July 19, 1949. R. H. VARIAN 2,476,337

SECRET RADIO COMMUNICATION

Filed Jan. 22, 1943

5 Sheets-Sheet 1

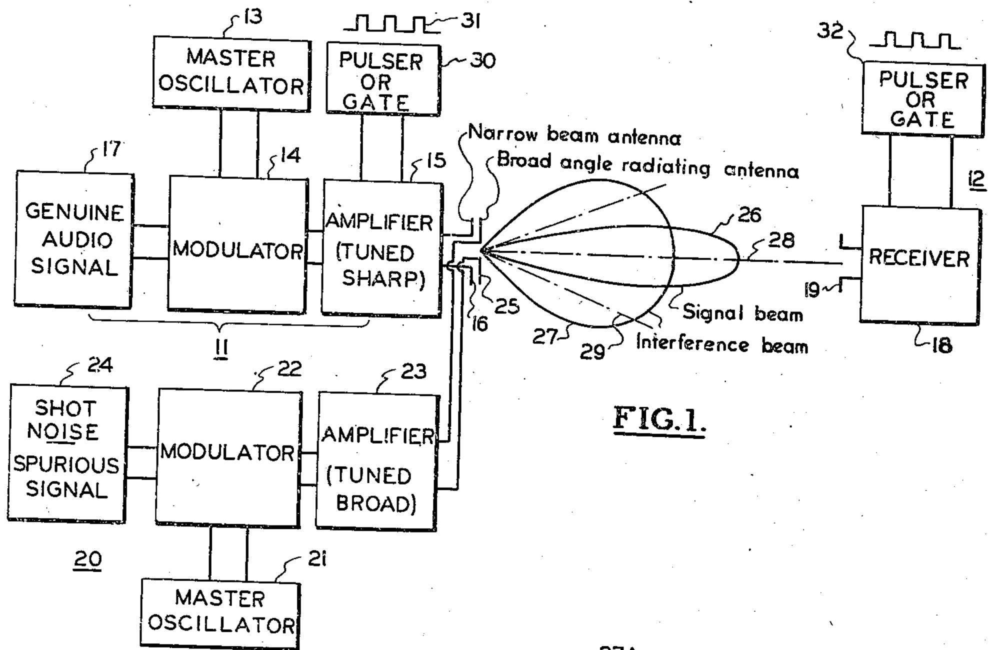

FIG. 1.

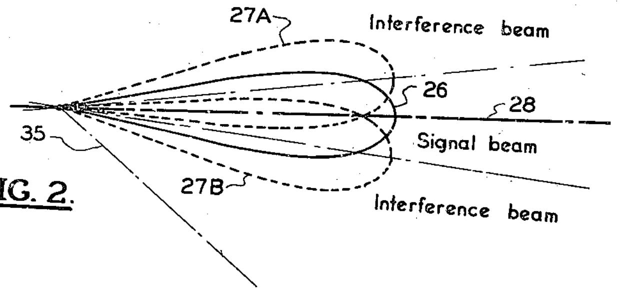

FIG. 2.

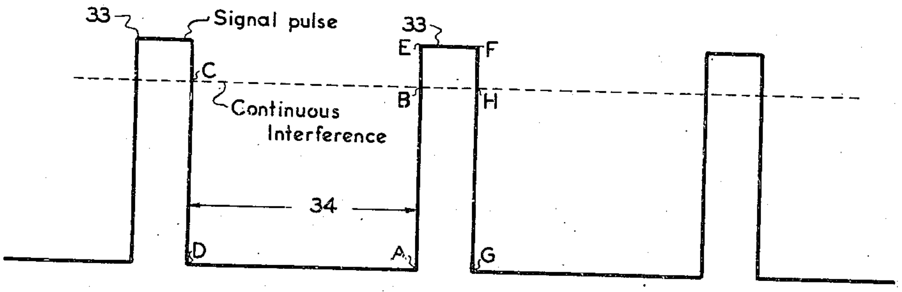

FIG. 3.

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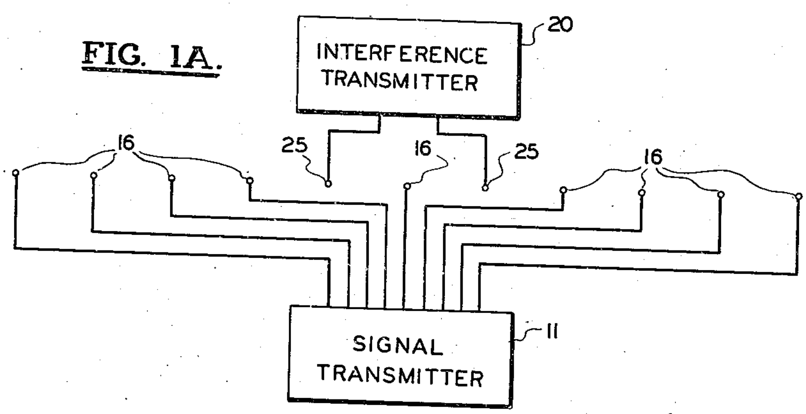
FIG. 1A.



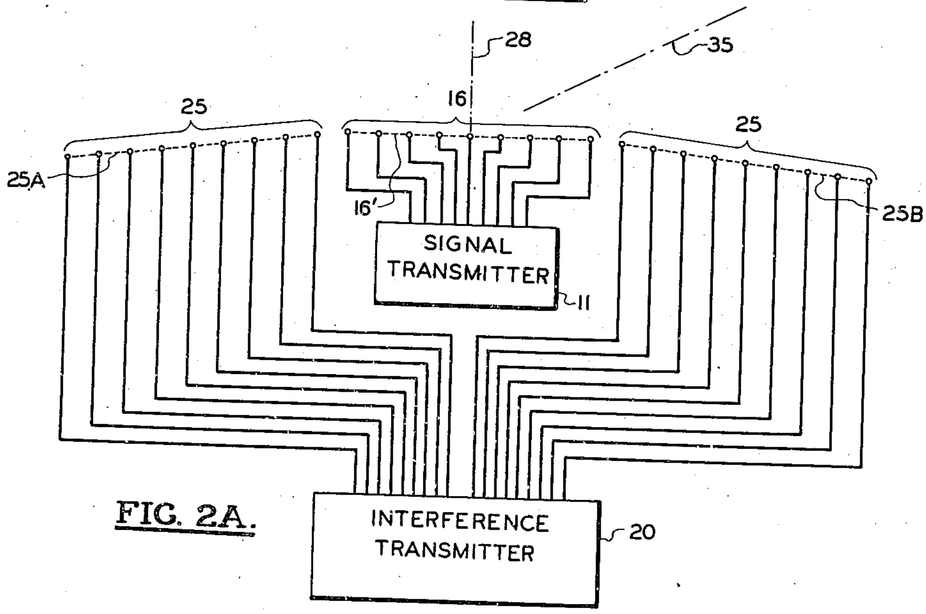


FIG. 2A.

