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2,480,705

FREQUENCY SHIFT KEYER

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2 Sheets-Sheet 1

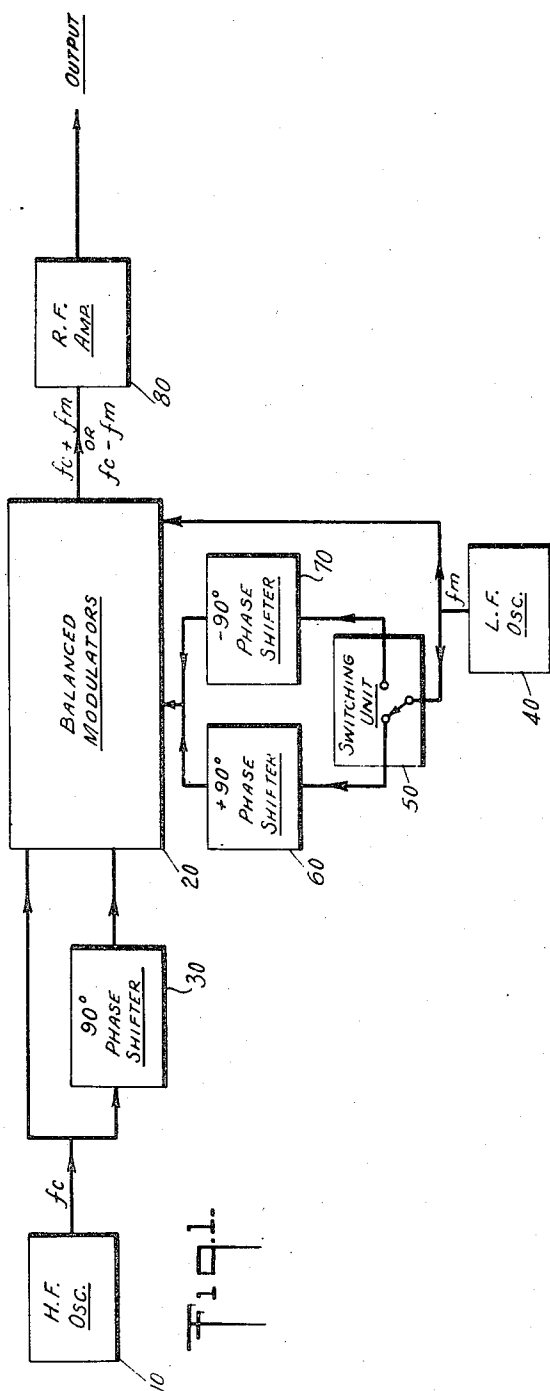
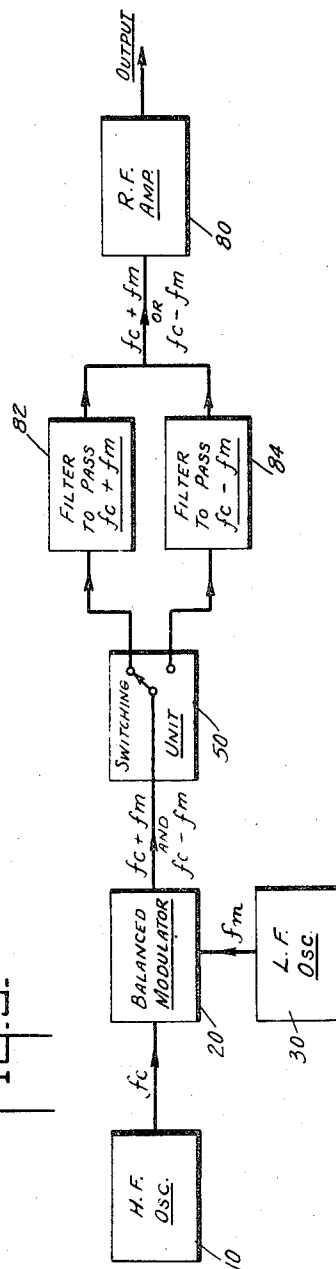


Fig. 3.



