March 8, 1949. C. E. ATKINS 2,463,502

METHOD AND SYSTEM OF SECRET COMMUNICATION

Filed May 21, 1942 3 Sheets--Sheet 1

Fig. 1.

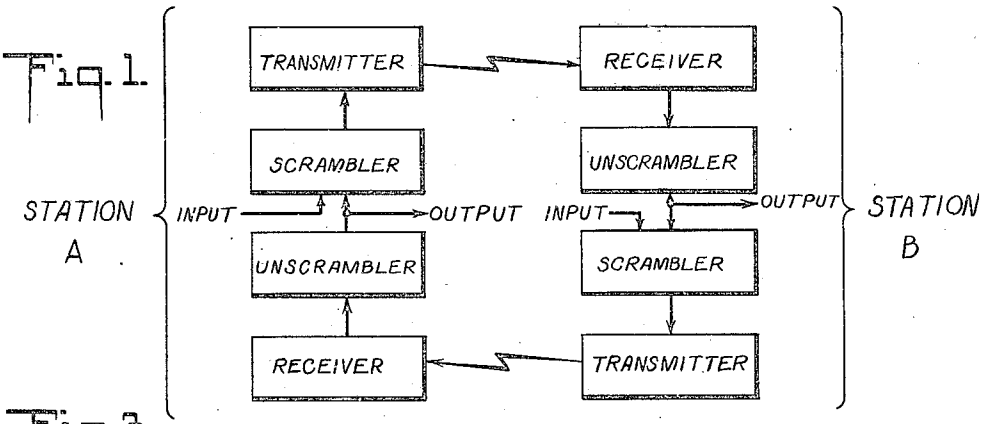


Fig. 3.

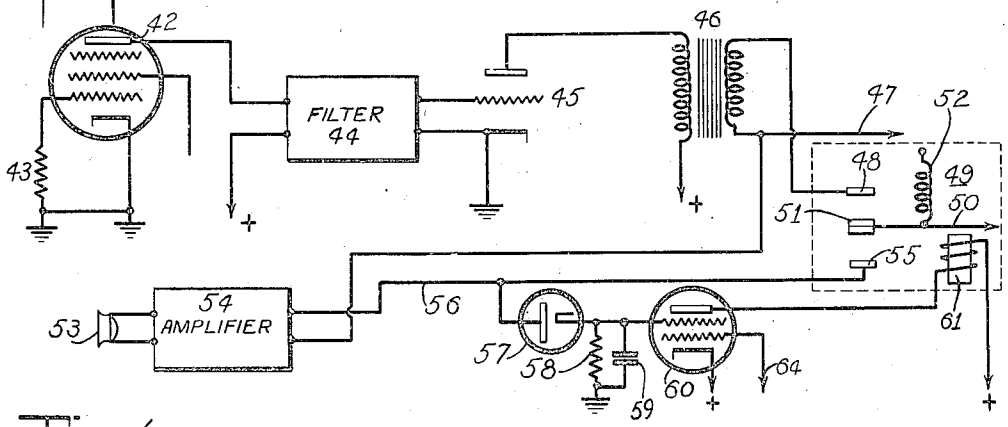
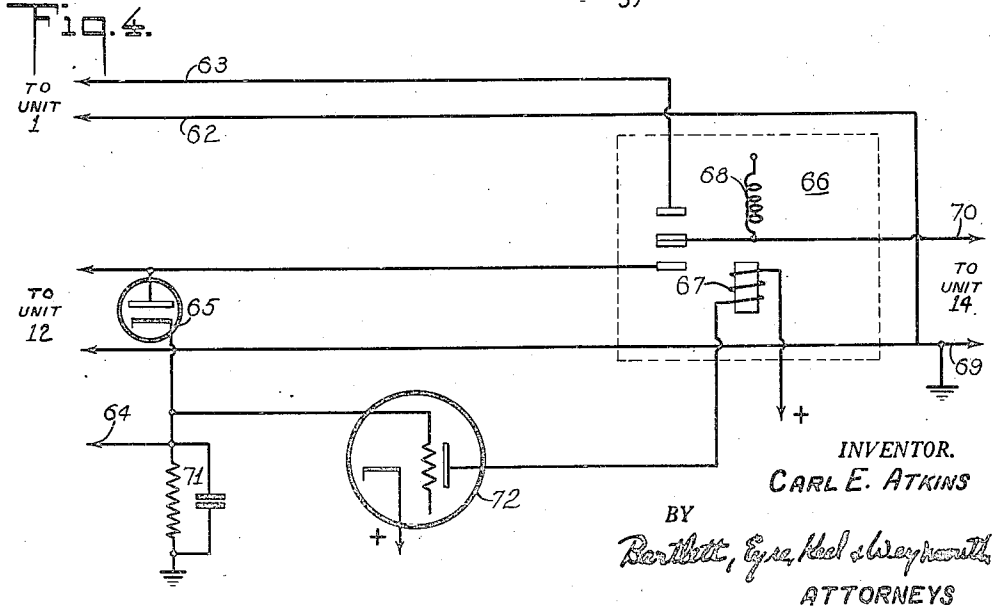


