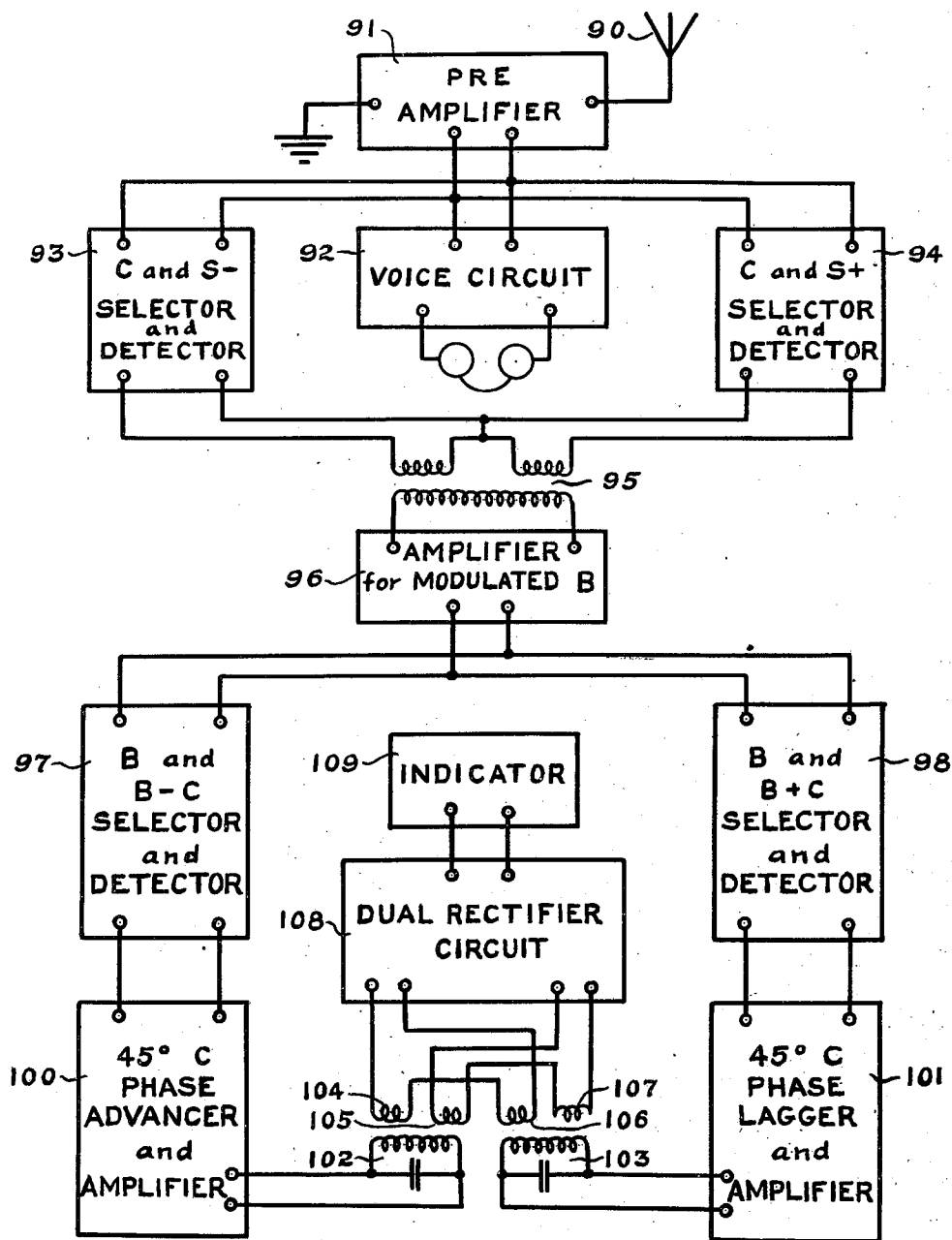


Fig. 5.