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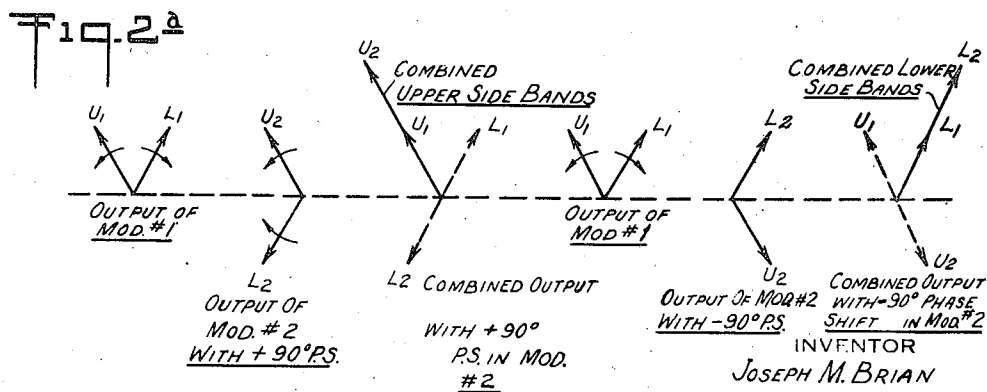
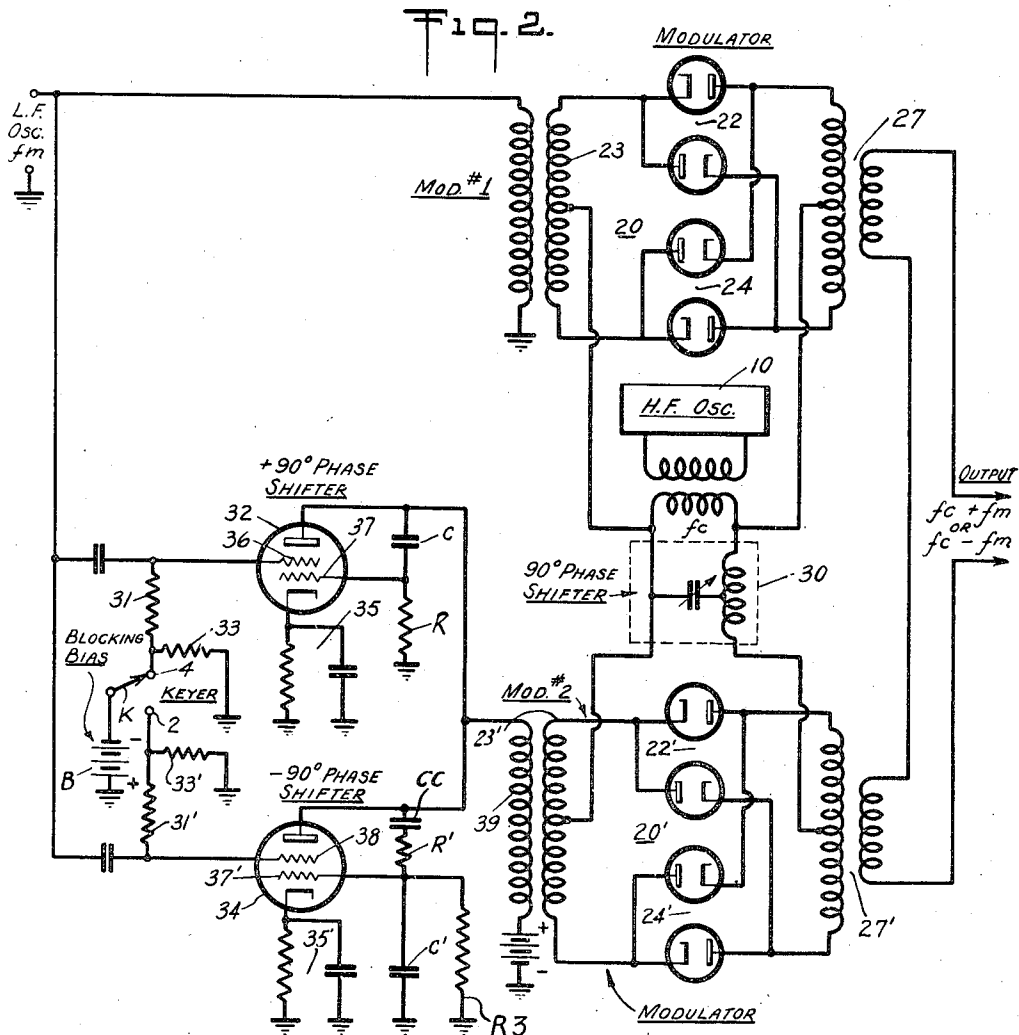
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FREQUENCY SHIFT KEYS

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2 Sheets-Sheet 2



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FREQUENCY SHIFT KEYER

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17 Claims. (Cl. 178—66)

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In this application I disclose an improved method of and means for securing frequency shift keying in signalling systems.