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2,476,337

SECRET RADIO COMMUNICATION

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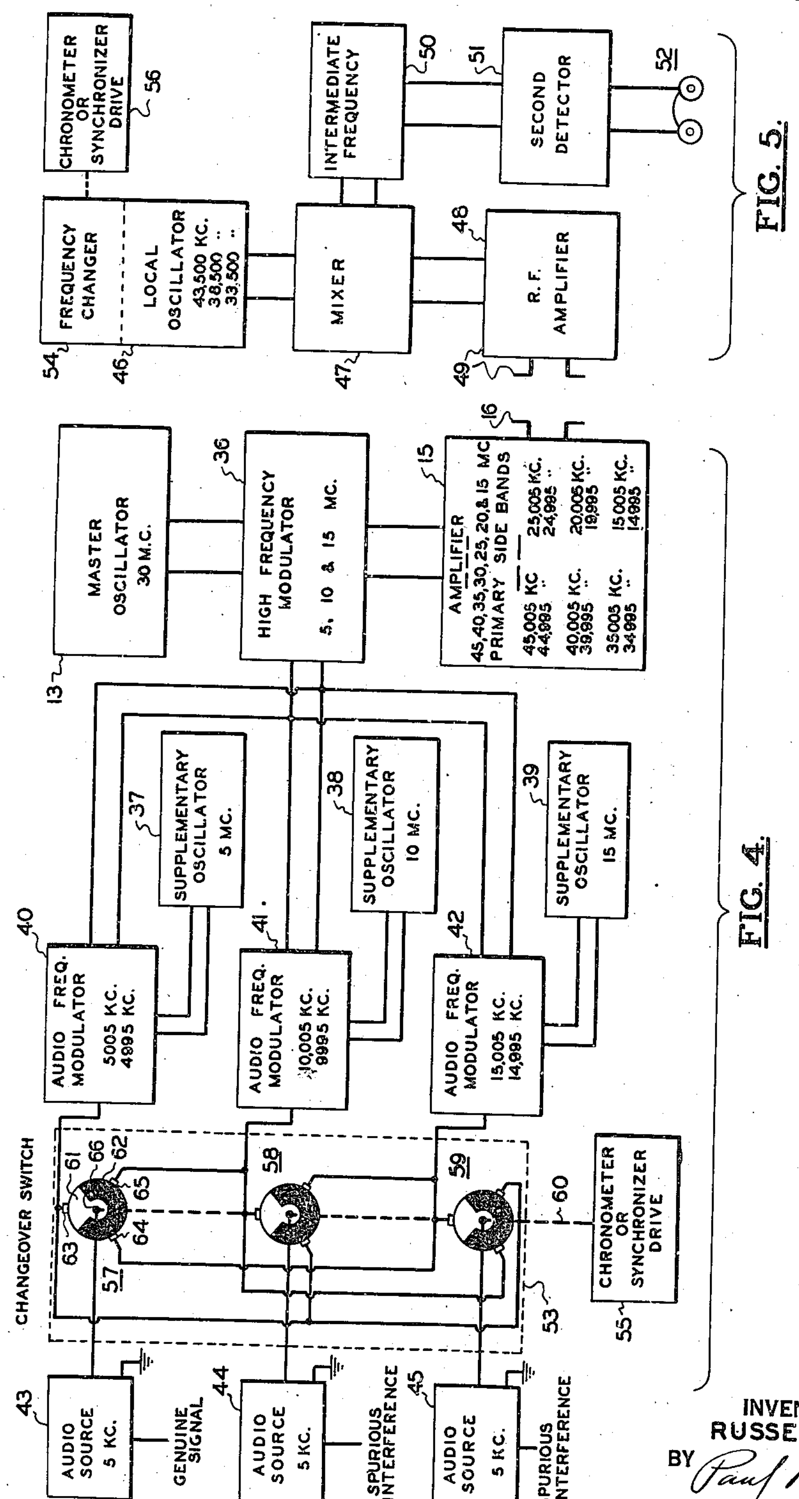

FIG. 5.

FIG. 4.

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July 19, 1949. R. H. VARIAN 2,476,337

SECRET RADIO COMMUNICATION

Filed Jan. 22, 1943

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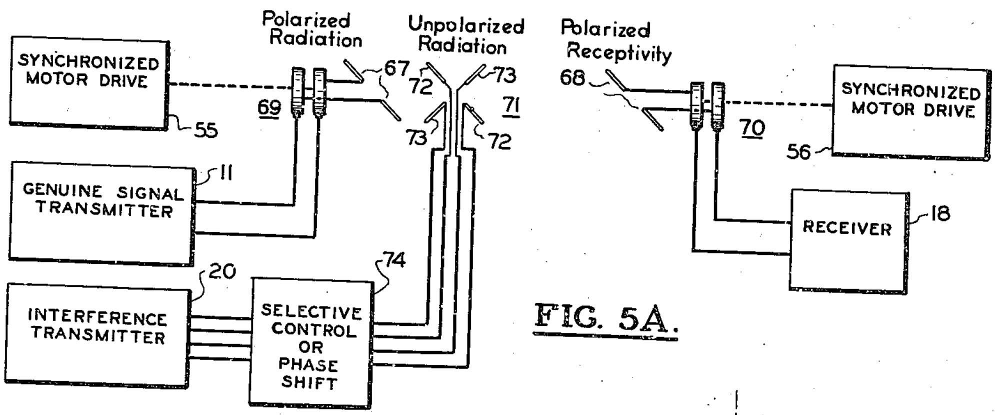

FIG. 5A.

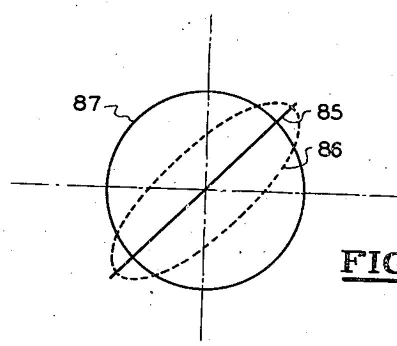

FIG. 7.

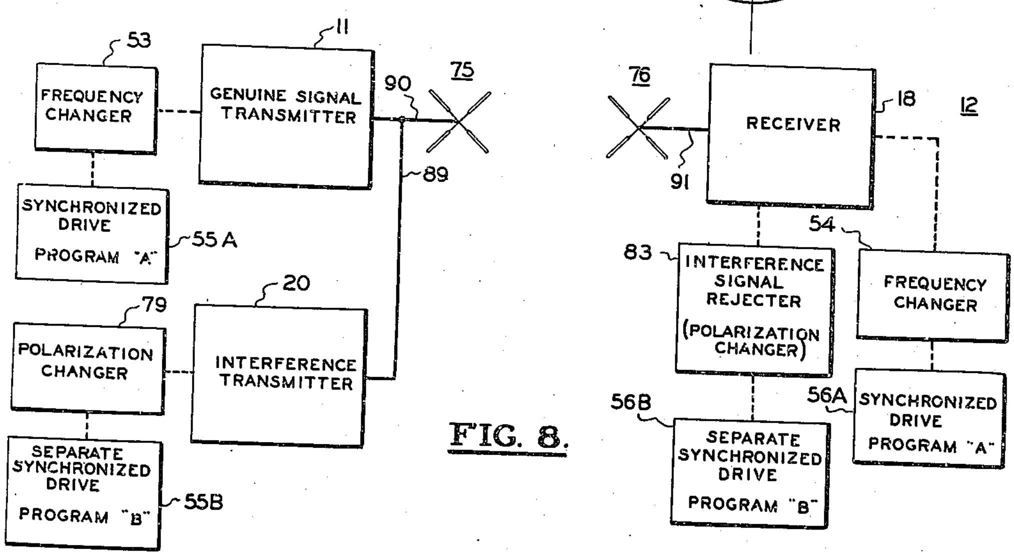

FIG. 8.