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SELECTIVITY BY PHASE QUADRATURE
USING TRIPLE SELECTIVITY CIR-
CUITS

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13 Claims. (Cl. 250—6)

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The present invention relates to a selective system of communication which is free from stray and intentional interference and in which the radiant energy is universally modulated at a high frequency to produce side bands which are in turn universally modulated at a lower frequency.

Universal modulation means that the relation between the carrier and its side bands may correspond to amplitude modulation or to phase or frequency modulation as regards first order side bands under the adjustment of a phase shifter device at the transmitter. In the present invention the same holds true as regards the main and side frequencies of the side bands of the carrier.

The present invention uses three orders of frequency; A the carrier, B the higher modulation frequency and C the lower modulation frequency. In addition the carrier A may be modulated at speech frequencies E. While the C frequency is preferably higher than speech frequencies there is no necessary restriction upon the values of A, B and C, and C may be in the audio range if desired.

It is to be further understood that the A signals in combination with its side bands due to the various modulations may be changed in frequency by a transmitter frequency converter and the received signals changed by a receiving frequency converter. When such converters are used at the transmitter or at the receiver or at both, the general operations will be the same as though the A currents were directly transmitted and received.

The invention also consists in certain new and original features of construction and combinations of parts hereinafter set forth and claimed.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its object and advantages, the mode of its operation and the manner of its organization may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which

Fig. 1 illustrates diagrammatically the invention as applied to a transmitter;

Figs. 2, 3 and 4 illustrate the various types of radiation from the transmitter;

Fig. 5 depicts diagrammatically the general features of a receiver; and

Fig. 6 illustrates a type of radiation received by the receiver depicted in Fig. 5.

Like reference characters denote like parts in the several figures of the drawings.

In the following description and in the claims

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parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring to the drawings Fig. 1 shows a transmitter which includes an A carrier generator 11, a B oscillator 12 and a C oscillator 13, associated with each of which are three wobblers 15, 16 and 17 respectively. There is also provided an amplifier 18 associated with a modulator 19 and a power amplifier 20 the output circuit of which is connected to an antenna 21. There is further provided a phase shifter 22, a push-pull modulator 23, an amplifier 24 a second phase shifter 25 and a second push-pull modulator 26.

The A carrier generator 11 is connected to the amplifier 18 which in turn is connected to the power amplifier 20 through a mixer network 30 comprising three resistors 31, 32 and 33, the last being connected to the rotatable coil 35, of the phase shifter 22, which is operated by means of a key 36. The fixed elements of the phase shifter 22 comprise coils 37 and 38, resistors 39 and 40 and condenser 41.

The primary of the phase shifter 22 is connected to the output circuit of the push-pull modulator 23 which includes diode tubes 42 and 43, a tuned circuit 45, chokes 46 and 47 and condensers 48, 49 and 50. The chokes 46 and 47 are connected in series with the secondary of a transformer 52, the primary of which is connected to the output circuit of the B oscillator 12.

The condensers 48 and 49 are connected in series with two coils 55 and 56 which are inductively coupled to a coil 57 in the output circuit of pentode tube 58 which forms part of the amplifier 24. The first grid of the tube 58 is connected through a resistor 59 to the rotatable coil 60 of the phase shifter 25 which is operated by a key 61. The phase shifter 25 is similar in construction to the phase shifter 22 and comprises coils 62 and 63, resistors 65 and 66 and condenser 67.

The first grid of the tube 58 is also connected through a resistor 69 to the output circuit of the push-pull modulator 26 which includes diode tubes 70 and 71, a tuned circuit 72, chokes 73 and 74 and condensers 75, 76 and 77. The chokes 73 and 74 are connected in series with the secondary of a transformer 78, the primary of which is connected to the output circuit of the C oscillator 13. The condensers 75 and 76 are connected in series with two coils 80 and 81 which are inductively coupled to a coil 82 in the output circuit of the A carrier generator 11.

Operation

In the operation of the transmitter shown in Fig. 1 carrier energy at A frequency is produced by the A carrier generator 11 and if desired may be modified by the wobbler 15 which preferably operates at a low audible or at a sub-audible rate of speed. B and C frequency energy are produced by the B and C oscillators 12 and 13 respectively which if desired may be wobbled in frequency by the devices 16 and 17 respectively and may also be keyed by change of frequency or amplitude of the signals produced. Usually, however, the key will not be used to vary the frequency of the signals when the wobbler is operative unless to supplement the wobbler operations.