In telegraphy systems of the frequency shift keying type one frequency is used to represent marking condition and a second and different frequency is used to represent spacing condition. The frequencies may be separated as desired, it being essential only that they be separated by a frequency band sufficient to permit readily a discrimination therebetween and selection thereof at the receiver. In practice they are usually separated by a band of frequencies of the order of eight hundred cycles. One frequency may be designated the marking frequency, the other frequency may be designated the spacing frequency. The marking frequency may be higher than the spacing frequency or vice versa. The currents of different frequency may be derived in various manners, some of which will be listed hereinafter. Often the currents are of relatively low frequency and appear as modulation on a higher frequency wave. At the receiver currents representing mark and space frequencies are produced and subjected to selection or frequency discrimination to receive the signals. The signals have characteristics of on-off telegraphy but may be considered frequency modulated signals since the frequency thereof shifts between two values in accordance with signals. One or the other of the currents may be on at all times but both thereof are never on simultaneously.

In the embodiments described, the frequency shift signals are shown as being produced in a transmitter for radiation. It will be understood, however, that they may be produced for transmission over lines.

Frequency shift methods and means are known in the art and I do not lay claim to the same broadly.

In existing frequency shift keying systems the marking and spacing frequencies are usually obtained by one of three general methods:

1. By shifting the frequency of a crystal oscillator by a small amount. This is usually done by connecting an extra capacitance in series with a keying device across the crystal. When the keying device is closed the extra capacitance in parallel with the crystal will slightly lower the frequency. When the key is raised the reduction of capacity across the crystal will slightly raise the frequency. Therefore, the frequency will be shifted in accordance with the keying.

2. By using a self-excited oscillator and connecting a reactance tube across all, or a portion,

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of the tuned circuit. Depending on the phase relationships in the reactance tube circuit, this tube appears as either a capacitive or inductive reactance across the tuned circuit. Varying the voltages on one or more elements of this tube will cause a change in effective reactance. Therefore, when a keying device is used to alter the voltages on one or more elements of this tube it will cause the oscillator frequency to shift in accordance with the keying.

3. By combining the output of a fixed high frequency oscillator and the output of a comparatively low frequency oscillator which is so arranged that its frequency shifts in accordance with the keying as described in 2 above. The sum or difference frequency of these combined signals is taken from the mixer and then amplified and used in the usual manner.

In these known systems the amount of frequency shift usually may not be quickly and easily varied to meet desired operating conditions.

An object of my invention is to provide a method of and means for frequency shift telegraphy wherein the amount of frequency shift may be quickly and easily varied.

In known systems of the type described above, when the amount of frequency shift is varied the center frequency is usually varied also, thereby necessitating changes throughout the transmitter circuits and/or at the receiver.

An object of my invention is to produce an improved frequency shift telegraphy system wherein the amount of frequency shift may be varied as desired readily without changing the mean or average frequency of the currents in the transmitter and/or at the receiver.

In the frequency shift systems as described above considerable difficulty is encountered in adapting the same to existing transmitter apparatus. For example, transmitters usually include a crystal for stabilizing their carrier frequency and it is not easy to shift the frequency of this crystal and/or to vary the amount of shift. This often requires use of a new crystal and of considerable circuit apparatus to adapt the existing transmitters to production of frequency shift telegraphy.

A further object of my invention is to provide frequency shift keying circuits or adaptors for producing frequency shift telegraphy currents as described above, which keying circuits or adaptors may be readily applied to new or existing transmitters with a minimum of change from the

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original circuits and without the use of additional crystal oscillator stabilizing apparatus.

The above objects are accomplished in accordance with my invention by applying oscillations of a sub-carrier frequency as modulation to a balanced modulator of the suppressed carrier single side band type and by utilizing one side band as the marking frequency and the other side band as the spacing frequency. In accordance with my basic idea the frequency shift keying currents represented by one side band or the other are obtained by applying the oscillations of one frequency in phase quadrature relation to two balanced modulators and by applying oscillations of a second and different frequency alternatively by electronic or mechanical switching means in phase opposed relation to the balanced modulators so that in the output, one side band or the other, depending upon the position of the electronic or mechanical switching means is selected and fed out of the modulators. In the embodiments described, the oscillations wherein the keying takes place are of lower frequency than the other oscillations. However, it will be understood that the keying may take place in the couplings for the higher frequency oscillations.