Fig. 4.



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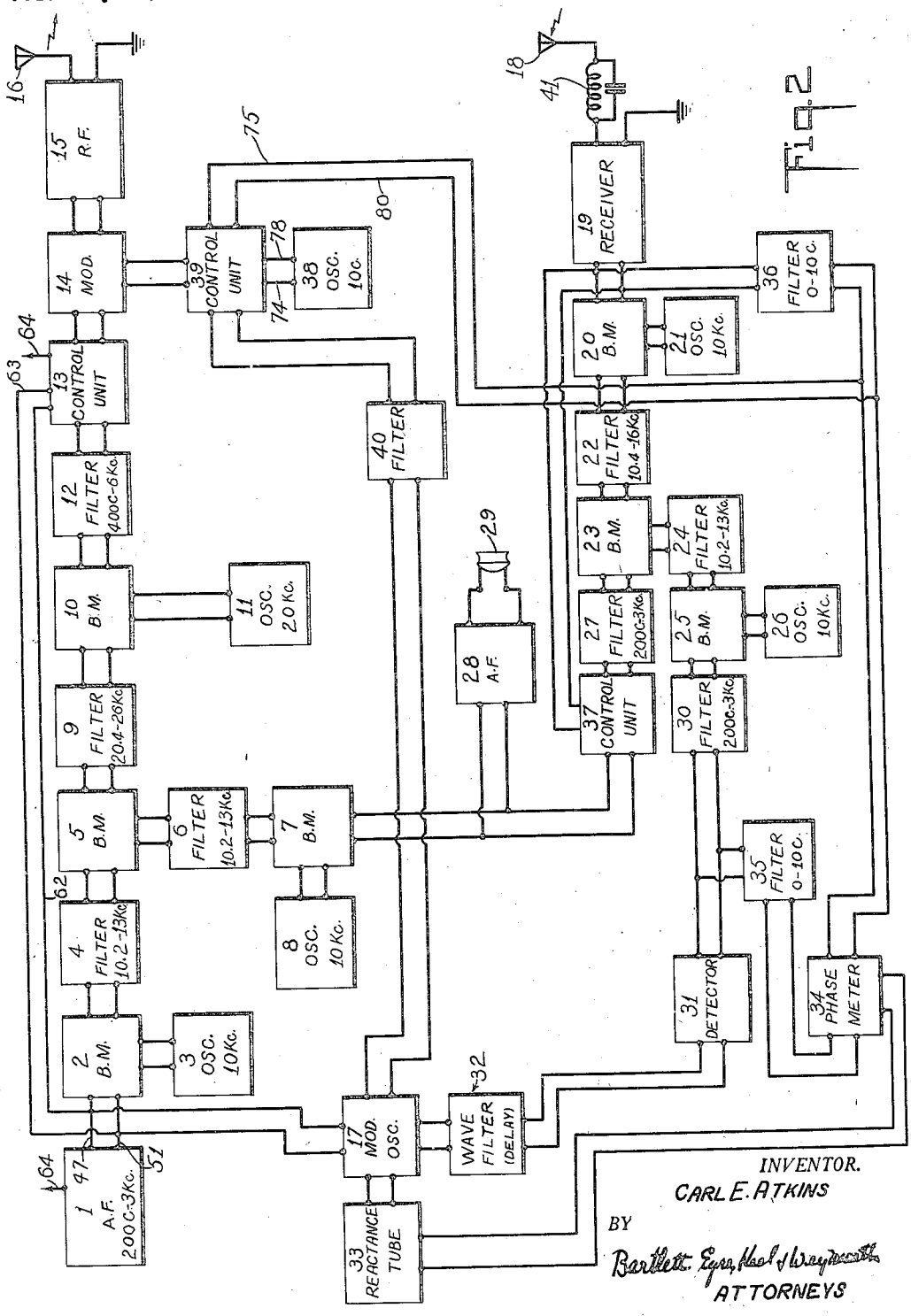