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July 19, 1949. R. H. VARIAN 2,476,337

SECRET RADIO COMMUNICATION

Filed Jan. 22, 1943 5 Sheets-Sheet 5

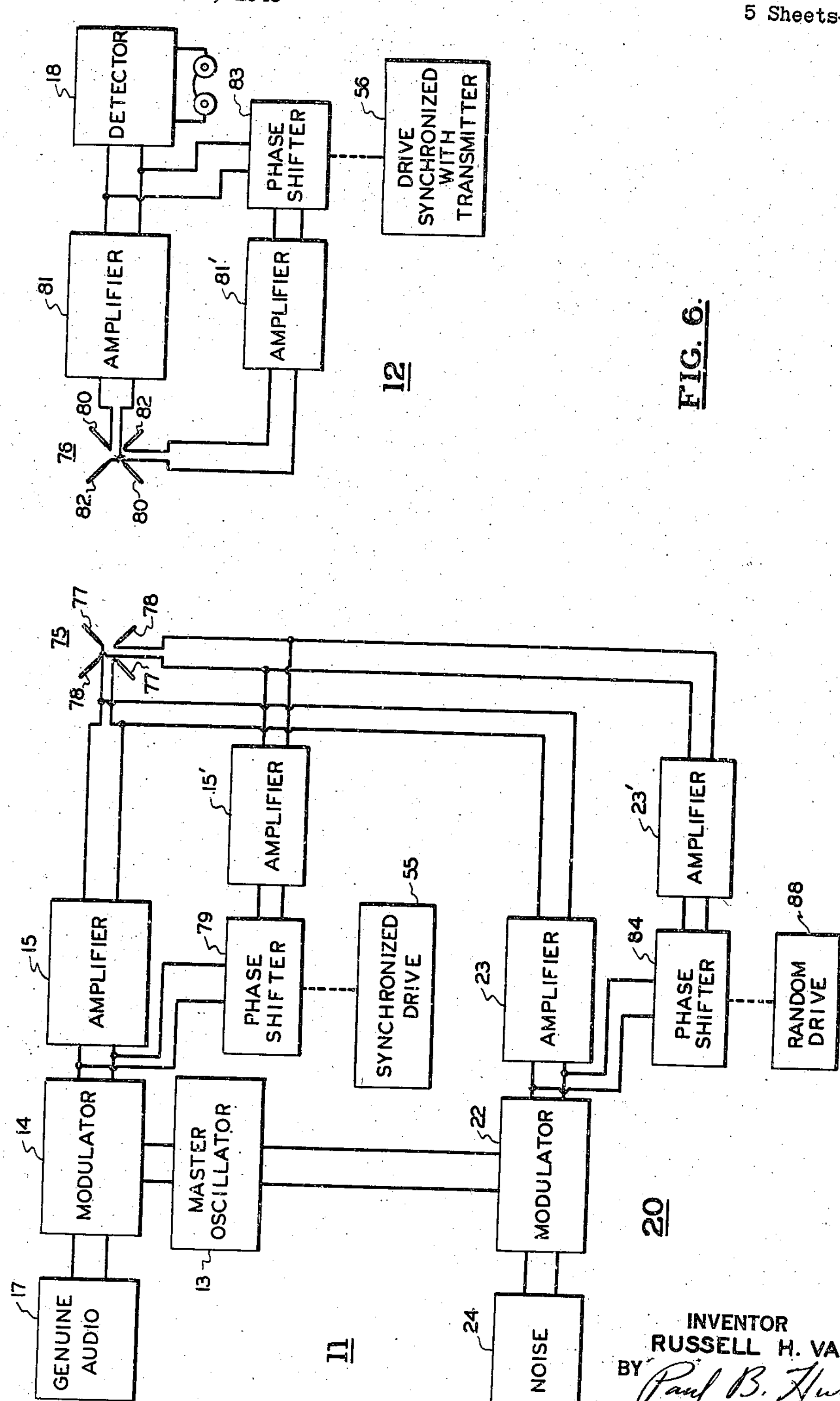

FIG. 6.

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Patented July 19, 1949

2,476,337

UNITED STATES PATENT OFFICE

2,476,337

SECRET RADIO COMMUNICATION

Russell H. Varian, Wantagh, N. Y., assignor to The Sperry Corporation, a corporation of Delaware

Application January 22, 1943, Serial No. 473,266

5 Claims. (Cl. 250—6)

1

My invention relates to systems of communication, apparatus therefor and methods of communication, and concerns particularly systems of radio communication.

An object of my invention is to provide secrecy in communication, with methods and apparatus for enabling only authorized listeners to receive either telephone or telegraphic communications.

A further object is to provide a secret system in which authorized listeners may receive directly and without loss of time for decoding.

In radio communication, the reception of signals by unauthorized or undesired listeners may be made difficult by transmitting the communications in as narrow a band of radio frequencies as possible in order to make it difficult for the undesired listeners to find the proper band on which to listen. In a case of radio telephone communication, for example, the band width may be reduced to 3000 cycles or less, although excessive compression of the band interferes with the quality of the reception and increases the difficulty encountered by authorized listeners in obtaining intelligible signals.

Furthermore, the difficulty of undesired listeners in receiving the signals may be increased by causing the signal level to rise relatively little above the noise level at the point of reception. In this case, however, the noise level is relatively fixed at various points of reception and unauthorized listeners close to the point of transmission will receive signals well above the noise level of their receivers. Thus merely holding the signal level down to a point slightly above the noise level at the desired point of reception would be ineffective in eliminating reception by undesired listeners at other points which are closer or more advantageously located, so that at such points the signal level is substantially higher than the noise level.

Compression of the signal to a narrow frequency band and holding the signal level down to the minimum necessary for reception by authorized listeners tend to make the discovery of signals by undesired listeners more difficult but do not prevent satisfactory reception of such signals after they have been found and may not prevent the discovery of such signals by skillful operators.

It is accordingly an object of my invention to provide methods and apparatus for both preventing the discovery of signals and preventing the reception of signals by undesired listeners regardless of the skill of the receiving operators

2

or the perfection of the receiving equipment with which they are provided.

In carrying out my invention in its preferred form, in order to make it equally difficult for an undesired listener to find the signal in either an advantageous or disadvantageous location, I provide means for transmitting interference or noise together with the genuine signal so that the ratio of signal level to noise level will be substantially the same throughout the area within which undesired listeners may attempt to pick up signals. In order to increase further the difficulty of undesired listeners in finding the signal, I utilize a system of transmission in which the transmission of genuine signals is relatively narrow or sharp and the transmission of interference, noise or spurious signals is relatively broad. I may resort to difference in breadth of transmission of the genuine signals and the interference in one or more of several different respects, such as with respect to space, frequency or time, for example. Thus I may use a highly directive radiator for transmitting the genuine signals over a very narrow angle of azimuth and simultaneously use a broader angle radiator for transmitting spurious signals or interference over a very wide angle so that at very nearly every point except at points in the line of the authorized receiver, the interference level will be as high as or considerably higher than the genuine signal level.

With respect to frequency, I may transmit the genuine signal from a very sharply tuned transmitting system, or I may confine the genuine signal to a very narrow band of frequencies; whereas the interference signals are transmitted over a very wide band, so that an unauthorized listener resorting to a wide band receiver to find the signal would encounter high noise levels and will hear only interference at every setting of his receiver.

For instance, if a channel 3,000 cycles wide is reserved for the signal, and the noise level is such that a wider band receiver cannot be used, and the signal is anywhere between 3×10^9 and 6×10^9 cycles, (5–10 cm. wave length) the unauthorized listener would have to search through 10^7 reception bands. If the searcher spent only one-tenth second per band, it would take days to make the search.

Of course it would take a great deal of power to spread noise over such a band width. Hence, in practice, an operator would not go to such extremes, but would change the transmission frequency at frequent intervals according to a pre-arranged plan so that the search time would be much longer than the time spent on one frequency.

