

March 8, 1949.

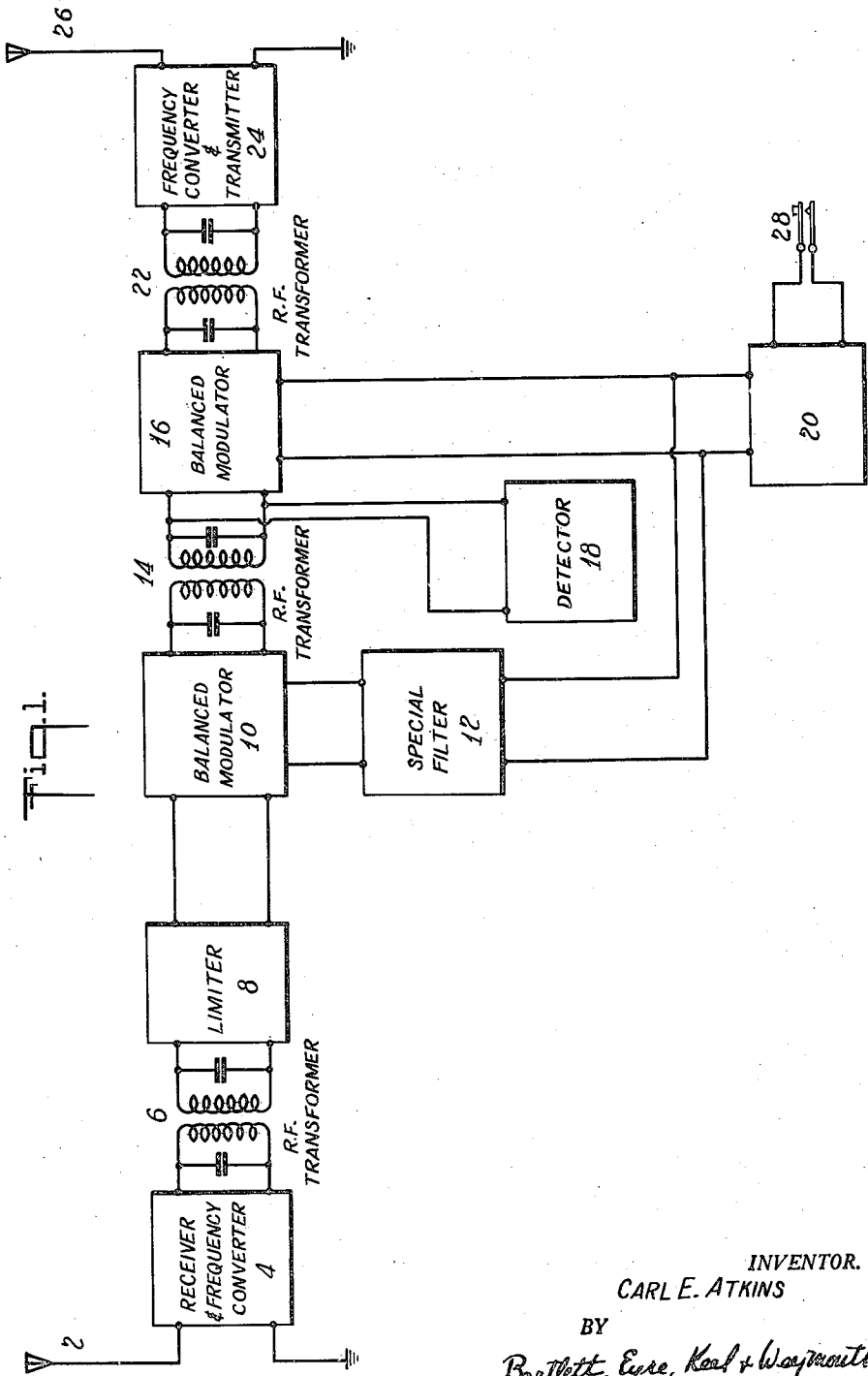
C. E. ATKINS

2,463,503

SECRET SIGNALING SYSTEM

Filed Dec. 9, 1942

3 Sheets-Sheet 1



INVENTOR.
CARL E. ATKINS

BY
Bartlett, Eyre, Keel & Waymouth
ATTORNEYS

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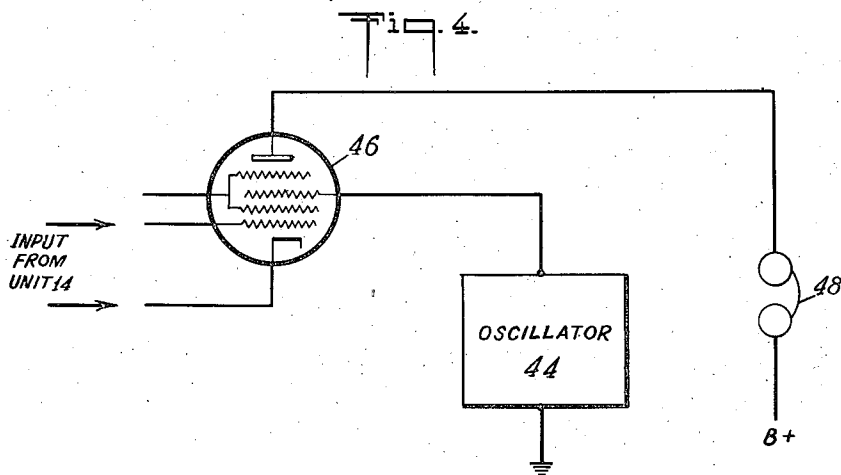
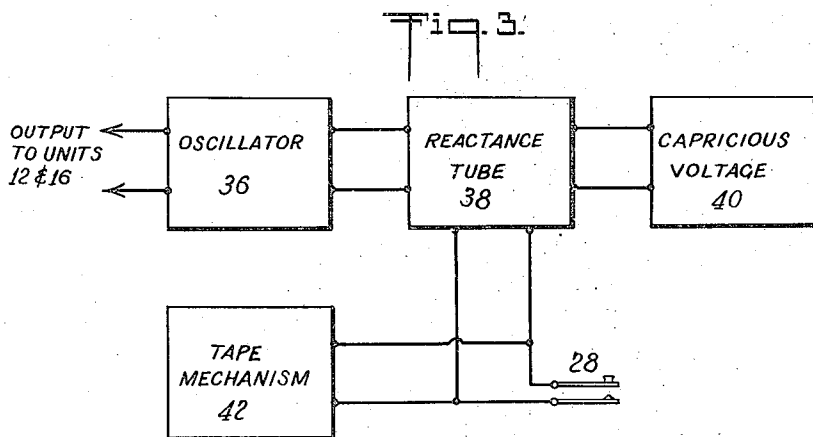
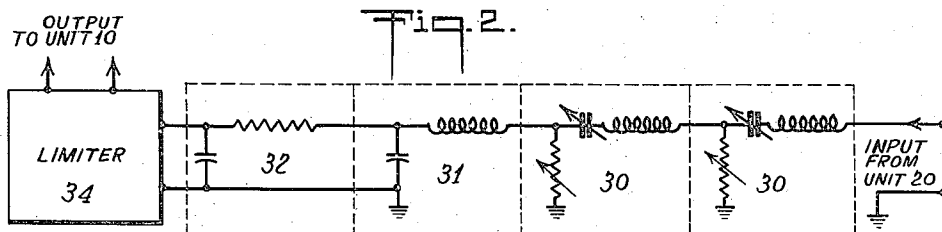
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SECRET SIGNALING SYSTEM