Fig. 2

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METHOD AND SYSTEM OF SECRET COMMUNICATION

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Fig. 5.

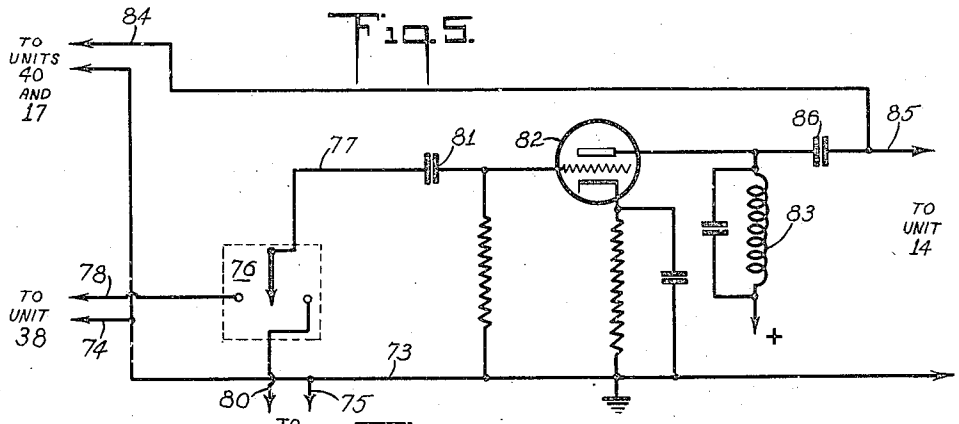


Fig. 6.