The carrier generator 11 actuates the amplifier 18, which may be modulated at speech frequencies by the modulator 19. The amplifier 18 feeds the power amplifier 20 through the resistor 32 of the mixer network 30.

Some of the energy from the carrier generator 11 is delivered through the phase shifter 25 and resistor 59 to the first grid of the tube 58. Some of the energy from the carrier generator 11 is delivered through the coils 80, 81 and 82 to the push-pull modulator 26 which is also actuated from the C oscillator 13. The side band energy output of the push-pull modulator 26 is delivered through the resistor 69 to the first grid of the tube 58.

It should be understood that the present invention contemplates signalling with the C oscillator 13 inoperative in which case only carrier energy from the generator 11 actuates the amplifier 24 and the main side band modulator 23. With the C oscillator operative the modulator 23 is actuated by the carrier energy and the C side bands. The push-pull modulator 23 is also actuated from the B oscillator 12.

In the operation of the modulator 23 the input frequencies do not appear in the output and therefore the carrier energy modulated by the C frequency does not pass through the resistor 33 and interfere with the carrier energy modulated by the speech frequencies E. The main side frequencies, which are due to the B oscillator with the C oscillator inoperative, and the secondary side frequencies on the main side frequencies when the C oscillator is operative are inserted through the resistor 33 upon the power amplifier 20.

The phase shifters 22 and 25, which may be of similar or identical construction, are here shown as of the continuously variable type with key arrangement for variation of the setting either way from a mean which is manually adjustable.

The push-pull modulators 23 and 26 are shown as of the diode rectifier type with the high frequency energy fed through blocking condensers 48, 49 and 75, 76 respectively and the low frequency energy fed through the chokes 46, 47 and 73, 74 respectively to build up voltages of both frequencies on the plates of the diodes. The modulated or side band output is delivered to suitable output circuits 45 and 72 respectively between the cathodes of the diodes and ground.

Figs. 2, 3 and 4 depict the spectral distribution of energy delivered by the power amplifier 20 to the antenna 21. These diagrams show the frequencies of the spectral lines and also the phase angles of the various spectral lines and must be regarded as pertaining to a fixed setting of the wobbler devices.

Fig. 2 illustrates in detail the spectrum of the radiated energy when, for example, all of the

modulations are of the amplitude type. Here the central group C comprises a carrier band consisting of a main spectral line of frequency corresponding to the carrier generator 11 of Fig. 1.

This is modulated at speech frequencies E to produce side bands intimately associated with the carrier. These are here indicated as of the speech inverted type. The outer groups are the lower and upper side bands S— and S+, each including a central line C₁ and C₂ spaced from the center of the carrier band C by the B frequency. Spaced from the lines C₁ and C₂ at a frequency distance equal to the C oscillator are secondary side frequencies S₁—, S₁+, S₂—, S₂+.

The operation of the A wobbler 15 will change the location of the central group of lines C, that of the B wobbler will change the B spacing and that of the C wobbler 17 will change the C spacing.

In Fig. 3 the carrier radiations are depicted as being "quasi-phase" modulated at the B frequency, while the side groups are also "quasi-phase" modulated at the C frequency. By "quasi-phase" modulated is meant that the carrier and side bands are related as in the carrier and first order side bands of a phase modulated wave.

Amplitude modulation of the main carrier at the B frequency is shown in Fig. 4 and the side groups are modulated intermediately between amplitude and quasi-phase modulation.

By the use of this type of depiction a more complete identification of the properties of the radiation may be obtained. Thus a standard broadcast type of receiver tuned centrally to the lower group S— would produce a current of frequency C if tuned to the radiations depicted in Fig. 2; a current of frequency 2C if tuned to the radiations shown in Fig. 3, and currents of both frequencies C and 2C if tuned to the radiations illustrated in Fig. 4.