It will also be understood that the keying may take place in the couplings applying the oscillations in quadrature to the two balanced modulators, rather than in the couplings applying the oscillations in phase opposed relation to the balanced modulators as shown.

One advantage to be gained by use of my method and means resides in the fact that all that is necessary to convert most existing transmitters to frequency shift keying is to supply the low frequency oscillator, the balanced modulators, the phase shifting circuits and the electronic or mechanical keying means for feeding the low frequency oscillations alternatively in phase opposed relation to the balanced modulators. As will be seen from the detailed description which follows these means are relatively simple and inexpensive, and easily added to most modulation systems known today. The low frequency oscillator may be an ordinary RC or beat frequency type such as can be found in most laboratories or radio stations. The center frequency determining oscillator may be the ordinary transmitter crystal controlled oscillator. Then, all that is necessary to adapt the arrangement to frequency shift signaling is to interrupt the circuit between the crystal controlled oscillator and a following stage and insert my balanced modulators arranged as described above.

Another advantage resulting from the use of my system resides in the fact that frequency or phase modulation may be applied to the low frequency oscillations so that the output comprising the alternatively present side bands may be frequency or phase modulated to thereby derive the benefits of frequency diversity.

Although it is believed that my invention in its broader aspects will be apparent to those skilled in the art from the foregoing description thereof, I will now describe detailed embodiments thereof. In this description reference will be made to the attached drawings wherein

Fig. 1 illustrates by rectangle and line connection one embodiment of my frequency shift telegraphy system.

Fig. 2 illustrates by circuit element and circuit connection the essential elements of a frequency shift telegraphy system as illustrated schematically by block diagram in Fig. 1.

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Fig. 2a illustrates by vector diagram the manner in which the upper or lower side band is selected in accordance with the electronic or mechanical switching means in Figs. 1 and 2 to provide the mark and space output frequencies represented by the two side bands.

Fig. 3 is a line connected block diagram of a modification of the arrangement of Fig. 1.

Fig. 1 illustrates the application of this type of frequency shift keying in the first general class described above. The high frequency oscillator 10 is so arranged that it feeds a voltage of frequency, f_c , directly into a pair of balanced modulators 20, and also a voltage of the same frequency through a 90° phase shifter 30. The oscillator 10 may be the regular frequency determining oscillator as found in any transmitter or it may be a separate unit as desired. A low frequency oscillator 40 feeds an audio voltage of frequency, f_m , directly into the balanced modulators 20 and also through a switching unit 50, and 90° phase shifter 60 or 70, depending upon the position of the switching unit 50. By properly combining and phasing these voltages in the balanced modulators a suppressed carrier single side band output may be obtained. A typical method of accomplishing this is described in U. S. Patent #1,773,116 by R. K. Potter. If the phase of the phase shifted frequency f_m supplied to the balanced modulators is shifted by 180° it will result in the suppression of the originally transmitted side band and the transmission of the other originally suppressed side band. In the proposed system this is accomplished by having the switching unit 50 connecting one audio signal to the balanced modulators 20 through the $+90^\circ$ phase shifter 60 for the spacing condition, while on the marking condition it connects the same audio signal to the modulators 20 through the -90° phase shifter 70. Thus, as the switching unit 50 alternately connects the one audio voltage to either $+90^\circ$ phase shifter 60, or -90° phase shifter 70, there is a shift of 180° which causes the output frequency of the balanced modulators, 20, to shift between a frequency of f_c plus f_m and f_c minus f_m . Depending on the type of balanced modulators used there may be other harmonics and combinations of the original frequencies in the output. It is, of course, necessary to select the proper output frequencies. However, if a ring-type modulator (as illustrated in Fig. 2) is used, the output will contain only one side band or the other when the equipment is properly adjusted. The output frequency from the balanced modulators may be amplified in the usual manner. If desired, the frequency may also be multiplied in this and succeeding amplifiers. If the frequency of the high frequency oscillator 10 is 5,000 kc. and that of the low frequency oscillator 40 is 400 cycles, the output frequency of the balanced modulators 20 will shift from $5,000 + 0.4$ to $5,000 - 0.4$ kc.; i. e., from 4,999.6 to 5000.4 kc., a shift of 800 cycles. Where a different frequency shift is required at the output frequency with frequency multiplication in the intermediate stages between the balanced modulators 20 and the output amplifier 80 the low frequency signal f_m should equal one-half of the desired frequency shift divide 1 by the order of multiplication.