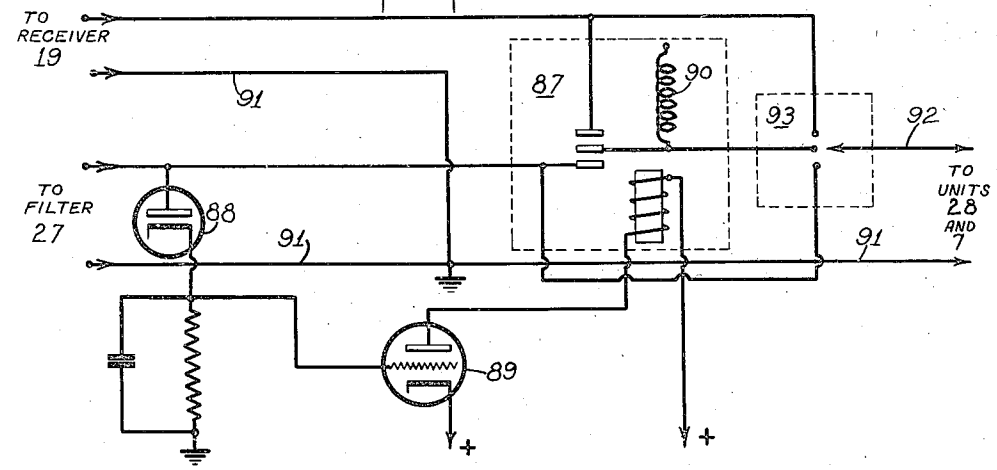
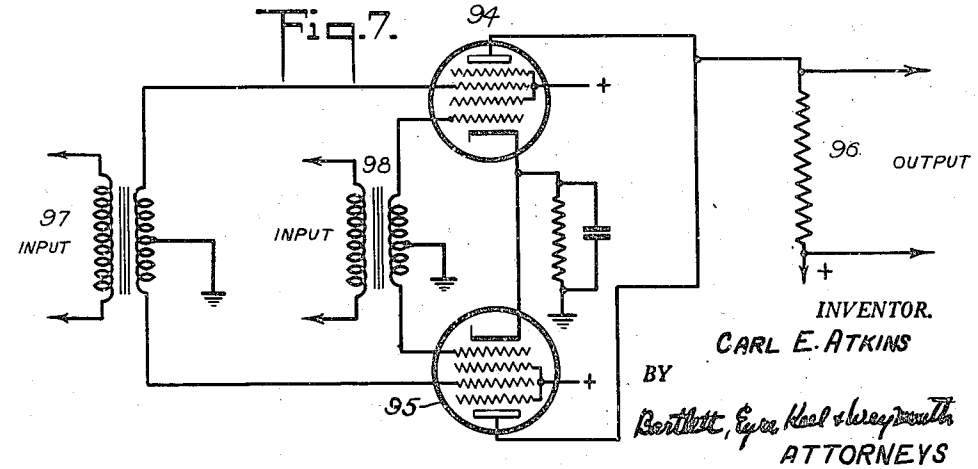


Fig. 7.



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UNITED STATES PATENT OFFICE

2,463,502

METHOD AND SYSTEM OF SECRET COMMUNICATION

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Application May 21, 1942, Serial No. 443,898

19 Claims. (Cl. 179—1.5)

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The present invention relates to a method and apparatus for secret communication between distant stations and is equally applicable to transmission of intelligence by radio and by wire.

So far as I am aware, all secret systems heretofore proposed or in use have required some sort of previous understanding between the sending and receiving stations, whether such understanding was in the form of a code or in the form of identical apparatus operating in a predetermined manner, and thus such systems were not completely proof against discovery by an unauthorized person of sufficient technical knowledge.

The system of the present invention, while requiring similar apparatus at the different stations, differs from prior systems in that even one having the identical apparatus and knowing the theory of the system would not be able to decode intercepted messages. This is because the coding or "scrambling" of the messages is not done according to any prearranged plan but solely according to the whim of the moment and is controlled not by the sender, but by the recipient, of the message. How this is effected will become clear as the description proceeds.

The system of the invention can be used for simultaneous two-way communication between two stations, in which case the intelligence introduced at one station is used to modulate or "scramble" the intelligence introduced at the other station, or the system can be used for one-way communication in which case the recipient introduces noise, frequency changes or other interfering phenomena to "scramble" the communication.

In the accompanying drawings the invention is illustrated as applied to communication by radio:

Fig. 1 is a diagram explanatory of the theory of the new system;

Fig. 2 is a diagram of transmitting and receiving apparatus at one station and illustrating one embodiment of the invention;

Fig. 3 is a circuit diagram illustrating in greater detail the audio-frequency input stage of the circuit of Fig. 2;

Fig. 4 is a circuit diagram of the control unit of Fig. 2, which determines whether scrambled or unscrambled signal energy will be transmitted.