If the C frequency as well as the B frequency is above audibility the standard broadcast type of receiver would be incapable of distinguishing between the three sample types of radiation here depicted. But these radiations can be distinguished by receivers of suitable design and with highly accurately adjusted receivers the signals may be sent with very slight changes of the relative phase relations. It is to be understood that these are only samples of the various radiations which can be produced by the transmitter depicted in Fig. 1 under the actions of the continuously rotatable phase shifters 22 and 25.

Figure 6 of the drawings illustrates the "quasi-phase modulation" of the carrier at the B frequency and the intermediate type modulation of the main side frequency at the C frequency. If the C frequency is audible, producing an audible tone in a broadcast type receiver tuned at S+ or at S— of Figure 6, the signals sent by operating the key 36 will be private.

The receiver shown in Figure 5 is adapted to receiving the signals from the transmitter arrangement shown in Figure 1 when so arranged to produce the radiations illustrated in Figure 6. That is, in Figure 5 the back-to-back demodulators 93 and 94 are used because the B energies produced by demodulating C with S+, Figure 6, and C with S—, Figure 6, are 180° out of phase, but the phase advancer and lagger circuits 100, 101 of Figure 5 are used because the secondary modulations are related so that the outputs of the detectors are 90° out of phase. Signalling could be made to change the indica-

tor 109 in a number of manners as for example, keying the C oscillator on and off thereby changing the magnitude of the outputs of 97 and 98, or by operating shifters 22 and 25 by keys 36 and 61, so that the phases of the outputs of 97 and 98 change but not the magnitudes.

This receiver shown in Figure 5 comprises an antenna 90, a preamplifier 91, a voice circuit 92, two selectors 93 and 94 connected by a transformer 95 to an amplifier 96, two selectors 97 and 98, two shifter amplifiers 100 and 101 the outputs of which are connected through tuned circuits 102 and 103 and coupling coils 104-107 to a dual rectifier circuit 108 and an indicator 109.

Operation

In the operation of the receiver shown in Fig. 5 the signals are received by the antenna 90 and are amplified by the preamplifier 91. The signals are then distributed to the voice circuit 92 and to the two radio frequency selectors 93 and 94. The selector 93 selects energy from the carrier and the lower side band regions and detects them to produce currents of the B frequency modulated at the C frequency. Similarly the selector 94 selects energy from the carrier and the upper side band regions and detects them to produce like currents of the B frequency modulated at the C frequency.

The two detected B frequencies are 180° out of phase, but the modulations are similar. The two detected B frequency currents modulated at the C frequencies are combined to give an accumulated effect using the push pull transformer 95 and the resulting signals are amplified by the amplifier 96.

Although the energy for the amplifier 96 could be supplied from either selector 93 or 94 it is preferable to use the arrangement shown in Fig. 5 so as to utilize the advantages of the "back to back" detectors.

From the output of the amplifier 96, which consists of B frequency modulated at C frequency, some of the energy is diverted to the selector and detector 97, responsive to B and B-C frequencies and some of the energy is diverted to the selector and detector 98, responsive to the B and B+C frequencies. The outputs of the detectors 97 and 98 are of C frequency, but the two outputs in general are of different phase.

It is preferable to utilize a phase comparator circuit giving null response if the transmitted radiation corresponds to amplitude modulations or phase modulations in the regions of S+ or S-, since these are most prevalent in potentially interfering transmitters. The phase comparison system is, therefore, designed to pass the outputs of the detectors 97 and 98 through opposite 45° shifter amplifiers 100 and 101 with tuned output circuits 102 and 103. As the output circuits 102 and 103 are additively and subtractively connected by coils 104-107 to the dual rectifier circuit 108 the indicator 109 will show which rectifier is more strongly actuated. Thus the indicator 109 is most strongly operative in one sense when the output of the amplifier 100 leads the output of the amplifier 101 by 90° and is most strongly operative in the other sense when the output of the amplifier 100 lags behind the output of the amplifier 101 by 90°. The indicator 109 is non-responsive if the outputs of the amplifiers 100 and 101 are in phase or 180° out of phase.