Furthermore, with respect to distribution of signals in time, I may utilize a pulse transmitter in combination with a receiver which is sensitive only during the intervals corresponding to the pulses of the transmitter for the transmission of genuine signals. Simultaneously, I may transmit interference either continuously or over much longer pulses so that a receiver which is not designed for reception during the same pulse intervals as the authorized receiver will have its reception blanketed by the interference.

A better understanding of my invention will be afforded by the following detailed description considered in connection with the accompanying drawings and those features of my invention which are believed to be novel and patentable will be pointed out in the claims appended hereto.

In the drawings,

Fig. 1 is a schematic diagram or block diagram of apparatus forming one embodiment of my invention.

Fig. 1A is a schematic diagram of an antenna array which may be used for the apparatus of Fig. 1.

Fig. 2 is a radiation pattern of a transmitter which may be used in connection with a modified embodiment of my invention.

Fig. 2A is a schematic diagram of an antenna array which may be used to obtain the pattern of Fig. 2.

Fig. 3 is a graph explanatory of the principle of operation of my invention in connection with the confinement of genuine signals to narrow time bands and the transmission of interference continuously or over wide time bands.

Fig. 4 is a schematic diagram of a transmitter forming another embodiment of my invention.

Fig. 5 is a schematic diagram of a receiver adapted for use with the apparatus of Fig. 4 and forming therewith a system constituting an embodiment of my invention.

Fig. 5A is a block diagram of a radio communication system forming another embodiment of my invention.

Fig. 6 is a block diagram of a modification of the arrangement of Fig. 5.

Fig. 7 is a graph explaining the principle of operation of the apparatus of Fig. 6; and

Fig. 8 is a block diagram of a radio communications system forming still another embodiment of my invention.

Like reference characters are utilized throughout the drawings to designate like parts.

In Fig. 1, I have represented schematically a radio communication system forming one embodiment of my invention and in which the apparatus is assumed to be of the type utilizing a modulated oscillator for transmitting a voice, telephone or modulated continuous-wave code signal. However, my invention is not limited thereto and the invention is explained in connection with such conventional elements of modern radio transmitting systems merely for the sake of illustration.

For transmission of the genuine signal to a desired or authorized listener I provide radio transmitting apparatus including means for transmission of the genuine signal, such means being represented by the group of rectangles **11**, and I provide receiving means represented by a group of rectangles **12**. In case a modulated radio frequency type of transmission is employed the genuine signal transmission means **11** comprises a master oscillator **13**, a modulator **14** for modulating the output wave of the oscillator **13**, in accordance with the intelligence to be transmitted, and if desired, an amplifier **15** for increasing the power of the modulated signal before application thereof to a radiator or antenna **16** represented for convenience as being of the dipole type. For actuating the modulator **14**, suitable means **17** is provided for impressing an audio signal on the apparatus. This may take the form of a keyed audio frequency oscillator, a microphone spoken into by the transmitting operator or the like.

The receiving means includes a conventional receiver **18** suitable for reception of signals of the type transmitted by the apparatus **11** and having suitable means such as antenna or loop **19** for picking up the radiation from the transmitting means **11**. It will be understood that the receiver **18** is tuned to the principal frequency or carrier wave of the transmitting means **11** and preferably is tuned sharply or has only sufficient band spread to receive the signals efficiently from the means **11**.

For the purpose of making it difficult for unauthorized listeners to find the genuine signal or to receive the signal, if per chance the unauthorized listener should make an adjustment of his receiver suitable for best reception of the genuine signal, I provide supplementary transmission bands or other means, which in the case of the apparatus of Fig. 1 constitutes a separate transmitter **20**. The transmitter **20** may be of the same general type as the transmitter **11**. In this case, it is also a transmitter of the type comprising a master oscillator **21**, a modulator **22**, an amplifier **23** and an audio input device **24**. The audio input device **24** may be a source of noise, spurious signals or other interference. For example, it may consist of a device such as a resistor or a saturated diode vacuum tube together with the requisite audio frequency amplification apparatus for reproducing thermal noise, shot effect noise or the like. For the sake of increasing the difficulty encountered by an unauthorized listener, the noise source **24** may be one producing an audio signal or sound similar to that produced by the genuine audio signal device **17**. For example, if the genuine audio signal source **17** is a keyed audio frequency oscillator, the source **24** may also be a keyed or interrupted oscillator having the same wave form and keying frequency, but arranged to produce no intelligible signal by its keyed code or to produce only spurious signals with faulty information. Likewise, if the genuine audio signal source **17** is a telephone microphone intended to be spoken into, the interference source **24** may be a phonograph or transcription device containing a recording of the same voice speaking into the genuine audio signal source **17** but uttering misleading though plausible sounding information.

The transmitter **20** including all of its elements, particularly the oscillator **21**, amplifier **23** and the radiator **25**, is arranged to transmit over a broad range whereas the transmitter **11** including the corresponding pertinent elements, is arranged to transmit over a narrow range in order that the desired listener knowing the range over which to listen, will be able to find the signal whereas the undesired listener will have great difficulty in finding the signal. For example, if the apparatus **11** is arranged to transmit signals over a very narrow frequency range known to the desired listener, the receiver **18** is tuned to this same frequency, the desired listener will receive the genuine signals without difficulty whereas the unauthorized or undesired listener attempting to find this signal will find that the genuine signal is so overlaid with diffuse interference from the apparatus 20 that such undesired listener will be unable to find the proper adjustment of the receiver for picking up the genuine signals. Thus, if the undesired listener utilizes a receiver which tunes very sharply it will be virtually impossible for him to find the signal. On the other hand, if he uses a broad tuning receiver so much interference will be received from the apparatus 20 that there will be no indication of the presence of the genuine signal 17 in the reception, for any adjustment of the undesired listener's apparatus.

Although a very convenient and satisfactory way of masking the genuine signals is to transmit and receive these signals on a narrow frequency range and to overlay the genuine signal with an interference signal spread over a very wide frequency range, my invention is not limited to this particular form of masking the genuine signals. Nor is my invention limited to this manner of using a narrow range transmission for the genuine signals and broad range transmission for the masking interference. For example, in place of broad and narrow frequency range, I may also make use of selective space radiation, or the transmission of the genuine signals over a small angle of azimuth or small range in space, with transmission of the interference or spurious signals over a large angle of azimuth or wide range in space. For example, the radiator 16, and to the extent necessary, the other apparatus constituting the transmitter 11, may be arranged to produce a highly directive radiation represented by the signal pattern 26 whereas the radiator 16, and to the extent necessary, the other apparatus forming the transmitter 20, is arranged to produce a signal either having no directive properties or which has a much wider angle of radiation represented by the radiation pattern 27.

Apparatus for producing more or less directive radiation such as represented by the patterns 26 and 27 is known to those skilled in the art and does not constitute part of my present invention and need not therefore be described in detail.

More or less directive radiation, such as represented by the patterns 27 and 26, may be obtained in any suitable manner according to the type of apparatus and wave-length employed. In the case of microwaves the angles of radiation may be controlled by the shape or size of the reflector or horn employed. In the case of longer wavelengths suitable antenna arrays may be employed. For example, the broad angle pattern 27 may be produced by a pair of vertical dipoles spaced one-quarter wave-length and fed with current having 90° difference in phase, as shown at page 419 of "Ultra High Frequency Techniques" by Brainerd, Koehler, Reich and Woodruff, published in 1942 by D. Van Nostrand Co., Inc. The narrow angle pattern 26 may be produced by larger numbers of vertical dipoles suitably spaced and with suitable phase relationships of current. For example, as shown at page 420 of the aforesaid "Ultra High Frequency Techniques," with an array of sixteen dipoles, they may be spaced $\frac{11}{32}$ wavelengths apart with 157.5° phase difference between currents in adjacent dipoles. An illustrative arrangement of dipoles constituting antenna arrays 16 and 25 is shown schematically in Fig. 1A.