Fig. 5 is a circuit diagram of a control unit of Fig. 2 which is part of the timing system for measuring the distance between stations;

Fig. 6 is a circuit diagram of the unit of Fig. 2 which controls the circuit connections between the receiver on the one hand and the scrambling

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unit and reproducer (audio-frequency output) on the other; and

Fig. 7 is a diagram of any one of the balanced modulators of Fig. 2.

The theory of the invention can best be understood by reference to Fig. 1. In this figure, A and B represent any two stations between which secret communication is desired. Each station is equipped with both a transmitter and a receiver irrespective of whether or not intelligence is to be communicated in only one direction or in both. If station A wishes to send a message to station B, a preliminary signal, which may be very short and completely devoid of information is first broadcast to B. This signal, at station B, is modulated or "scrambled" by the addition of noise or intelligence at the whim of the operator and retransmitted back to station A. At station A the incoming mixed signal is unscrambled by balancing against the original signal which cancels out the original signal. What remains is the intelligence, or noise, added by station B and this is used to modulate or scramble the continuing signal from A which latter may now be the beginning of the message to be transmitted. At B the message is decoded by balancing against the noise or intelligence previously added to the preliminary signal, additional noise or intelligence is then added to the message for retransmission back to A where the procedure is repeated as before. Thus at each station, as indicated in Fig. 1, there is a transmitter, and a receiver, an unscrambler for the received signal, and a scrambler for the transmitted signal. In each case the intelligence or noise introduced at one station is mixed with the intelligence or noise introduced at the other station and in each case the added intelligence or noise makes the complete circuit from one station to the other and back.

The simple diagram of Fig. 1 does not include various elements that are, of course, required for the practical operation of the system. For example, for the initial signal, a by-pass about the scrambler of station A and one about the unscrambler of station B must be provided and preferably these by-passes should be automatic in operation. Also, because an appreciable time is taken in the transmission of a signal from station A to station B and back again and through the circuits at each station, delay means must be included at each station in order that the intelligence or noise introduced at one station may be used later at the same station to unscramble the returned signal. Such delay means require measurement of the distance between the two stations

and preferably automatic means should be included for measuring this distance and for adjusting the delay means in accordance with such distance.

Many different types of apparatus involving various known techniques of scrambling could be utilized in practical embodiments of the invention, as broadly outlined above. In order, however, to demonstrate one complete practical embodiment of the invention, I have shown in Fig. 2 station equipment employing balanced modulators for facilitating frequency scrambling. Alternative arrangements for practicing the invention will occur to those skilled in the art.

Fig. 2 represents diagrammatically the complete equipment at one station. Identical equipment will be provided of course, at each station with which communication is to be had. Unit 1 in Fig. 2 represents a source of audio-frequency voltages in the region of 200 to 3000 cycles, which, as hereinafter described in connection with Fig. 3, may be either intelligence or noise. The output leads from unit 1 are connected by parallel connections to a balanced modulator 2 which may be of the type shown in Fig. 7, to a control unit 13, shown in detail in Fig. 4, and to a modulator-oscillator 17 forming part of the timing mechanism. Units 1 and 13 are also tied together through a lead 64 for a purpose hereinafter described in connection with Fig. 3 and 4. Unit 13 is a relay mechanism which operates to connect either unit 1 or a filter 12 to a modulator 14 which controls the character of the radiated oscillation produced by the radio frequency unit 15 which in turn feeds the transmitting antenna 16. Units 14, 15 and 16 may be any known variety of apparatus utilizing single or double side band amplitude modulation, frequency modulation or phase modulation. When unit 13 connects unit 1 with modulator 14 unscrambled signal energy from unit 1 is radiated by antenna 16 whereas when filter 12 and modulator 14 are connected by unit 13 intelligence or noise from unit 1 that has been scrambled at balanced modulator 5 on its passage through the series of filters and modulators 2, 4, 5, 9, 10 and 12 is delivered to modulator 14 for radiation by antenna 16.