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3 Sheets-Sheet 2



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CARL E. ATKINS

BY
Barthlett, Eyre, Keel & Weymouth
ATTORNEYS

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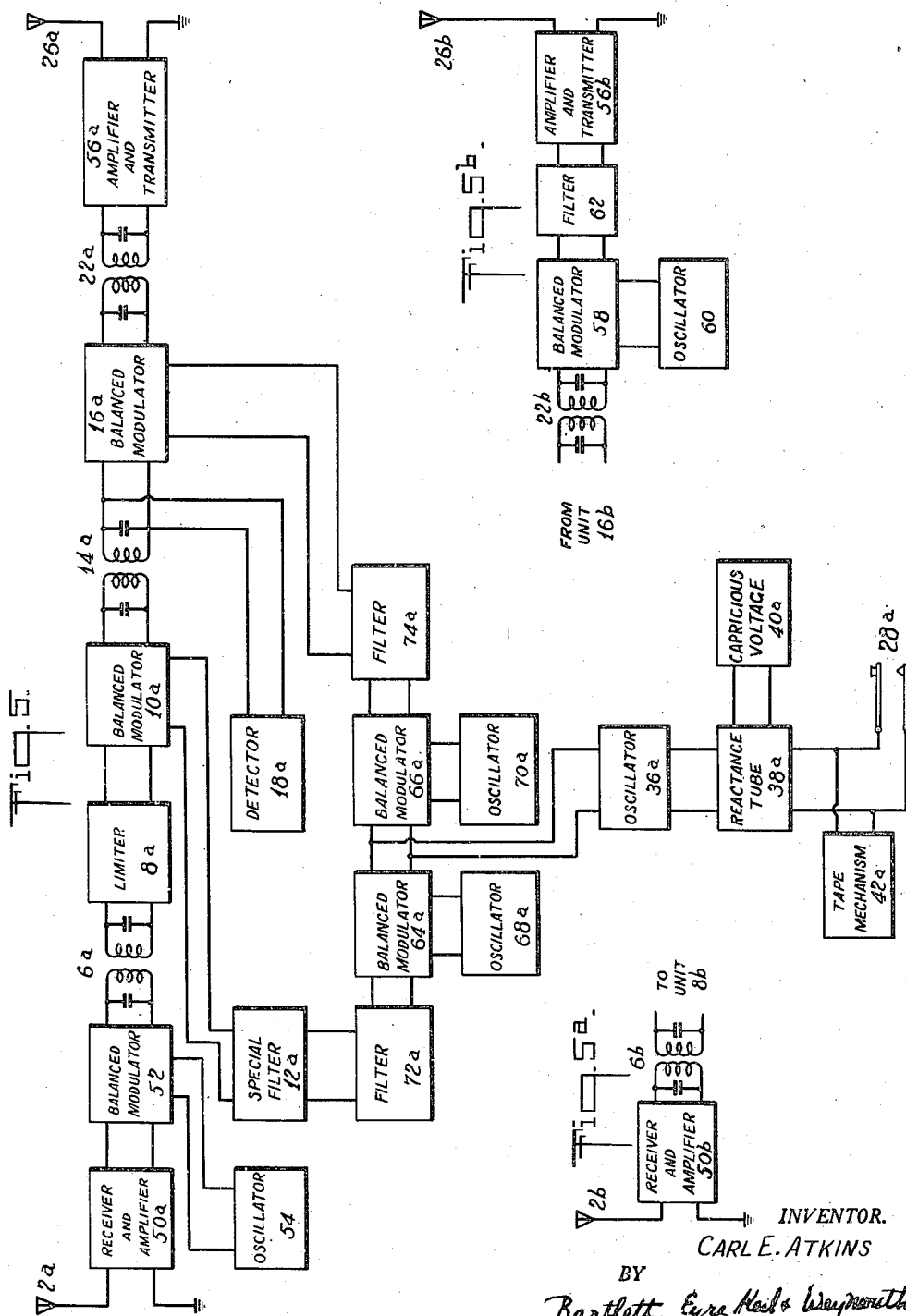
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SECRET SIGNALING SYSTEM

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3 Sheets-Sheet 3



INVENTOR.