In case a system of broad and narrow angle radiation is employed the pick-up means 19 of

the receiver 12 will of course be located along the line of maximum radiation of the transmitter 11, substantially the center line of the radiation pattern 26. As indicated in Fig. 1, the radius (indicating signal strength) of the radiation pattern 26 along its center of symmetry 28, is considerably greater than that of the radiation pattern 27 indicating that a receiver placed along this line or within a relatively narrow angle along either side thereof, will receive stronger signals from the genuine signal transmitter 11 than from the interference transmitter 20. However, an unauthorized or undesired listener who does not know where to place his receiver is most likely to be located outside the narrow angle represented by the radiation pattern 26. For example, if his receiver is along the line 29 it will be apparent that, since at this point the radiation or signal strength of the pattern 27 is considerably greater than that of the pattern 26, the interfering or spurious signals will be far stronger than the genuine signals and it will be impossible for such an undesired listener to make any adjustment of his receiver which will enable him to receive the genuine signal.

Although for the sake of convenience, I have separately described the arrangements for masking genuine signals by broad range interference signals with respect to frequency range and with respect to space range or angle of radiation, and either method may be used without the other, it will be understood that both methods may be and advantageously are used simultaneously.

Furthermore, I may also make use of a narrow distribution of genuine signal with respect to time and a broad distribution of the interference with respect to time, separately or together with one or both of the other means of masking genuine signals which have already been described. For example, the transmitter 11 may be provided with a pulser or gate 30 separately represented for convenience by the rectangle 30 and which is arranged to give the output of the transmitter 11 a characteristic represented by the symbolic pulse or square wave graph 31. In connection with such pulsing systems which do not in themselves constitute my present invention, the output signal is transmitted during short intervals, such intervals having a duration of 10 micro seconds, for example, which transmission intervals or pulses are repeated at much longer intervals. They may occur at rates of 2000 pulses per second, for example. In this case the receiving means 12 likewise includes a corresponding device which may effectively be referred to as a pulser or gate 32 which makes the receiver sensitive only during the transmission intervals or pulses of the transmitter 11. The gate 32 is necessarily synchronized by suitable means, not shown, with the pulse rate of the transmitter 11 but such means do not constitute a part of my present invention and are known to those skilled in the art.

The interference transmitter 20 may, if desired, be provided with a pulser similar to pulser 30 but having either a different pulse rate or producing much longer pulses. Consequently, any receiver not knowing the pulse length and pulse rate on which to receive will have the reception blanketed by strong interference because the receiving apparatus will be sensitive during such long intervals of time while the transmitter interference is being received, that the interference will be much stronger in proportion than the genuine signal even though the receiver should occasionally be sensitive at the proper time for receiving the received signal. If the receiver of the unauthorized listener is set for continuous reception, the genuine signal will most certainly be blanked out by interference. This is illustrated in Fig. 3. As shown in Fig. 3, the genuine signal occurs in pulses 33 which are of short duration compared with the intervals 34 between pulses. If the interference transmitter 20 operates continuously or transmits in long pulses, it will be seen that the total energy transmitted by the interference transmitter will be far greater than the energy in the genuine signal transmitted during the pulses 33. A continuously sensitive receiver will be affected by the total energy. As shown in Fig. 3, the area ABCD represents the energy present when only the interference is being transmitted, and the area AEFG, which is very much smaller, represents the energy of the genuine signal. If the intensity of the genuine signal AE is made slightly greater than the intensity AB of the interference signal, it will be observed that the excess energy during the pulse interval represented by the pulse area BEFH is very considerably smaller than the energy represented by the area DCHG, corresponding to the energy of the interference signal.

Thus, it is apparent that I have described a secret communication system with means for radiating a genuine signal narrowly restricted in a discriminating parameter, means for radiating a masking interference signal much less narrowly restricted by the same discriminating parameter, and means for receiving a signal having substantially identical restrictions on reception in the same discriminating parameter as the genuine signal radiating means. Various parameters may be employed, such as frequency, space angle, and time, as already described, but my invention is not limited to these parameters.

In connection with Fig. 1, I have described an arrangement for blanking genuine signals transmitted over a narrow angle of radiation by interference signals transmitted over a broad angle of radiation. My invention in this respect, however, is not limited to the use of radiators having radiation patterns of a specific form illustrated at 26 and 27 in Fig. 1. For example, in place of a broad angle interference radiation having the pattern 27 of Fig. 1, I may utilize an interference beam which is split into two relatively narrow parts 27A and 27B, together with a genuine signal beam having a radiation pattern 26 directed along a line midway between the split patterns 27A and 27B of the interference signal. The arrangement of Fig. 2 has the advantage that along the line 28 on which the authorized receiver is placed, noise or interference reception is very nearly nil whereas at a few degrees either side of the line 28, interference reception becomes very strong and the genuine signal reception falls off very rapidly. There is, of course, no need for the interference beam on either side of the loops 27A or 27B, for example, along the line 35, if the transmitting apparatus 11 is correctly designed, since there will be no genuine signal beam at this angle. Care should, of course, be taken in the design of the apparatus 11 and the radiators 16 to insure the absence of minor loops at other angles than along the line 28 unless corresponding masking interference signals are provided at such angles. The patterns 26, 27A, and 27B may be produced in any suitable manner. For example, three multiple-dipole arrays may be placed in three lines 25A, 16, and 25B, making small angles to each other as represented in Fig. 2A.

In connection with the masking of genuine signals by interference signals spread over a broad range of frequencies, I have heretofore implied that such interference signals are spread throughout the broad range in question and that the genuine signals are confined to a fixed narrow range of frequencies. However, my invention is not limited thereto. If desired, the interference signal may be concentrated to a greater or less extent in several different parts of the broad range, and furthermore, the genuine signal may be transferred from one frequency to another according to a predetermined pattern or program in order to increase the difficulty encountered by an unauthorized listener. For example, as illustrated in Figs. 4 and 5, the transmitting apparatus may include a plurality of transmission bands for interference or spurious signals and a transmission band for genuine signals with means for interchanging the bands on which the genuine and interference signals are transmitted. Although separate radiators may be employed for different transmission bands, my invention is not limited thereto and, as illustrated in connection with Figs. 4 and 5, the transmitting apparatus may be provided with different transmission channels all of which use the same radiator.

The transmitter, represented schematically in Fig. 4, comprises a master oscillator 13, a high frequency modulator 36, a radio frequency amplifier 15, and a suitable antenna or radiator 16. For the purpose of causing transmission on several different frequencies from the radiator 16, the high frequency modulator 36 is modulated at a plurality of different frequencies higher than the audio frequency signals to be transmitted but preferably lower than the frequency of the master oscillator 13, which determines the principal carrier frequency of the radiation from the antenna 16. To this end I provide a plurality of oscillators which I have designated supplementary oscillators 37, 38, and 39, each having a different frequency from the other supplementary oscillators. Corresponding to the supplementary oscillators 37, 38, and 39, are conventional audio frequency modulators 40, 41, and 42. Audio frequency signals from sources represented by rectangles 43, 44, and 45 are impressed on the modulators 40, 41, and 42, each modulator having audio signals from only a single source impressed thereon at any given instant. The modulated frequency outputs resulting from the combinations of the units 37 and 40, the units 38 and 41, and the units 39 and 42, are impressed on the high frequency modulator 36, so that the output of the master oscillator 13 is doubly modulated and a large number of side bands is transmitted through the amplifier 15 to the antenna 16 and radiated therefrom.