In order to understand the purpose of the various units in Fig. 2 the path of the initial and subsequent signals from one station to another will now be described. As Fig. 2 illustrates apparatus at either station the subscript *"a"* will be used when a unit of station A is to be identified and the subscript *"b"* will be used to identify a unit at station B. Assume that the operator at A initiates the communication. He will produce audio-frequency signal energy in the frequency range 200 to 3000 cycles in unit 1—*a*. This will be applied through control unit 13*a* to modulator 14*a* which in turn controls the radio-frequency apparatus 15*a* and makes possible radiation from antenna 16*a*. A few milliseconds later this energy is picked up by antenna 18*b* at station B and delivered to receiver 19*b*. The demodulated output of receiver 19*b* is fed to control unit 37*b*, hereinafter described in connection with Fig. 6, whereupon it is delivered to the audio-frequency amplifier 28*b* and reproducer 29*b* and thus becomes audible at station B. The output of control unit 37*b* is also applied to a balanced modulator 7*b* the output of which goes through a filter 6B to balanced modulator 5*b*, where it is scrambled with intelligence or noise originating at unit 1*b* of station B. Balanced modulator 7*b* is fed from a 10 kilocycle oscillator 8*b* so that the interaction in 7*b* of the audio-frequency intelligence in the range 200 to 3000 cycles with the 10 kilocycles from oscillator 8*b* produces a plurality of sum and difference frequencies. The difference frequencies in the range 7000 to 9800 cycles are eliminated by filter 6*b* while the sum frequencies in the range 10,200 to 13,000 cycles are passed by the filter and applied to one pair of terminals of balanced modulator 5*b*. There will be no output from balanced modulator 5*b* unless there is simultaneously applied thereto suitable energy originating in the audio-frequency unit 1*b*. Unit 1*b*, as heretofore indicated, produces energy in the band 200 to 3,000 cycles and this energy is applied to the balanced modulator 2*b* where it is mixed with energy from a 10 kc. oscillator 3*b*. The output from 2*b*, comprising the sum and difference frequencies, is delivered to filter 4*b* which passes only the sum frequencies in the range of 10,200 to 13,000 cycles, which are thereupon applied to a pair of terminals of balanced modulator 5*b*. Energy thus arriving at 5*b* serves to cross-modulate energy originating at unit 1—*a* of station A and arriving at 5*b* through balanced modulator 7*b* and filter 6*b*. Filter 9*b* passes only the sum frequencies from balanced modulator 5*b*, that is frequencies in the range 20,400 cycles to 26 kc. Energy passed by filter 9*b* is passed to a balanced modulator 10*b* where it is mixed with energy from a 20 kc. oscillator 11*b* and delivered to filter 12*b* which passes only frequencies in the range 400 to 6000 cycles through control unit 13*b* to modulator 14*b*, radio-frequency apparatus 15*b* and 16*b*.

An appreciable time later this radio-frequency energy is picked up by receiving antenna 18*a* at station A where it is applied to receiver 19*a* and upon demodulation to balanced modulator 20*a* where it is mixed with energy from a 10 kc. oscillator 21*a*. The output of 20*a* is filtered by unit 22*a* which passes the sum frequencies in the range 10.4 to 16 kc., and applied to balanced modulator 23*a* which is simultaneously activated by the output of filter 24*a*. The energy passed by filter 24*a* originated in unit 1—*a* and has been delayed by passage through units 17*a*, 32*a*, 31*a*, 30*a*, 25*a* and 24*a* as hereinafter described, for a length of time equal to that taken by the signal in passage from station A to station B and back again and through the various units at the two stations. Thus balanced modulator 23*a*, by mixing with the output from filter 24*a*, the energy received by antenna 18*a*, part of which corresponds to energy which originated in unit 1—*a* and has traveled from station A to station B and back, operates, in conjunction with filter 27*a*, which passes only the difference frequencies, as an "unscrambler" of the received energy. The output from filter 27*a*, which is thus only the signal (noise, or intelligence) introduced at unit 1*b* of station B, is passed through control unit 37*a* and audio-frequency unit 28*a* to the reproducer 29*a* and also through unit 37*a* to the balanced modulator 7*a* for use in scrambling, at balanced modulator 5*a* the continuing energy supplied by unit 1—*a* as described in connection with station B.