CARL E. ATKINS

BY

Bartlett, Eyrre, Hall & Weymouth

ATTORNEYS

UNITED STATES PATENT OFFICE

2,463,503

SECRET SIGNALING SYSTEM

Carl Edward Atkins, Evanston, Ill., assignor to
Tung-Sol Lamp Works, Inc., Newark, N. J., a
corporation of Delaware

Application December 9, 1942, Serial No. 468,345

14 Claims. (Cl. 250-6)

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My present invention relates to radio communication and more particularly to a secret point-to-point communication system of the type disclosed in my prior application Serial No. 443,898, filed May 21, 1942. The present invention comprises improved apparatus and an improved method of operation for insuring against interception of the transmitted signals and comprises also novel means for preventing an enemy compass station from taking a bearing to determine the location of one or the other of the communicating stations. Thus the present system makes possible radio communication under conditions where "radio silence" is now considered necessary. The invention includes also a method of, and means for, correcting for frequency drift of the oscillators at the communicating stations.

Present radio compass apparatus can take a bearing only on a relatively stable carrier. Even when phase or frequency modulation is employed, the center frequency around which the modulation takes place is held with a high degree of stability, and hence the center frequency, from the fact that the instantaneous frequency passes through it with regularity, yields a detectable stable "carrier." The system of the present invention, which is so arranged as to permit of random fluctuation of the signalling carrier, thus substantially eliminates the possibility of detection by enemy compass stations of the location of either of the communicating stations.

In my present system, as in that of my prior application, secrecy is obtained by the use of reciprocal modulation devices; signal energy introduced at one station serving to cross modulate or "scramble" the signal transmitted from the other station. Signal energy introduced at each station returns to the point of introduction into the system before elimination.

For an understanding of the invention, reference may be had to the accompanying drawings, of which

Fig. 1 is a block diagram of the communication apparatus at either of two communicating stations;

Fig. 2 is a diagram of the special filter of Figs. 1 and 5;

Fig. 3 is a diagram of the signal originating apparatus of Fig. 1;

Fig. 4 is a diagram of the signal detecting apparatus of Figs. 1 and 5;

Fig. 5 is a block diagram of the apparatus at one of two communicating stations representing a preferred modification of the invention wherein correction is made for oscillator drift, and

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Figs. 5a and 5b are diagrams representing the receiving and transmitting units respectively of the other communicating station.

In accordance with one embodiment of the present invention, each of the communicating stations will be equipped with the apparatus schematically illustrated in Fig. 1. The corresponding elements of the apparatus at each station may be identical, but preferably, as hereinafter more fully described, there will be a difference in the constants of certain of the corresponding elements to permit of different operating frequencies. The apparatus of Fig. 1 will first be described in general terms applicable to the arrangement at either station. The preferred differences as between the corresponding elements will be made clear in the later explanation of the operation of the system.

In Fig. 1 a receiving antenna 2 is arranged to supply energy to a combined receiver and frequency converter 4. The receiving portion of unit 4 should be so constructed as to be able to pass a relatively wide band of frequencies. The particular width of the band passed, as well as the sensitivity and characteristics of the receiving apparatus is of course a matter of design, but for convenience in description and in order to give a concrete example of the operation of the system, the width of the band passed may be taken as 20 or 30 kc. The converter portion of unit 4 is arranged to change the received signals, which are of the order of a few megacycles, to an intermediate frequency, say of 100 kc. The output of unit 4 is transmitted through a radio frequency transformer 6, having suitable band-pass characteristics, to a limiter stage 8. The limiter 8 may be of any type known to the art, such as a saturated pentode or a pair of diodes. If desired, a limiter circuit of the type disclosed in my earlier filed application Serial No. 425,843, filed January 7, 1942, now Patent No. 2,390,502 granted December 11, 1945, could be utilized herein as unit 8. The output from limiter 8 is fed to one pair of input terminals of a balanced modulator 10; the other pair of input terminals of which receive energy from a special filter 12 hereinafter to be described in connection with Fig. 2. Balanced modulator 10 may be any type known to the art but preferably is of the type disclosed and claimed in my copending application Serial No. 457,807, filed September 10, 1942, now Patent No. 2,441,127 granted May 11, 1948, which insures suppression of the beating frequencies in the output circuit. The energy from limiter 8 heterodynes in

balanced modulator 10 with the energy delivered from filter 12 so that sum and difference frequencies appear at the output terminals of unit 10 are impressed upon a radio frequency transformer 14 which is a band pass circuit passing the difference frequencies only. Thus if the frequency of the energy from filter 12 is around 40 kc., the pass band of transformer 14 will center around 60 kc. Energy from transformer 14 appears at the input terminals of a balanced modulator 16 and concurrently at the input terminals of a detector unit 18 hereinafter more fully described in connection with Fig. 4. In balanced modulator 16, which is preferably of the same type as unit 10, energy from transformer 14 heterodynes with energy of a frequency of about 40 kc. supplied from a unit 20. Unit 20 is the point of origin of the signal to be transmitted and will be hereinafter described in connection with Fig. 3. The sum and difference frequencies from unit 16 are delivered to a radio frequency transformer 22 having band pass characteristics such as to pass the sum frequencies only to a frequency converter and transmitter unit 24. The frequency of the energy delivered to unit 24 is thus of the same order of magnitude as that of the energy delivered by unit 4, that is, about 100 kc. Unit 24 converts the received energy by suitable heterodyning action to a signal frequency of several thousand kilocycles, amplifies the energy and delivers it to a transmitting antenna 26.

The apparatus at one of the communicating stations has now been briefly and more or less broadly described but suggested signaling frequency values have been given. As heretofore indicated, the apparatus at each station could be identical, but for convenience it is preferred to use different operating frequencies for the signal originating in units 20 of the respective station. These frequencies can be the same but, if so, provision has to be made for suppressing the second harmonic of the operating frequency throughout the system. The use of different frequencies thus simplifies the apparatus although it does require a difference in the constants of the elements forming the various networks. Such differences in constants would not, of course, show in the simple block diagram of Fig. 1, which may therefore be considered as representing the apparatus at either station.