My invention is not limited to the use of any specific frequencies, frequency ratios or frequency differences. Nevertheless, for the sake of convenience in explanation and by way of illustration, but not by way of limitation, various arbitrarily selected frequencies have been designated in various parts of the apparatus to distinguish one part from another and will be referred to in the subsequent discussion. For example, let it be assumed that the master oscillator produces a primary carrier at 30 megacycles and that the supplementary oscillators 37, 38, and 39 produce supplementary or subsidiary carriers at 5 megacycles, 10 megacycles and 15 megacycles, respectively. Then when the audio sources 43, 44, and 45 are not energized, so that there is no modulation in the devices 40, 41 and 42, the 5, 10 and 15 megacycle sub-carriers are impressed on the high frequency modulator 36, producing three upper side bands and three lower side bands at 45, 40, 35, 25, 20 and 15 megacycles. If it is assumed that the frequency components of the audio frequency sources do not extend beyond 5 kilocycles, the outermost side bands produced by the modulator 40 are 5,005 and 4,995 kilocycles. Similarly, the outermost side bands of the modulators 41 and 42 are 10,005 kilocycles, 9,995 kilocycles, 15,005 kilocycles. and 14,995 kilocycles. If these side bands are impressed on the high frequency modulator, the radiated wave from the antenna 16 will include additional side bands as follows: There will be side bands at 45,005 kilocycles, 44,995 kc., 15,005 kc., and 14,995 kilocycles, resulting from the modulation produced by the audio source connected to the modulator 42 combined with the subsidiary modulation of the 15-mc. supplementary oscillator 39. Additional side bands resulting from audio sources acting through the 10 megacycle supplementary oscillator 37 and the 5 megacycle supplementary oscillator 38, will produce additional side bands 40,005, 39,995, 35,005, 34,995, 25,005, 24,995, 20,005 and 19,995 kilocycles. Thus it will appear that when only three different audio frequency modulators 40, 41 and 42 and corresponding supplementary oscillators 37, 38 and 39 are used, a large number of different side bands are produced in the radio frequency radiation. In practice, I may employ many more supplementary oscillators and audio frequency sources placing interference or spurious audio frequency information on all of the audio sources except one on which the genuine signal is placed. In order to separate the genuine information from the spurious information or interference, the authorized listener is provided with a receiver which selects either the upper or lower side bands corresponding to the genuine audio frequency information.

As illustrated in Fig. 5, the receiver may be of the superheterodyne type although not necessarily so. If the receiver is of the superheterodyne type, it may comprise a conventional local oscillator 46, a mixer 47, a radio frequency amplifier 48, a receiving antenna or loop 49, an intermediate-frequency amplifier 50, a second detector 51 and head phones, or the like, 52. Assuming that the genuine audio frequency information is placed on the audio frequency modulator 42 corresponding to the supplementary oscillator 39, upper side bands in the radiated carrier will be produced between 45,005 and 44,995 kilocycles and lower side bands will likewise be produced between 15,005 kilocycles and 14,995 kilocycles. The receiver may be designed to select one or the other of these groups of side bands. For example, if the receiver has an intermediate frequency amplifier 50 designed for 1500 kilocycles and if the upper side bands of the radiated wave are to be selected, the local oscillator 46 may be adjusted to oscillate at 43,500 kilocycles. The local oscillator 46 will then beat with the intermediate side band at 45,000 kilocycles (which is produced by the 15-megacycle supplementary oscillator 39 modulating the oscillator 34). Since this difference between 45,000 and 43,500 kilocycles is 1500 kilocycles, the beat frequency will be 1500 kilocycles and the signal will be picked up in the second detector 51 and the head phones 52, being modulated at an audio frequency corresponding to the original input audio frequency as a result of the spread of the

radiated carrier between 45,005 and 44,995 kilocycles.

If only three different supplementary oscillators 37, 38 and 39 are provided, the local oscillator 36 is provided also with two other adjustments. For the specific frequencies assumed, these may be 38,000 kilocycles and 33,500 kilocycles. Having been informed on which of the supplementary oscillators the genuine signal is to be placed, the authorized receiving operator adjusts his receiver accordingly and selects the genuine signals, tuning out the spurious signals or interference.

In order to increase the difficulties of the unauthorized listener a greater number of supplementary oscillators than illustrated may be provided, and furthermore, means are preferably provided for rapidly changing the genuine signal from one set of side bands to another. Corresponding means are provided in the receiver for shifting the signals according to the same program. For example, a change-over switch 53 may be provided in the transmitter of Fig. 4 and a corresponding frequency changer 54 may be provided in the receiver of Fig. 5. The frequency changer 54 may be a conventional device such as a selector switch for changing inductances or capacitances in a tuned circuit of the oscillator 46. The change-over switch 53 and the frequency changer 54 are driven by suitable devices for causing them to follow the same program. For example, chronometers or synchronizer drivers 55 and 56, respectively, may be provided. The synchronizer driver may be of the type used in radio television utilizing synchronizing pulses but my invention is not limited thereto. Particularly, when it is desired to eliminate any possibility of trouble from jamming of signals, it may be preferable to utilize ship's chronometers for driving the change-over switch 53 and the frequency changer 54. Since my system is particularly useful for the rapid secret direct voice communication between ships of a fleet, the changeover switch 53 and the frequency changer 54 may readily be driven by chronometers on the respective ships.

In connection with the apparatus of Figs. 4 and 5, I find it advantageous not only to limit the genuine signal to one of the audio sources at the source 43 but also to provide different spurious signals on the other audio sources, such as the source 44 and 45. For example, the audio source 43 may consist of a microphone spoken into by the communications officer on the transmitting ship, and the other audio sources, such as the sources 44 and 45 may consist of phonographs having separate recordings of the same voice but different sentences or words, each recording stating plausible sounding information which, however, reveals no useful information to an unauthorized listener.

To increase the difficulty of an unauthorized listener in attempting to record reception on a large number of different frequencies corresponding to different side bands, and later trying to select the information which is genuine, I prefer to operate the linkage 60 between the chronometer 55 and the change-over switch 53, and correspondingly, between the chronometer 56 and the frequency changer 54, in such a manner that the change-over switch 53 and the frequency changer 54 are operated at a high rate of speed so as to clip off the words of the intelligence transmitted on any given set of side bands. Consequently an unauthorized listener continuously tuning to any one of the given different frequencies on which the apparatus transmits, will be unable to pick up any intelligible words.

Accordingly, the change-over switch 53 is preferably of a suitable type such as an electronic switch or mechanical switch adapted for operation at a high rate of speed and producing relatively little frictional load on the chronometer 55. My invention is not limited to the use of a specific form of changeover switch but for the sake of illustration, I have schematically represented a mechanical form of switch comprising three rotating members 57, 58 and 59, driven through a suitable linkage 60 by the chronometer 55. The rotating member 57 comprises a conducting segment 61 and a non-conducting segment 62, the latter forming a greater part of the periphery of a circle. The angular length of the segment 61 will, of course, depend on the number of audio sources provided and the length of time each of which is to be connected to each of the modulators 41 and 42. Although ordinarily more than three audio sources will be employed, in the case of three audio sources, the angular length of the segment 61 will be slightly under 120°. Cooperating with the rotating member 57 is a plurality of brushes 63, 64 and 65, each connected to a different one of the modulators 40, 41 and 42. There is also a brush 66 connected to the output of one of the audio sources, such as the audio source 43. The conducting segment 61 is extended along the axis in such a manner that it makes continuous contact with the brush 66. Rotating members 58 and 59 are similarly constructed and arranged.