Thus at each station the energy received by antenna 18 is a mixture of energy originating in units 1 of both stations. In each station the energy originating at that station is eliminated from the incoming signal and what remains, corresponding to energy originating at the other station, is used to scramble the outgoing signal.

The circuit connection for supplying the delayed replica of the original intelligence or noise of unit 1 through filter 24 to balanced modulator 23 will now be described. Energy from unit 1 is applied to a modulator-oscillator unit 17 simultaneously with its application to the balanced modulator 2 and to modulator 14 (when control unit 13 permits). In unit 17 the audio-frequency intelligence of unit 1 is converted to a suitable radio frequency value, which is not necessarily that used in the inter-station signaling. The modulated frequency output of unit 17 is applied to an electric wave filter 32, the output of which feeds a detector 31 and filters 30 and 35. Filter 35 blocks all frequencies substantially above 10 cycles. It passes frequencies of 10 cycles or less to one pair of input terminals of a phase meter 34, the other pair of input terminals of which are connected through filter 36 with the receiver 19. Filter 36, like filter 35, blocks all frequencies above 10 cycles.

At each station there is a 10 cycle oscillator 38 which, through a control unit 39 can be connected to feed unit 17 through a phase changing filter 40 and to feed modulator 14. As this 10 cycle note is used for measuring the distance between stations, that is for adjusting the time of delay of the replica energy delivered through filter 24 to balanced modulator 23, the oscillator 38 at only one of the communicating stations will be in use at any one time. In the following description we will assume that at the moment control unit 39*a* at station A is arranged to connect oscillator 38*a* to modulator 14*a* and unit 17*a* and that control unit 39*b* at station B is arranged to connect the output of filter 36*b* with unit 14*b*. Unit 17*a* has its radio frequency characteristics controlled by a reactance tube 33*a* arranged to shift the radio frequency up or down in accordance with the polarity and magnitude of the D. C. voltage applied from the output terminal of phase meter 34*a*.

Energy radiated from station A and picked up at station B has been modulated by the 10 cycle pulsation supplied by oscillator 38*a* and this energy is available in the demodulated output of receiver 19*b* where it is fed through filter 36*b* to control unit 39*b* and from there to modulator 14*b*. At modulator 14*b* it is used to modulate the outgoing energy from antenna 16*b*. After some time delay this 10 cycle note reappears in the output of receiver 19*a* of unit A whereupon it is passed through filter 36*a* and applied to phase meter 34*a*.

Phase meter 34 is any device which will yield a D. C. output potential which is zero when two applied signals are in phase and which varies in sign and proportionately in magnitude according to the phase angle between the signals. A phase meter suitable for use as unit 34 has been developed by the Cruft Laboratory of Harvard University and is described in the February 1942 issue of Electronics on page 110. The D. C. potentials of the output of phase meter 34*a* are applied to the reactance tube 33*a* which in turn changes the frequency of modulator-oscillator 17*a*. This in turn varies the time of passage through wave filter 32*a* and detector 31*a* until such time as phase parity is established between the 10 cycle inputs to the phase meter 34*a*. When this occurs the time of passage of the energy through filter 32*a* is equal to that required for the transmission of the signal from station A to station B and back again. Thus energy from unit 1*a* which is delivered through unit 17*a*, wave

filter 32*a*, detector 31*a*, filter 30*a*, balanced modulator 25*a* and filter 24*a* arrives at balanced modulator 23*a* in the same length of time that it has taken the energy originating in unit 1*a* to be transmitted to station B and back. Adjustment of the delay circuit at station B will be, of course, effected in the same manner as just described for station A. That is, oscillator 38*b* will be connected to units 14*b* and 17*b* at station B and the output of filter 36*a* at station A will be connected through control unit 39*a* with unit 14*a*.