Before describing the operation of the system as a whole, the major differences in the constants of the apparatus at the two stations will be indicated by assuming that the numerical values of the frequencies heretofore given apply to one station, say station A, at which the operating signal frequency generated in unit 20 is around 40 kc., and by assuming that the operating signal frequency generated in unit 20 of the other station, say station B, is around 60 kc. (For simplicity, when referring to units at station A and station B, the subscripts *a* and *b* respectively will hereinafter be used.) For the frequency values heretofore given, the converting portion of unit 4b will have such constants as to convert the frequency of received energy to about 100 kc. Transformer 14b will have a pass band centering around 40 kc. and unit 24b will convert energy of a frequency of about 100 kc. to energy of a frequency of several megacycles. Detector unit 18a will be constructed to detect signal energy in the neighborhood of 60 kc. and detector unit 18b will be constructed to detect signal energy in the neighborhood of 40 kc., that is, the detect-

ing unit of one station is responsive to the operating frequency generated at the other station.

The operation of the system of Fig. 1 will be understood from the following description. As in the system of my prior application Serial No. 443,898, filed May 21, 1942, energy introduced at station A is mixed or scrambled with energy received from station B and this mixture is transmitted to station B where it is unscrambled by the balancing out of the energy theretofore transmitted from station B. The signal energy from station A so separated out at station B is mixed or scrambled with continuing signal energy introduced at station B and this new mixture is transmitted to station A where detection of the signal energy introduced at station B is made. Assume, for example, that station A initiates a signal in unit 20a and for convenience call this the "prime signal." Station B also initiates a signal in unit 20b which may or may not carry intelligence but is used for scrambling purposes at station A. For convenience call this latter signal the "secondary signal." When and if this "secondary signal" is applied to balanced modulator 16a it will mix with the "prime signal" from unit 20a to form the "prime mixture" which passes through the radio frequency transformer 22a to the frequency converter and transmitter 24a. The signal radiated by antenna 26a is then the "prime communications signal." At station B, after conversion to the intermediate frequency in units 4b and 6b, demodulation takes place in balanced modulator 10b where the energy from limiter 8b is heterodyned with energy from filter 12b. Filter 12b passes energy from unit 20b but is constructed to delay the passage of such energy for a period of time corresponding to that required for energy to travel from unit 20b through units 16b, 22b, 24b and antenna 26b, through the intervening space to station A, through the apparatus at that station, back to station B and through units 4b, 6b and 8b to balanced modulator 10b. The output, therefore, from unit 10b and transformer 14b will be the "prime signal" only; that is, the signal energy introduced at unit 20a. This "prime signal" is delivered to unit 18b for detection and also to balanced modulator 16b where it is mixed with the continuing "secondary signal" from unit 20b and becomes the "secondary mixture." In transformer 22b this "secondary mixture" is applied to unit 24b where by simple or complex heterodyning it becomes the "secondary communications signal" for radiation from station B. This "secondary communications signal" arrives at antenna 2a and is applied to unit 4a where it undergoes the conversion necessary to pass through limiter 8a to balanced modulator 10a. The energy appearing in radio frequency transformer 6a is, of course, the "secondary mixture." After passing through the balanced modulator 10a, where it is heterodyned with the delayed primary signal from filter 12a, it becomes the "secondary signal" in transformer 14a. From transformer 14a this "secondary signal," that is the signal originating in unit 20b, is applied to detector 18a for detection and to balanced modulator 16a for retransmission to station B after mixture with the continuing signal from unit 20a.

The entire system, including the apparatus at both stations, constitutes an "end-to-end" oscillator where the frequency of oscillation undergoes several changes but is fundamentally determined by certain relationships hereinafter described. The amplitude of oscillation of the

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system is determined by the limiter units 8a and 8b. Additional limiters may of course be placed at other strategic points in the system to prevent overload of any apparatus in the chain.

From the above description it will be apparent that if units 20a and 20b include suitable means for varying the frequency by a few kc. in an irregular manner, as for example by means of a key 28 indicated diagrammatically in Fig. 1, the signals from unit 20a will appear as corresponding increments and decrements of frequency in both the incoming and outgoing communication signals and in the radio frequency transformer 14b and detector 18b. These frequency changes will not appear in radio frequency transformer 14a or detector 18a if filter 12a is properly adjusted. If now concurrent frequency changes are produced in unit 20b these will not interfere with the detection of the signal from station A as they will not appear in detector 18b but will show up at station A at detector 18a. If the frequency changes from unit 20b are irrelevant changes, they will have only the scrambling function, detected of course, but ignored by the operator at station A. They could be intelligible signals and thus a message could be sent simultaneously in both directions. At times the coincidental decrement in the frequency originating in unit 20a may completely mask an increment originating in unit 20b. In this case there would be no change in the frequency of the radiated energy and thus no external evidence that intelligible communication was in progress. If the keyed intelligence produced in the units 18a and 18b consist of differing amounts of frequency increase and frequency decrease, then the two radio frequency carriers serving the two points will have their frequencies varied in a random and capricious manner completely camouflaging an exchanged intelligence and further rendering the task of locating the apparatus by means of compass bearings difficult if not impossible.

In the system of my prior application S. N. 443,898 no attempt was made to change the operating frequency of the cooperating apparatus. This took place on an independent basis and the scrambled signal was applied as amplitude modulation (or frequency or phase modulation) to the respective signalling carriers. It was thus implicit in that arrangement that all intelligence and scrambling frequencies were passed around the chain with negligible phase shift or with a certain definite amount of phase shift that was constant throughout the intelligence and scrambling band widths. If the signalling and scrambling frequencies appear only as modulation on an otherwise stable carrier, and if phase shift throughout their respective operating bands is zero or constant, then such phase shift, if any, can be added to the "phase shift" due to time delay in the transmission space between the communicating stations. In the present system, however, because the operating frequency is being changed it is necessary to introduce reactive phase shift means so that the amount of phase shift will change with the signalling frequency. This will be in addition to the delay means necessary to allow for the fixed phase shift that is independent of the prime signal frequency. The arrangement disclosed diagrammatically in Fig. 2 has been devised, therefore, to insure phase shift change with signal frequency and to provide the necessary delay means between units 20 and 10.