In Fig. 2, 20 and 20' are the balanced modulators, each comprising two pairs, 22 and 24, of diodes in a conventional ring type modulator arrangement. The diodes are shown in separate envelopes but pairs thereof may be in a common envelope. Other types of rectifiers may be used.

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The cathode of one diode and the anode of the other diode of each pair are tied together and coupled differentially by a winding 23 which is the secondary winding of a transformer the primary winding of which is coupled to one source of alternating current, in the embodiment illustrated, the low frequency source 40.

The other balanced modulator 20' is similarly coupled by winding 23' to the low frequency source 40. This coupling includes phase shifting and phase reversing means including the two tubes 32, 34. Tubes 32 and 34 each have an anode coupled to the primary winding of transformer 23', and have control grid electrodes 36 and 38 coupled to the low frequency source 40. The grid 36 is connected to the cathode of tube 32 by resistances 31 and 33, and the cathode bias and condenser unit 35. Grid 38 is similarly coupled to its cathode by resistances 31', 33' and 35'. The biases supplied by these connections are such that the tubes amplify applied alternating current voltages. A source of blocking bias B has its positive terminal grounded and its negative terminal coupled to a key K arranged to put the negative source on resistance 31 or 31' to block tube 32 or tube 34.

The anode circuit of tube 32 includes a capacity C and resistance R of which C is of relatively high reactance and R is of relatively low resistance so that the alternating current through C—R is leading the voltage about 90°. The grid 37 then is excited by a voltage relatively retarded about 90° with respect to the voltage on grid 36. Tube 32 then will feed out of its anode into winding 39 a voltage relatively retarded about 90°. The tube 34 has its anode connected to ground by a coupling condenser CC and phase shifting resistor R' and capacitor C' in series. The grid 37' is connected to the junction point between resistor R' and capacitor C' and to ground by resistor R3. The resistance of R' is made large as compared to the reactance of capacitance C' so that the current through R'C' is in phase with the voltage across R'C'. The potential on the grid 37' is in phase with the potential drop across C' and this potential is relatively advanced 90°, with respect to the voltage on grid 38. Tube 34 therefore feeds to its anode an alternating current voltage relatively advanced about 90°. If key K is put on contact #2 tube 32 amplifies and the alternating current voltage on winding 39 is of a first phase and the phase of the alternating current voltage is shifted about 180° when tube 34 is unblocked by putting key K on the contact #4. Key K may be operated by hand but in practice is operated by electronic or mechanical means. The oscillations from source 10 are supplied in parallel to the pairs of modulators. A phase shifter 30 is included in the coupling between one of the balanced modulators and the source 10 so that one of the parallel excited balanced modulators is excited by an alternating current voltage about in quadrature with the voltage on the other balanced modulator. The outputs of the modulators are combined in series or additively in the secondaries of transformers 27 and 27'.

In Fig. 2a I have illustrated graphically the manner in which one side band or the other is cancelled by virtue of the fact that the said side band energies of the two modulators are of opposed polarity. The figure also shows graphically how the other side band energies of the two modulators being of like phase add to supply the keyed output. When tube 32 is active, i. e.,

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unblocked by putting the key K on the #2 contact corresponding side bands add in the common output circuit while the remaining side bands oppose and cancel. In the example given, the upper side bands add and the lower side bands cancel when K is on the #2 contact. When K is on the #4 contact the lower side bands add and the upper side bands cancel. The carrier cancels in both positions of switch K. The keyed side bands are supplied to use as desired from the common output circuit.

Fig. 3 shows a method of securing frequency shift keying when a balanced modulator is used to suppress the carrier and electric filters to eliminate either side band. A high frequency oscillator 10 feeds voltage of frequency f_c into a balanced modulator 20. A low frequency oscillator 30 feeds a voltage of frequency f_m into the same balanced modulator 20. If a ring-type modulator is used the output of the modulator will contain the frequencies, f_c plus f_m , and f_c minus f_m , the carrier being suppressed. The output of the balanced modulator is connected through a switching unit 50 to either the filter 82, designed to eliminate the lower side band and pass the upper side band, or to the filter 84, designed to pass the lower side band and suppress the upper side band. Switching unit 50 may be of either the electronic or mechanical type, being actuated in accordance with the keyed intelligence. In this system the switching unit is so arranged that for the spacing condition the output of the balanced modulator 20 is fed into filter 82 so that the frequency fed to the amplifier 80 is f_c plus f_m , while for the marking condition the filter 84 is connected to the output of the balanced modulator so that the voltage fed to the amplifier 80 is f_c minus f_m . Therefore, the frequency applied to the input of the amplifier will shift from f_c plus f_m to f_c minus f_m in accordance with the keying.