It is thus seen that by the use of the first modulation at B frequency, of a quasi-phase nature,

the system is made highly selective against disturbances which produce like effect throughout the band. And by the use of the second modulation at C frequencies the system is made highly selective against amplitude or phase modulation at the vicinity of the C frequency.

Signalling may be accomplished by the key 36 of the transmitter shown in Fig. 1 which due to the dual channel radio selector circuit changes the strength of the signal to the amplifier 96 of the receiver depicted in Fig. 5 which in turn changes the strength of indication of the indicator 109. The signalling may also be accomplished by the key 61 which changes the nature of the modulation of the B frequency in the amplifier 96 and therefore changes the amount of indication produced in the indicator 109.

If the A, B and C frequencies are all above audibility and suitable minor precautions are taken to avoid dot-dash phase modulation reception, then the signalling is private against reception by continuous wave on broadcast receivers.

The circuit arrangement illustrated in Fig. 5 is but one of the many possible arrangements which may be used with the transmitter shown in Fig. 1. Other systems of signalling and reception based on these principles can readily be devised by those skilled in the art. The broad feature of the invention is in the superior selectivity and superior degree of privacy which can be accomplished by successive modulation, especially by other than amplitude modulations at the condition of maximum indicator response.

Although only a few of the various forms in which this invention may be embodied have been shown herein, it is to be understood that the invention is not limited to any specific construction but might be embodied in various forms without departing from the spirit of the invention or the scope of the appended claims wherein for brevity the term intensity of modulation will be used to denote the ratio of a side frequency amplitude, produced by modulation, to one half the carrier amplitude, and the term argument of modulation will be used to denote the phase relation between the carrier of a modulated signal relative to that of the resulting side frequencies.

What we claim is:

1. The steps in a method of signalling which comprise generating a carrier frequency and two auxiliary frequencies, combining the carrier frequency and the two auxiliary frequencies to produce a spectrum comprising the carrier and two groups of three side frequencies, said two groups being symmetrically located one above and the other below the carrier frequency, and signalling by varying the phase relation prevailing among the seven components of said spectrum.

2. The steps in a method of signalling which comprise generating a carrier frequency and two auxiliary frequencies, combining the carrier frequency and the two auxiliary frequencies to produce a spectrum comprising the carrier and two groups of three side frequencies, said two groups being symmetrically located one above and the other below the carrier frequency, and signalling by varying the phase relation prevailing among the seven components of said spectrum while maintaining their amplitudes constant.

3. The steps in a method of signalling which comprise generating a carrier frequency and two auxiliary frequencies, combining the carrier frequency and the two auxiliary frequencies to pro-

duce a spectrum comprising the carrier and two groups of three side frequencies, said two groups being symmetrically located one above and the other below the carrier frequency, varying the phase relation prevailing among the seven components of said spectrum in accordance with signals desired to be transmitted, radiating the energy as thus varied, receiving the radiated energy and indicating changes in the phase relation prevailing among the received seven components.

4. The steps in the method of receiving the energy transmitted by the method described in claim 1 which comprise selecting the transmitted carrier and one group of said frequencies, detecting said selected energy to produce one of said auxiliary frequencies modulated by the other auxiliary frequency, selecting and detecting said first named auxiliary frequency and one of its accompanying side frequencies, separately selecting and detecting said one of its accompanying side frequencies and another of its accompanying side frequencies, and comparing and indicating the relative phases of the resulting detected currents.

5. The steps in a method of signalling which comprise generating a carrier frequency and two auxiliary frequencies, modulating a portion of the carrier frequency by one of the auxiliary frequencies, combining only the side bands resulting from said modulation with another portion of the carrier frequency in adjustable phase relation to produce energy of the carrier frequency modulated by said side frequencies with a fixed magnitude of modulation but adjustable modulation argument, modulating the resulting energy with the other auxiliary frequency, modulating another portion of said carrier frequency with the signal energy desired to be transmitted, combining said modulated portion of the carrier frequency with the side bands only resulting from the last named modulation with the last named auxiliary frequency in adjustable phase relation to produce energy of carrier frequency modulated by said last named resulting side bands with a fixed magnitude of modulation but adjustable modulation argument, varying the adjustment of one of said phase relations in accordance with other signals desired to be transmitted and radiating the energy resulting from said last named combination.