As indicated in Fig. 2, the apparatus, all of which corresponds to unit 12 of Fig. 1, comprises

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a series of like sections or cells 30, in this case two in number, a section or cell 31, a resistance condenser cell 32 and a limiter 34. Each cell 30, of which as many may be used as are found necessary in any particular set-up, comprises an inductance and adjustable condenser in series and an adjustable shunt resistor. By means of the condenser of each cell 30 each cell can be operated at or near the resonant frequency of the signal from unit 20 and by means of the adjustable shunt resistors the output from each cell 30 can be held constant while the magnitude of phase shift is controlled. Cell 31 comprises a simple series resonant circuit of inductance and capacity and serves to provide a higher output voltage to make up for the inevitable attenuation caused by passage through the sections 30. The last section 32 serves to introduce a relatively constant delay compared to the frequency shift. Cell 32 feeds to limiter 34, which is non-reactive and is necessary because of the unavoidable amplitude change occurring with the phase shift when the frequency is changed. Limiter 34 in turn delivers the delayed signal energy to balanced modulator 20 of Fig. 1. The adjustment of the filter sections can be effected manually or automatic means such as disclosed in my prior application S. N. 443,898 could be provided. In practice the main adjustments could be made during manufacture of the equipment, with only minor slight adjustments required when the apparatus was in use, such other adjustments being necessary only to correct for minor changes in the alignment of the apparatus at the other station and to allow for changes in signalling distance.

As previously explained, the sole purpose of the apparatus of Fig. 2 is to delay the application to balanced modulator 10 of the frequency changes originating in unit 20 until such time as these changes have traversed the oscillatory chain and are applied to balanced modulator 10 from limiter 8. I have found from experimental work that this can be done with a remarkable degree of efficacy. If the prime and secondary signals are of the same frequency the apparatus in Fig. 2 will be substantially identical. If these frequencies are different then this apparatus will have correspondingly different constants. I have found that I can obtain very good phase control in this system with a filter of this kind if it is properly aligned. Sometimes it is necessary to stagger the tuned circuits so that the phase shift in the filter corresponds precisely with the kind and degree of phase shift throughout the oscillatory chain.

The apparatus 20 of Fig. 1 is shown in Fig. 3 as including a self-excited oscillator 36 operating at the prime or secondary signal frequency. For the values heretofore given, the frequency of oscillator 36 at station A would be 40 kc. and that at station B 60 kc. A reactance tube 38 serves, when operating, to change the frequency of oscillator 36 by an amount dependent upon the constants of the tube and upon the voltage impressed upon it from a source 40 of capriciously changing voltage. The key 28 serves to close the circuit making the reactance tube operative. An automatic tape mechanism 42 may be substituted for the key in order to utilize automatic sending or to provide irregular keying for scrambling at the other station. Preferably reactance tube 38 is so arranged that when key 28 is depressed a certain minimum frequency change will take place so that the resultant beat will be definitely detectable at the opposite end of the chain. In like

manner the decrement or increment of frequency must be limited to a value not greater than 25% of the total band width of the system, since allowance must be made for simultaneous changes in the same direction initiated in the apparatus 20 at the other station. Unit 40 may be any device the output voltage of which varies in an irregular manner. It might, for example, be a high gain radio frequency pentode such as the 6SD7GT having a high resistance in its control grid circuit.

Suitable detecting apparatus, corresponding to unit 18 of Fig. 1, is diagrammatically illustrated in Fig. 4 as a simple heterodyne system including an oscillator 44 supplying energy to a mixer tube 46 where it beats with energy from R.F. transformer 14 to produce an audio frequency beat detectable in head phones 48. Oscillator 44 is operated at the signalling frequency originating at the other station, that is, for the values heretofore given, at station A oscillator 44a would operate at a frequency of 60 kc. and at station B oscillator 44b would operate at a frequency of 40 kc.

Instead of the simple heterodyne detector illustrated in Fig. 4, other means for detecting the signal, either audibly or visually, could of course be employed.

In the system of Fig. 1 no means are shown or described to correct for undesired changes in the frequency of the oscillators used for frequency conversion of the received or transmitted energy. The effect of such changes, in the system of Fig. 1 are cumulative, as will be apparent from the following.

Assume for simplicity that the frequencies of the energy delivered by units 20a and 20b remain constant at 40 and 60 kc. respectively. Assume further that unit 24a converts the "prime mixture" of a frequency of 100 kc. to energy of a frequency of 2350 kc. by heterodyning the prime mixture with energy from a 2250 kc. oscillator. If the frequency of such oscillator shifts to 2249, the frequency of the "prime communications signal" would then become 2349 kc. At unit 4b at station B the frequency of the incoming signal would therefore be converted to 99 kc. and energy of 99 kc. would be heterodyned in unit 24b with energy from, for example, an 1850 kc. oscillator and radiated as the "secondary communications signal" at a frequency of 1949 kc. At station A the frequency of the incoming signal would be again converted in unit 4a to energy of 99 kc. and thereafter energy of 99 kc. would heterodyne in unit 24a with energy from the oscillator thereof still operating at 2249 kc. The result would be a further decrement of 1 in the radiated signal from station A. Thus with each complete transit of the signal energy about the loop comprising the two stations and the space therebetween the frequency of the radiated signal and that of the intermediate frequencies would be further decreased so long as the oscillator associated with unit 24a continued to operate at the frequency of 2249 kc. instead of 2250. If such condition lasted too long the frequency of the energy applied to any of the filter circuits might drop below the pass bands thereof, thus, temporarily at least, interfering with the operation of the system. The same is true, of course, as to the other oscillators of the system. This condition could be corrected by provision of known means for stabilizing the frequency of the various oscillators. A more practical and the preferred arrangement, however, is disclosed in Figs. 5, 5a and 5b wherein automatic correction is made for oscillator drift and to which reference may now be had.