From the drawing, it will be apparent that as the linkage 60 rotates the members 57, 58 and 59, the brush 66 will be connected successively through the conducting segment 61 to the brushes 63, 64 and 65, thus connecting the output of the audio source 43 successively to the modulators 40, 41 and 42. A similar action takes place with respect to the output of the audio outputs 44 and 45, except that each audio source is connected to a different one of the modulators at any given instant. It is also apparent that as a result of the rotation of the members 57, 58 and 59 the audio frequency modulator 40 is connected successively to the audio source 43, 44 and a similar condition exists with respect to the other audio frequency modulators 41 and 42. Consequently, the genuine audio frequency signals applied to the audio source 43 are constantly being shifted from one set of side bands to the other and each set of side bands is successively carrying signals resulting from different audio sources. The constant rapid shifting about from one carrier to the other makes it impossible for an unauthorized listener to receive any intelligible signals. The program according to which the shifting takes place may, of course, be changed from time to time by changing the rate of speed at which the change-over switch 53 and the frequency changer 54 are driven or by substituting different change-over switch units with different programs. Furthermore, my invention is not limited to the use of the relatively simple rotary succession program just explained.

It will also be noted that if the unauthorized listener succeeds in accomplishing the proper transposition of bands so that he obtains intelligible information, he is still in a state of uncertainty because in the illustrative system described for simplicity there are three different programs which can give intelligible information, and two of these give false information. With a greater number of audio sources than illustrated, the unauthorized listener would have even greater difficulty.

Another respect in which the range of distribution of genuine signal radiation may be made different from that of the masking interference is the polarization of the radiated wave. For example, as illustrated in Fig. 5A, the transmitter 11 and the receiver 18 may be arranged to transmit and receive waves polarized in a predetermined plane, whereas the interference transmitter 20 is arranged to transmit waves polarized in a different manner or unpolarized. In order to increase the difficulty of reception by unauthorized listeners, the plane of polarization is preferably varied either by physical rotation of the transmitting and receiving antennae or by electrical rotation of the plane.

In the specific arrangement illustrated in Fig. 5A, the genuine signal transmitter 11 is provided with a radiator 67 designed to transmit waves polarized in a predetermined plane, and the receiver 18 is provided with a receiving antenna 68 arranged to be responsive to waves polarized in the same plane as those transmitted by the antenna 67. The antennae 67 and 68 are arranged to be rotated in unison by a suitable means such as synchronized motor drives 55 and 56, respectively, which may be synchronized in any suitable manner, as by means of ship's chronometers at the transmitting and receiving stations, respectively. For permitting rotation of the antennae 67 and 68, suitable connections to the transmitter 11 and receiver 18 are provided which are represented for simplicity in the drawing as slip ring and brush connections 69 and 70, respectively, although it is well known to those skilled in the art that other types of connections to a rotating element are used.

For increasing the confusion encountered by an unauthorized listener, the synchronized drives 55 and 56 may be arranged to produce rotation in accordance with a predetermined program with variations in speed or direction of rotation at predetermined intervals. For masking the genuine signal radiation from the transmitter 11 and preventing an unauthorized listener from attempting to decipher the program, in accordance with which the antenna 67 is rotated, the interference transmitter 20 may be provided with an antenna system 71 which transmits radiation extending outside of the plane of polarization of the radiation from the antenna 67. For example, the antenna system 71 may consist of a plurality of pairs of antenna elements 72 and 73 which are excited incoordinately with respect to each other to produce unpolarized radiation.

Alternatively suitable phase-shifting, amplitude-controlling or other selective control means represented generally in Fig. 5A by the reference numeral 74 may be interposed in the connections between one of the transmitters 11 or 20 and the corresponding radiation system 67 and 71 for causing polarization or variation in polarization according to different patterns from the antenna systems 67 and 71. With this arrangement, an unauthorized listener attempting to set up a receiver and to coordinate it with the transmission from the genuine signal transmitter 11 will be prevented from finding the genuine signal and from receiving it by the interference according to a different polarization pattern from the interference transmitter 20. For instance, the apparatus 74 may include a ±90° phase-shifter on one antenna. This will produce circular polarization which cannot be eliminated by orientation of the antenna, and if the direction of rotation of the polarization is frequently reversed, a circular polarization reeceiver cannot eliminate it.

One manner of accomplishing variation of the polarization pattern electrically is illustrated more in detail in Fig. 6. In this case the transmitting apparatus including the genuine signal transmitter 11 and the interference transmitter 20 is shown as having a common radiator or antenna system 75, and the receiving apparatus 12 is shown as having a corresponding antenna system 76. The antenna system 75 comprises a polarized antenna 77 represented schematically as being of the dipole type. A second similar polarized antenna 78 is arranged at right angles to the first antenna 77. One of the antenna is connected to the amplifier 15 so as to be energized thereby, and for energization of the other antenna 78, a second amplifier 15' is provided having a phase shifter 79 interposed between it and the modulator 14. In this manner, polarized resultant radiation takes place from the antenna system 75, but the radiation is polarized in accordance with a different pattern from plane polarization. For this arrangement there may be a common master oscillator 13.

For making the receiving apparatus 12 responsive to the radiation from the antenna system 75, the receiving antenna system 76 is arranged in a similar manner with a polarized antenna 80 corresponding to the antenna 77 connected through an amplifier 81 to the reeciver or detector 18, and a second polarized antenna 82 at right angles to the antenna 80 connected through a second amplifier 81' and a phase shifter 83 to the detector or receiver 18. The phase shifters 79 and 83 are so set that the polarization pattern of the receptivity of the receiver corresponds to that of the radiation of the transmitter. Thus, in the specific case illustrated, a circular or elliptical pattern may be produced according to the degree of phase shifter employed and the relative intensities of radiation from the antennae 77 and 78.

For masking the transmission from the antenna system 75 produced by the genuine signal transmitter 11, the interference transmitter 20 may be arranged in a similar manner to the genuine signal transmitter 11 having a pair of amplifiers 23 and 23' energizing the antennae 77 and 78, respectively, with a phase shifter 84 interposed between the modulator 22 and the amplifier 23'. The phase shifter 84 may be so adjusted as to produce resultant radiation polarized in accordance with a different pattern from the resultant radiation produced by the genuine signal transmitter 11.

I may also produce synchronized variation in the pattern of polarization of the genuine signal transmission and of the receiving apparatus receptivity by utilizing the phase shifters 79 and 83, which are driven synchronously by suitable devices such as synchronized motor drives 55 and 56. In this case the genuine signal transmission and the receptivity will be in accordance with a polarization pattern which is constantly varying from planar to various degrees of elliptical and circular polarization.

As illustrated in Fig. 7, when the output from the amplifiers 15 and 15' is in phase, the radiation produced thereby will be polarized with respect to a plane 85, shown in an arbitrarily assumed angle. As the phase shifters 79 and 83 are changed in adjustment, the polarization pattern will become elliptical, as represented by the curve 86 in Fig. 7; and with the phase shifters 79 and 83 set for quadrature relations, the polarization pattern will become circular, as represented by the curve 87 in Fig. 7.

The phase shifter 84 of the interference transmitter 20 may be driven at random or in accordance with a different program from the synchronized drives 55 and 56 by a driving mechanism 88, thus super-imposing on the genuine-signal radiation from the system 75 radiation which is polarized but falls outside the pattern of polarization of the signal transmitted by the transmitter 11 and which likewise falls outside the corresponding receptivity pattern of polarization of the receiving apparatus 12.