This same idea of shifting from one side band to the other for the marking and spacing conditions may be applied to other suppressed carrier single side band systems, as well as the two described above.

What is claimed is:

1. The method of creating frequency shift signals which includes these steps, modulating energy of a first frequency by energy of a second frequency in a manner such as to provide an output wherein the carrier is suppressed, and selecting from said output alternatively and in accordance with keying signals one side band for marking condition and the other side band for spacing condition.

2. The method of creating frequency shift signals which includes these steps, modulating energy of a first frequency by energy of a second frequency in a manner such as to provide an output including side band currents, and selecting from said output alternatively and in accordance with signals one side band representing mark and the other side band representing space.

3. The method of producing oscillatory energy that shifts from a first frequency representing mark to a second frequency representing space which includes these steps, generating two portions of oscillatory energy of a first frequency in quadrature relation, generating two other portions of oscillatory energy of a second frequency in quadrature relation, combining each of said first two portions of energy with a different one of said two other portions to derive beat note currents, combining the beat note currents to

derive output energy, and reversing the phase of one of the quadrature related energy portions in accordance with signals.

4. The method of producing oscillatory energy that shifts from a first frequency representing mark to a second frequency representing space which includes these steps, generating two portions of oscillatory energy of carrier frequency in quadrature relation, generating two other portions of oscillatory energy of a lower frequency in quadrature relation, combining each of said first two portions of energy with a different one of said two other portions to derive beat note currents, combining the beat note currents to derive output energy, and reversing the phase of one of the quadrature related energy portions of lower frequency in accordance with telegraphy signals.

5. In a frequency shift telegraphy system, in combination, a balanced modulator system supplied with carrier energy and modulating energy, an output circuit coupled thereto, and means controlled by a signal for alternatively supplying from said modulator to said output one side band or the other while suppressing the carrier.

6. In a frequency shift telegraphy system, two carrier suppressing modulator systems which are arranged to be excited in quadrature by oscillations from two sources, an output circuit coupled to both modulators, and means controlled by signals for reversing the phase of the oscillations from one source supplied as excitation to one modulator system.

7. In a telegraphy system, in combination, two carrier suppressing modulators, two sources of oscillations of different frequency, couplings between each of said sources and both of said modulators for modulating therein oscillations from one source by oscillations from the other source, means in the couplings between one source of oscillations and the modulators to establish a quadrature relation between the voltages supplied to the respective modulators, means in the couplings between the other source and said modulators for relatively shifting the phase of one of the voltages fed by said other source to said modulators about 90° , signal controlled means for reversing the phase of said last named voltage, and means for adding the modulator outputs in series.

8. In a telegraphy system, in combination, two carrier suppressing modulators, two sources of oscillations of different frequency, one of which is of carrier frequency, couplings between each of said sources and both of said modulators for modulating therein oscillations from said carrier frequency source by oscillations from the other source, means in the couplings between said source of oscillations of carrier wave frequency and the modulators to establish a quadrature relation between the voltages of carrier wave frequency supplied to the respective modulators, means in the couplings between the other source and said modulators for relatively shifting the phase of one of the voltages fed by said other source to said modulators about 90° , means controlled by signal markings for reversing the phase of said last named voltage, and means for adding the modulator outputs in series.

9. In a telegraphy system, in combination, a pair of suppressed carrier modulators, means for feeding oscillations of a first frequency in parallel relation to said pair of modulators, one of said modulators being excited in quadrature relation with respect to the excitation of the other of said modulators, means for feeding oscillations of a

second frequency in push-pull relation to one of said modulators, means for feeding oscillations of said second frequency in push-pull relation to the other of said modulators, means for reversing the phase of said last named oscillations in accordance with signal markings, and means for combining the outputs of said pair of modulators in series.