The apparatus disclosed diagrammatically in Fig. 5 is that at one station, say station A. The equipment at station B will be identical except for the receiving and transmitting portions, which are shown respectively in Figs. 5a and 5b and except for such differences in the elements as are required by the use of different signal frequencies in the units corresponding to unit 20 of Fig. 1. As the apparatus of Fig. 5 is in many respects like that of Fig. 1 like reference numbers are given to like units of the system; the subscript "a" being used to indicate station A equipment and the subscript "b" being used to indicate station B equipment. In Fig. 5 the unit 50a is a receiver and amplifier receiving energy from antenna 2a and delivering energy to a balanced modulator 52 where it heterodynes with energy from an oscillator 54. Radio frequency transformer 6a having a pass band centered to pass the difference frequencies from unit 52, delivers the converted energy through limiter 8a to balanced modulator 10a where it heterodynes with delayed signal energy from special filter 12a as in the circuit of Fig. 1. Also, as in Fig. 1 energy from unit 10a, after passing through R. F. transformer 14a which passes the difference frequencies only, is delivered to detector 18a and to balanced modulator 16a as the "secondary signal" where it heterodynes with the "prime signal" energy. Radio frequency transformer 22a, passing the sum frequencies only, delivers the "prime mixture" to an amplifier and transmitter 56a for delivery to the transmitting antenna 2a without further frequency conversion. At station B the "prime mixture" is received by a receiver and amplifier 50b and delivered directly thereby to the radio frequency transformer 6b as indicated in Fig. 5a. After passage through the units of station B corresponding to those of station A, the "secondary mixture" appears at one pair of input terminals of a balanced modulator 58 (Fig. 5b), where it heterodynes with energy from an oscillator 60. Energy from unit 58 is passed through a filter 62 which passes the sum frequencies to the amplifier and transmitter 56b for delivery to the transmitting antenna 26b.

Before describing the equipment at each station for applying the signal energy to the balanced modulators 10 and 16, the method by which the apparatus so far described corrects for oscillator drift will be described. For convenience, the same numerical values of frequencies heretofore used in explaining the operation of the system of Fig. 1 will be used, that is, the intermediate frequency will be taken as about 100 kc. of which 40 kc. is attributable to the "prime signal" and 60 kc. to the "secondary signal." The frequency of the "secondary communications signal" will be taken as about 1950 kc. With these values oscillator 54 at station A will be a 2050 kc. oscillator and oscillator 60 at station B will be an 1850 kc. oscillator. Thus there is addition of frequencies at one station and subtraction at another. Thus increments of frequency at one point become decrements of frequency at another point and a slight discrepency in one or another of the beating oscillators 54 and 60 cannot initiate a frequency gambit because the returning signal would be off in the opposite direction, thus compensating for the original error. This will be apparent from the following wherein, as before, we assume the frequencies of the prime and secondary signals as constant. Assume, for example that the frequency of oscillator 54 drops to 2049 kc., then the frequency of the energy passed by units 6a

and 8a would be 99 kc. as would be that of the energy transmitted to station B and that of the energy beating in unit 58 with that from oscillator 60. Accordingly filter 62, passing the sum frequencies, would pass energy of 1949 kc. which would be transmitted back to station A. Thus energy of 1949 kc. beating in unit 52 with energy from oscillator 50, still delivering energy of 2049 kc. instead of 2050 kc. would be converted after passing through unit 6a to 100 kc., the desired value. Thus the discrepancy introduced by oscillator 54 is automatically compensated for.

With the above described arrangement it is apparent, however, that desired changes in signal frequency will also come back inverted and hence the delayed signal energy cannot be applied as in Fig. 1 to balanced modulator 10a or 10b, as the frequency changes thereof must be inverted before application thereto. One arrangement for so inverting the frequency changes of the signal energy is shown in Fig. 5. In Fig. 5 units 36a, 38a, 40a, 42a, and key 28a correspond to the parts of unit 20 of Fig. 1 shown in Fig. 3, and hence need no further description. Oscillator 36a, however, will be a 120 kc. oscillator, instead of a 40 kc. oscillator for the frequency values of the system hereinbefore assumed, and oscillator 36b will be a 180 kc. oscillator instead of a 60 kc. oscillator. As shown in Fig. 5, the output from oscillator 36a is delivered in parallel to a pair of balanced modulators 64a and 66a. In unit 64a the energy from oscillator 36a beats with energy from an oscillator 68a and in unit 66a energy from oscillator 36a beats with energy from an oscillator 70a. Oscillator 68a is a 160 kc. oscillator and oscillator 70a is an 80 kc. oscillator. The output from unit 64a is fed to the special delay filter 12a through a filter 72a having a pass band centering at 40 kc. and the output of unit 66a is fed to balanced modulator 16a through a similar filter 74a. With this arrangement if the frequency from oscillator 36a increases to 122 kc., for example, due to operation of key 28a, the frequency at the output of filter 72a becomes 38 kc. or 160 minus 122, and the frequency at the output of filter 74a becomes 42, or 122 minus 60. Thus increments and decrements in the frequency of the energy from oscillator 36 caused by operation of key 28a appear as increments and decrements respectively in the energy delivered to balanced modulator 16a but as decrements and increments respectively at the input to balanced modulator 10a. In the corresponding apparatus at station B oscillator 36b is a 180 kc. oscillator, oscillator 68b is a 240 kc. oscillator, oscillator 70b is a 120 kc. oscillator and filters 64b and 74b have pass bands centering at 60 kc.

From the above description it will be apparent that the system of Figs. 5, 5a and 5b differs from that of Figs. 1 and 3 in three respects. First by the provision of means for insuring one frequency inversion in the entire system, second in the provision of means for insuring inversion of the frequency changes of delayed signal energy applied to the back balanced modulator of each station, and third, in the omission of one heterodyning operation at each station by radiating the prime mixture without prior conversion to a higher frequency. Of these three differences in the system the first two are concerned with the prevention of frequency drift due to changes in oscillator frequency and the third is merely a simplification that could equally well be employed in the system of Fig. 1. For that matter, if desired, means could be provided, in the system

of Fig. 5, for converting the prime mixture to a higher communications frequency by heterodyning. This would not introduce any undue complications affecting the stabilizing requirements provided the additional oscillators employed for the conversion were kept at each point on the same side of the signal. That is, if a communications signal frequency of say 2350 kc. were desired and if this frequency is obtained by beating the 100 kc. prime mixture with energy from a 2250 kc. oscillator at the transmitter of station A, then an oscillator of the same frequency, that is, 2250 kc. must be used at the receiver at station B to reconvert to 100 kc. If the oscillator at station B were 2450 kc. a second inversion in the system would take place and the beneficial results of the first inversion would be nullified. The provision of the additional heterodyning process, if applied, as above indicated, to the same side of the signal, would not create instability as one inversion in the total system is sufficient to erase slight errors occurring anywhere.