6. The steps in a method of signalling which comprise generating a carrier frequency A and two auxiliary frequencies B and C, modulating a portion of carrier A by the auxiliary frequency C, eliminating from the products of said modulation both the carrier A and the auxiliary frequency C while retaining only the resulting side bands, combining said resulting side bands with another portion of the carrier A in adjustable phase relation to produce energy of the carrier frequency A modulated by said side frequencies with a fixed magnitude of modulation but adjustable modulation argument, modulating said produced energy with the B frequency, eliminating from the products of said last named modulation the produced energy and the B frequency while retaining the resulting side bands, combining said last named resulting side bands with another portion of said carrier frequency A in adjustable phase relation to produce energy of carrier frequency A modulated by said last named resulting side bands with a fixed magnitude of modulation but adjustable modulation argument, radiating the energy resulting from said last

named combination and signalling by varying the adjustment of one of said phase relations.

7. In signalling apparatus a carrier frequency generator, a first auxiliary frequency generator and a second auxiliary frequency generator, means including a balanced modulator for modulating a portion of the carrier frequency energy by said first auxiliary frequency energy whereby only side bands are present in the output of said first named means, means for combining the output of the first named means with another portion of the carrier frequency energy in adjustable phase relation, means including a balanced modulator for modulating the output of said last named means with the other auxiliary frequency whereby only side bands are present in the output of said last named balanced modulator, means for combining said last named output with another portion of said carrier frequency energy in adjustable phase relation, a radiating system and means for impressing the energy resulting from said last named combination upon said radiating system and means for varying the adjustment of one of said phase relations in accordance with signals desired to be transmitted.

8. The steps in a method of signalling which comprise generating a carrier frequency and two auxiliary frequencies, modulating a portion of the carrier frequency by one of said auxiliary frequencies, combining only the side bands resulting from said modulation with another portion of the carrier frequency energy in adjustable phase relation, modulating the energy resulting from said combination with the other of said auxiliary frequencies combining only the side bands resulting from said last named modulation with another portion of the carrier frequency energy in adjustable phase relation, said last named portion of the carrier frequency energy being itself modulated in accordance with signals desired to be transmitted, radiating the energy resulting from said last named combination and varying the adjustment of one of said phase relations in accordance with other signals desired to be transmitted.

9. The method described in claim 8 wherein the carrier frequency energy is wobbled in a predetermined manner.

10. The method described in claim 8 characterized by that at least one of the auxiliary frequencies is wobbled in a predetermined manner.

11. The method described in claim 8 characterized by that the carrier and at least one of the auxiliary frequencies are wobbled in a predetermined manner.

12. The steps in a method of signalling which comprise generating a carrier frequency and an auxiliary frequency, modulating a portion of the carrier frequency by the auxiliary frequency, combining only the side bands resulting from said modulation and another portion of the carrier frequency in adjustable phase relation to produce energy of the carrier frequency modulated by said side frequencies with a fixed magnitude of modulation but adjustable modulation argument, varying said phase relation in accordance with signals desired to be transmitted, and modulating said last named portion of the carrier energy with other signals desired to be transmitted.

13. The steps in a method of signalling which comprise generating a carrier frequency and an auxiliary frequency, modulating a portion of the carrier frequency by the auxiliary frequency, combining only the side bands resulting from said

modulation and another portion of the carrier frequency in adjustable phase relation to produce energy of the carrier frequency modulated by said side frequencies with a fixed magnitude of modulation but adjustable modulation argument, transmitting the energy so combined, varying said phase relation in accordance with signals desired to be transmitted, utilizing other

signals to modulate said other portion of said carrier frequency energy, receiving the radiated energy and indicating changes in the phase relation prevailing among the received components of the received energy.

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