As already explained, I may cause one of the characteristics of the genuine signal transmission to vary in accordance with a predetermined program, causing the same characteristic of the receiver to vary in accordance with said program in order that the receiver will follow the genuine signal transmission through any masking interference. Also, instead of varying such a characteristic of the genuine signal transmission, I may vary a characteristic of the interference transmission and cause the receiver to follow the variation in characteristic of the interference transmission in accordance with the same program in such a manner as to eliminate or reject the interference transmission. An example of a system where frequency is the variable characteristic and where both the genuine signal transmission and the interference transmission have the variable characteristic is represented by the embodiment of Figs. 4 and 5. In this case, however, the variation program of the interference transmission must be coordinated with that of the genuine signal transmission owing to the fact that both transmissions have the same characteristic varied, namely, frequency. Thus, the receiving apparatus of Fig. 5 is simultaneously made receptive to the genuine signal transmission and unreceptive or in a condition to reject the various interference transmissions.

The variation program of the interference transmission may be wholly unrelated to the variation program of the genuine signal transmission if different characteristics are varied in the genuine signal transmission and the interference transmission. Various characteristics have already been mentioned, such as frequency, space angle, time, and polarization, e. g. Ordinarily, it will not be practicable to vary the space angle or azimuth from which the transmission is received by the receiver, but any characteristic of signal transmission or reception, which may readily be varied at the receiver, may be employed.

As illustrated in Fig. 8, the genuine signal transmitter 11 has one characteristic varied in accordance with a predetermined program, and the receptivity adjustment of the receiver 18 is varied in accordance with the same program. The interference transmitter 20 has another characteristic varied in accordance with a program which may be coordinated with the first program but which may also be an entirely different and unrelated program. For eliminating this interference, the receiver has an adjustment varied in accordance with the same program as the interference transmitter for causing the receiver to reject the interference. In the case of interference transmitted at different frequencies in accordance with a fixed program, the receiving apparatus may have a signal rejector which is varied to tune out the interference. Although such a signal rejector may take the form of an anti-resonant circuit or a filter adjustable for eliminating different specific frequencies at each adjustment, this is not necessary, and the signal rejector (for variable-frequency interference) may merely be the tuning portion of the receiver 18, the resonant frequency of which is varied to make the receiver responsive to some frequency other than the interference frequency as explained in connection with Fig. 5.

For the sake of illustration I have represented in Fig. 8 and shall describe a specific system in which the variable characteristic of the genuine signal transmission is frequency, and the variable characteristic of the interference transmission is polarization. Thus, the genuine signal transmitter 11 is provided with a frequency changer 53 operated in accordance with a predetermined program, designated program A, by a suitable device such as a synchronized drive 55A. Simultaneously, the receiving apparatus has its tuning varied by a frequency changer 54 driven by a synchronized drive 56A which is synchronized with the device 55A and thus operates in accordance with the same predetermined program A.

As represented in Fig. 8, the genuine signal transmission and the interference transmission are simultaneously radiated from an antenna system 75, and both transmissions are picked up by an antenna system 76. The requisite connections and intermediate apparatus between the transmitters and the transmitting antenna 75 are represented diagrammatically by lines 89 and 90. Similarly, the connections between the receiving antenna 76 and receiver 18 are represented diagrammatically by the line 91.

For varying the polarization pattern of the transmission from the interference transmitter 20, suitable apparatus such as a polarization changer 79 is provided. For one form of variable polarization pattern, the polarization changer 79 may take the form of the elements illustrated and explained in greater detail in connection with Fig. 6. The polarization changer 79 is driven by a separate synchronized drive operating in accordance with a predetermined program designated as program B.

For eliminating the variable polarization interference transmission resulting from the interference transmitter 20, a portion of the receiving apparatus 12 determining the polarization reception characteristics of the receiver 18, shown as a rectangle and designaed as a signal rejector 83, is made variable. It is caused to vary in accordance with the same program, namely, program B, in accordance with which the synchronized drive 55B of the interference transmitter 20 is operated. For this purpose there is provided a drive 56B, operating synchronously with the drive 55B. The speed, variations in speed and direction, and other features of the program of the devices 55B and 56B, need bear no relation whatsoever to the corresponding features of the devices 55A and 56A. The genuine signal transmission may also be varied in accordance with the interference variation program provided the receiving apparatus is arranged to reject interference in accordance with the interference-variation program.

For causing the receiver 18 to reject the interference from the interference transmitter 20, the polarization-determining portion of the apparatus, in this case the signal rejector 83, is so set that the recevier 18 is constantly responsive to polarized input waves which are 180° out of phase with those resulting from the interference transmitter 20. The receiver is therefore unresponsive to the polarized waves from the interference transmitter 20. Thus, the polarization-determining apparatus serves as a signal rejector. The form taken by the apparatus designated as the rejector 83 will, of course, depend upon the type of variation in the polarization pattern employed, which must correspond to that employed for the interference transmission. If the type of variation in polarization is that discussed in connection with Fig. 6, the polarization changer 83 may take the form of a phase-shifter suitably associated with other apparatus as described in connection with Fig. 6. As previously explained, however, for the arrangement of Fig. 8, since the polarized wave is to be rejected, the polarization-adjusting mechanism in the apparatus of Fig. 8 is so set as to be 180° out of phase with the setting which would be employed for the system of Fig. 6, in which the receiver 18 is intended to be responsive to the variable polarization pattern from the transmitter 11.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A method of maintaining secrecy of radio signal transmission, which comprises transmitting radio signals in pulses adapted to be received by a pulse receiver, and masking such signals by transmitting interference having a lower peak intensity than the pulse signals but having an average intensity substantially as great as the peak intensity of the interference, said transmitted interference being of such strength relative to said signals as to require synchronism of receivers with the transmitted pulses.

2. A secret communication system comprising means at a first point for sending a series of pulses of high frequency energy from said first point to a second point remote from said first point, means for modulating said pulses in accordance with intelligence to be transmitted to said second point, means at said second point for receiving and demodulating said pulses to recover said intelligence, means for transmitting to said second point a signal interfering with said series of pulses, and means independent of the received pulses for varying the sensitivity of said receiving and demodulating means synchronously with said pulses for discriminating against said interfering signal.

3. A secret communication system comprising means for transmitting a series of intelligence-modulated pulses of a predetermined radio frequency to a remote point, means for transmitting at said radio frequency a signal interfering with said series of pulses at said remote point, means positioned at said remote point for receiving and demodulating said pulses, and means for rendering said receiver sensitive during said pulses and insensitive during intervals between said pulses whereby said receiver may discriminate said intelligence-modulated pulses from said interfering signal.

4. A secret communication system comprising means for transmitting intelligence-bearing radio

signals to a remote point, means for interrupting said signals according to a predetermined time-pattern, means for transmitting to said remote point further signals interfering with said intelligence-bearing signals, said further signals being of such strength as to preclude utilization of said intelligence-bearing signals in a receiver dependent upon reception of said intelligence-bearing signals for synchronization therewith, a receiver at said remote point adapted to receive said intelligence bearing signals, and means for varying the sensitivity of said receiver synchronously with said predetermined time-pattern for distinguishing sad intelligence-modulated signals from said further signals.

5. A secret communication system comprising means at a first point for transmitting to a second point recurrent fixed-duration impulses at a predetermined repetition frequency and characterized by durations of a smaller order of magnitude than the intervals between successive impulses, means for modulating said impulses in accordance with intelligence to be conveyed to an intended communicant at said second point, receiving means at said second point tuned to receive said impulses and gated at said predetermined repetition frequency in synchronism with said transmitted impulses independently of reception of said impulses, and means at said first point for transmitting a signal interfering with said fixed-duration impulses and characterized by longer transmission time than the duration of said impulses and so related to said recurrent impulses in the respects of carrier frequency, radiation pattern and power as to prevent utilization of said impulses in non-synchronous impulse receivers.

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