In the description of the system of Figs. 5, 5a and 5b, the frequency of the radiated prime mixture has been given as 100 kc. and that of the secondary communications signal as 1950 kc. These values were given because they had been used in connection with the description of Figs. 1 to 4, and therefore were useful in simplifying the description of Fig. 5 and in bringing out the points of similarity and the points of difference in the two systems. These frequencies of 100 kc. and 1950 kc. are widely separated and inharmonically related and hence obviously a substantially higher frequency for the prime mixture would be used in practice. Also, although the system of Figs. 5, 5a and 5b has been described as one in which the prime mixture is radiated while the secondary mixture is converted to a higher frequency for radiation, the system is equally arranged for radiation of the secondary mixture and heterodyning of the prime mixture as this is only a matter of nomenclature. That is, Fig. 5 could represent station B and Figs. 5a and 5b apparatus at station A. In the system as described the frequency of the heterodyning oscillator 60 at station B was given as below the communications signal frequency, while that of oscillator 54 at station A was given as above this frequency. That is for a transmitted frequency of 1950 kc. oscillator 60 was stated to be an 1850 kc. oscillator and oscillator 54 was stated to be a 2050 kc. oscillator. Obviously the system would operate equally as well if the frequencies of these oscillators were interchanged; the requirement merely being that they operate on opposite sides of the transmission frequency.

The improved secret signalling system has now been described in connection with two specific embodiments thereof, each arranged for transmission of telegraph signals. The systems as shown, with modifications which would be apparent to those skilled in the art, could be adapted for telephony. Also, while certain of the features of my prior application Serial No. 443,898 have not been specifically discussed herein, they could be advantageously employed with the present systems. For example, the means disclosed therein for automatically or manually bypassing the scrambling and unscrambling devices during initiation of communication could be employed in the present systems. Such means are useful in determining whether or not communication between the points is possible and also in adjusting the apparatus. Such means, however,

where telegraph signals are involved, are not essential as I have found that end-to-end contact based on all the heterodyning processes indicated can be brought about spontaneously in the same manner as in any proper oscillatory system. Also, in the present disclosure, no means have been described or illustrated for keeping energy radiated from the transmitting antenna out of the receiving antenna at that station. Unless the transmitting frequencies of the two stations are substantially different shielding or other means should of course be provided. Preferably the arrangement disclosed in a copending application Serial No. 449,256, filed July 1, 1942, now Patent No. 2,426,581 granted September 2, 1947, should be employed, as that arrangement permits of concurrent transmission and reception without interference, even when the frequencies of transmission and reception are identical.

In the above description specific values of the signalling and transmitting frequencies have been suggested. These have been given merely as an aid to the understanding of the invention and should not be taken as a limitation thereto. For example, instead of signalling frequencies of tens of kc., frequencies of several hundreds kc. could be employed and the frequencies at each station although preferably different could be the same. I claim:

1. A secret station-to-station communication system comprising in combination means at each station for introducing energy, means at each station for scrambling the energy introduced at that station with the energy introduced at the other station, and controllable means at each station for unpredictably varying the frequency of the energy introduced at that station.

2. A secret station-to-station communication system comprising in combination means at each station for introducing energy, means at each station for scrambling the energy introduced at that station with the energy introduced at the other station, and controllable means at each station for unpredictably varying the frequency of the energy introduced at that station, including means at each station for producing a delayed replica of the energy introduced at that station, said means including adjustable networks for introducing reactive phase shift to compensate for phase shift due to the changes in frequency of the introduced energy.

3. A secret station-to-station communication system comprising in combination means at each station for introducing energy, means at each station for scrambling the energy introduced at that station with the energy introduced at the other station, and controllable means at each station for unpredictably varying the frequency of the energy introduced at that station, means including an oscillator being provided at one station for converting the scrambled energy to a higher frequency for radiation to the other station and wherein means also including an oscillator is provided at the other station for converting the frequency of the received energy to the frequency of the scrambled energy of the first station, said oscillators having operating frequencies on opposite sides of the frequency of the radiated energy whereby frequency changes in the radiated energy due to a shift in the operating frequency of either oscillator are compensated for.

4. In a secret station-to-station communication system the combination comprising a re-

ceiver and transmitter at each station, a frequency converter including an oscillator associated with the transmitter at one station and a frequency converter including an oscillator associated with the receiver at the other station, said oscillators having operating frequencies on opposite sides of the frequency of the energy radiated from the first station, means at each station to introduce signal energy of capriciously varying frequency, means at each station for producing a delayed replica of the signal energy introduced at that station with the capricious frequency variations thereof inverted, means at each station for utilizing said delayed replica for separating out from the energy received by the receiver the signal energy introduced at the other station, and means at each station for utilizing such separated energy for scrambling the signal energy introduced at that station.

5. In a secret station-to-station communication system the combination comprising a receiver and transmitter at each station, a frequency converter including an oscillator associated with the transmitter at one station and a frequency converter including an oscillator associated with the receiver at the other station, said oscillators having operating frequencies on opposite sides of the frequency of the energy radiated from the first station, means at each station to introduce signal energy of capriciously varying frequency, means at each station for producing a delayed replica of the signal energy introduced at that station with the capricious frequency variations thereof inverted, means at each station for utilizing said delayed replica for separating out from the energy received by the receiver the signal energy introduced at the other station, and means at each station for utilizing such separated energy for scrambling the signal energy introduced at that station, said means at each station for producing a delayed replica of the signal energy including adjustable networks for introducing reactive phase shift to compensate for phase shift due to the changes in frequency of the introduced signal energy.