10. In a frequency shift telegraphy system, a pair of electron discharge system balanced modulators having input electrodes and output circuits, a source of oscillations of substantially fixed frequency, couplings for applying oscillations from said source in parallel to corresponding input electrodes of said modulators, phase displacing means in at least one of said couplings, a source of oscillations of relatively low frequency, couplings for applying oscillations from said last named source in pushpull relation to corresponding input electrodes in both of said balanced modulators, means in said last-named couplings controlled in accordance with signals for advancing or retarding the phase of the low frequency oscillations applied in pushpull relation to one of said modulators, and a series output circuit coupled to both of the output circuits of said modulators.

11. In a frequency shift telegraphy system, two carrier suppressing modulators each having input and output circuits, a source of oscillations of substantially fixed frequency, couplings for applying oscillations from said source in parallel to the input circuits of said modulators, phase displacing means in at least one of said couplings, a source of oscillations of relatively low frequency, couplings for applying oscillations from said last named source in pushpull relation to the input circuits of both of said modulators, one of said last couplings comprising two paths alternatively conductive in accordance with signals, means in said paths for relatively shifting the phase of the low frequency oscillations applied in pushpull relation to the input circuit of one of said modulators, and a series output circuit coupled to the output circuits of both of said modulators.

12. In a frequency shift telegraphy system, two carrier suppressing modulators each having input and output circuits, a source of oscillations of substantially fixed frequency, couplings for applying oscillations from said source in parallel to the input circuits of said modulators, phase displacing means in at least one of said couplings, a source of oscillations of relatively low frequency, couplings for applying oscillations from said last named source in pushpull relation to the input circuits of both of said modulators, one of said last couplings comprising two paths each having a tube, means in said paths for relatively shifting the phase of the low frequency oscillations applied in pushpull relation to the input circuit of one of said modulators, keying means controlled by signals for differentially controlling the conductivity of said tubes, and a series output circuit coupled to the output circuits of both of said modulators.

13. In a telegraphy system, a balanced modulator, a source of oscillations of carrier frequency coupled to said modulator, a source of oscillations of lower frequency coupled to said modulator whereby side band energy is produced by said modulator, an output circuit, a filter for each side band, a coupling between each filter and said output circuit, a coupling between each

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filter and said modulator, and a key in at least one of the last named couplings.

14. In a frequency shift telegraphy system, two carrier suppressed modulator systems which are arranged to be excited in quadrature by oscillations from two sources, an output circuit coupled to both modulators, and signal controlled discharge devices reversing the phase of the oscillations from one source supplied as excitation to one modulator system.

15. In a telegraphy system, in combination, two carrier suppressing modulators, two sources of oscillations of different frequency, couplings from each of said sources to both of said modulators for modulating therein oscillations from one source by oscillations from the other source, a phase shifting network in the couplings between one source of oscillations and the modulators to establish a quadrature relation between the voltage supplied by said one source to the respective modulators, a phase shifting network in the couplings between the other source and said modulators to establish a phase quadrature relation between the voltages fed by said other source to said modulators, key controlled tubes in said last couplings for shifting the phase of one of said last named voltages about 180° in accordance with signals, and an output circuit coupling the modulator outputs in series.

16. In a telegraphy system in combination, a pair of suppressed carrier modulators, connections for feeding oscillations of a first frequency in parallel relation to said pair of modulators, one of said modulators being excited in quadrature relation with respect to the excitation of the other of said modulators, electron discharge tube means for feeding oscillations of a second frequency in push-pull relation to one of said modulators, connections for feeding oscillations of said second frequency in push-pull relation to the other of said modulators, a key cooperat-

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ing with said electron discharge tube means for reversing the phase of said second-named oscillations in accordance with signal markings, and an output circuit for combining the outputs of said pair of modulators.

17. In a frequency shift telegraphy system, a pair of electron discharge system balanced modulators having input electrodes and output circuits, a source of oscillations of substantially fixed frequency, couplings for applying oscillations from said source in parallel to corresponding input electrodes of said modulators, phase displacing means in at least one of said couplings for establishing a phase quadrature relation between the oscillations fed to the respective modulators, a source of oscillations of relatively low frequency, couplings for applying oscillations from said last named source in push pull relation to corresponding input electrodes in both of said balanced modulators, the said couplings between said last named source and one of said balanced modulators comprising a pair of electron discharge devices having their input electrodes coupled to said last named source and their output electrodes coupled to said one of said balanced modulators, phase shifting reactances in said last named couplings, a key connected with the input electrodes of said electron discharge devices, and a series output circuit coupled to both of the output circuits of said modulators.

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