6. In a secret station-to-station communication system the combination comprising a receiver and transmitter at each station, a frequency converter including an oscillator associated with the transmitter at one station and a frequency converter including an oscillator associated with the receiver at the other station, said oscillators having operating frequencies on opposite sides of the frequency of the energy radiated from the first station, means at each station to introduce signal energy of capriciously varying frequency, means at each station for producing a delayed replica of the signal energy introduced at that station with the capricious frequency variations thereof inverted, means at each station for utilizing said delayed replica for separating out from the energy received by the receiver the signal energy introduced at the other station, and means at each station for utilizing such separated energy for scrambling the signal energy introduced at that station, said means at each station for introducing signal energy and for producing a delayed replica thereof including a source of energy, the frequency of which is capriciously variable about a fixed value, a pair of oscillators producing energy having frequencies above and below said fixed value and departing equally therefrom, a device for heterodyning energy from said source with energy

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from one of said oscillators, a device for heterodyning energy from said source with energy from the other of said oscillators, whereby energies delivered by both said devices have frequencies capriciously varying about the frequency difference between said fixed value and that of either of said oscillators and the variations of the frequency of the energy from one of said devices is inverted relative to the variations of the frequency of the energy from the other of said devices, and means for delaying the energy from one of said devices for providing the delayed replica, with inverted frequency variations, of the energy from the other of said devices.

7. In a station-to-station secret communication system the combination comprising a transmitter and a receiver at each station, a source of signal energy at each station and controllable means for capriciously varying the frequency of the energy delivered thereby, means at each station for producing a delayed replica of said signal energy and for utilizing the same to separate from the energy received by the receiver at one station the signal energy introduced at the other station, a detecting device at each station connected to receive such separated energy, means at each station for scrambling such separated energy with signal energy introduced at that station and means for delivering such scrambled energy at each station to the transmitter thereof for radiation to the other station.

8. In a station-to-station secret communication system the combination comprising a transmitter and a receiver at each station, a source of signal energy at each station and controllable means for capriciously varying the frequency of the energy delivered thereby, means at each station for producing a delayed replica of said signal energy and for utilizing the same to separate from the energy received by the receiver at one station the signal energy introduced at the other station, a detecting device at each station connected to receive such separated energy, means at each station for scrambling such separated energy with signal energy introduced at that station and means for delivering such scrambled energy at each station to the transmitter thereof for radiation to the other station, the source of signal energy at each station including an oscillator having a predetermined operating frequency and said controllable means for capriciously varying the frequency of said source including a reactance tube, operative when energized to vary the frequency of said oscillator, a source of capricious voltage for energizing said tube and manually controlled means for connecting said last mentioned source with said tube, and wherein said detecting devices each includes an oscillator, the oscillator of the detecting device at one station having the same operating frequency as the oscillator of said first mentioned source at the other station.

9. In a station-to-station secret communication system the combination comprising a transmitter and a receiver at each station, a source of signal energy at each station and controllable means for capriciously varying the frequency of the energy delivered thereby, means at each station for producing a delayed replica of said signal energy and for utilizing the same to separate from the energy received by the receiver at one station the signal energy introduced at the other station, a detecting device at each station connected to receive such separated energy, means at each station for scrambling such

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separated energy with signal energy introduced at that station and means for delivering such scrambled energy at each station to the transmitter thereof for radiation to the other station, said means at each station for producing a delayed replica of the signal energy including a series of networks each including an inductance and an adjustable capacitance connected in series, and adjustable resistors serving to couple the networks together, said networks serving to introduce reactive phase shift in said replica signal to compensate for phase shift due to changes in frequency of the signal energy.

10. The method of secret signalling between two stations which comprises introducing signal energy at each station, controllably causing the frequency thereof to vary capriciously and scrambling such energy at one station with the energy introduced at the other station.

11. The method of secret signalling between two stations which comprises introducing signal energy at each station, controllably causing the frequency thereof to vary capriciously and scrambling such energy at one station with the energy introduced at the other station, including obtaining a delayed replica of the signal energy introduced at one station by applying a reactive phase shift to a portion of the signal energy to compensate for frequency changes in the signal energy, then adding a fixed phase shift to such portion to compensate for the distance between stations and for the time taken for passage through the apparatus at each station and finally utilizing such delayed replica for unscrambling the energy received at the station to detect signal energy introduced at the other station.

12. The method of secret signalling between two stations which comprises introducing signal energy at each station, controllably causing the frequency thereof to vary capriciously and scrambling such energy at one station with the energy introduced at the other station, including converting the scrambled energy at one station to a higher frequency for transmission to the other station, reconvertng at the other station the transmitted energy upon receipt thereof to the frequency of the scrambled energy at the first station and utilizing oscillators for such frequency conversions having operating frequencies above and below the frequency of transmission to prevent frequency drift.

13. The method of secret signalling between two stations which comprises introducing signal energy at each station, controllably causing the frequency thereof to vary capriciously and scrambling such energy at one station with the energy introduced at the other station, including deriving at each station a delayed replica, with the frequency changes inverted, of the signal energy introduced at that station and utilizing such replica at that station for detecting the signal energy introduced at the other station.

14. The method of secret signaling between two stations which comprises introducing signal energy at each station, scrambling such energy at one station with the signal energy introduced at the other station, supplying at one station energy of a fixed frequency, utilizing said supplied energy for converting by heterodyne action the scrambled signal energy to a higher frequency for transmission to the other station, supplying at the other station energy of a frequency on the opposite side of the transmission band from that supplied at the first station and

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utilizing such energy supplied at the second station for reconvertng by heterodyne action the converted scrambled signal energy received at that station.

CARL EDWARD ATKINS.

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REFERENCES CITED

The following references are of record in the file of this patent:

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Certificate of Correction

Patent No. 2,463,503.

March 8, 1949.

CARL EDWARD ATKINS

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 3, line 4, before the word "are" insert *and*; column 6, line 25, for the numeral "20" read *10*; line 71, for the indistinct numeral after the word "tube" read *38*; column 12, line 9, claim 4, for "capricously" read *capriciously*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 6th day of September, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.