The 10 cycle modulation frequency is selected for the timing frequencies because with a frequency this low it requires 100 milliseconds for the completion of a single cycle. Thus a round trip equivalent to 18,600 miles can be made before the commencement of a second cycle. Should the system be used over greater distances, a correspondingly lower frequency could be selected, and for shorter distances higher timing frequencies could, of course, be used.

Wave filter 40 is constructed with constants such that the ten cycle note will be advanced in phase by an amount sufficient to compensate for the time taken by energy from unit 1 to pass through the units 2, 4, 5, 9, 10, 12, and 13. Instead of the filter 40, other suitable means could be employed for insuring parity between the incoming and outgoing signals. For example, a suitable delay circuit, interposed between units 1 and 17 or between units 39 and 14, could be used instead of the phase shifter 40.

Filter 30 is constructed to pass frequencies between 200 cycles and 3 kc. Balanced modulator 25 is fed with energy from a 10 kc. oscillator 26 and filter 24 passes the sum frequencies to the unscrambling unit 23.

A wave trap 41 tuned to the frequency of the transmitter at each station is provided between the receiving antenna 18 and receiver 19 to help keep energy from antenna 16, some of which will be picked up by antenna 18 of the same station, from overloading the receiver 19. Precautions should, of course, be taken to provide a maximum of shielding between the two antennae of each station.

In Fig. 2, for simplicity in the description, four separate 10 kc. oscillators and a separate 20 kc. oscillator have been shown but obviously a single source could be provided for 10 kc. energy and the 20 kc. oscillator 11 could be a frequency doubler or a selective circuit tuned to 20 kc. and operating from the 10 kc. source.

A better understanding of the function of units 1 and 13 of Fig. 2 and the interaction therebetween will be had by reference to Figs. 3 and 4 which illustrate one specific embodiment of the invention as applied to these respective units. Unit 1 as shown in Fig. 3 includes a source of noise or the like comprising a vacuum tube 42 of any convenient type, as for example a high gain R. F. pentode such as the 6SD7GT, having a resistor 43 of relatively high resistance in its control grid circuit and feeding into a filter 44 designed to pass frequencies in the 200 to 3000 cycle region. The output of filter 44 is applied to an amplifier tube 45 the plate circuit of which is connected to the primary of a transformer 46. The secondary winding of the transformer 46 is connected to an output lead 47 of unit 1 and to a fixed contact 48 in a relay device 49 the movable element of which connects to the other output lead 50 of unit 1. The movable element of the relay 49 carries a contact 51 and a spring 52 biases the mov-

able element in a direction to close contacts 48 and 51 so as to deliver energy from tube 42 to output leads 47 and 50. The output currents from tube 42 may consist of either thermal agitation noise from resistor 43, shot-effect noise developed by tube 42 or a combination of both. Unit 1 includes also means for delivering to the output leads energy corresponding to intelligence initiated by the operator and these means include a microphone 53 arranged to receive speech and connected through an amplifier 54 across the output lead 47 and a second fixed contact 55 in relay device 49. The lead 56 connecting the amplifier 54 with contact 55 also connects with a diode 57, the load circuit of which contains a network comprising a resistor 58 and condenser 59. The voltage developed across the network in the load circuit of diode 57, when energy is delivered by amplifier 54, is applied to the control grid of a vacuum tube 60 in the plate circuit of which is the solenoid coil 61 of the relay 49. The cathode of tube 60 is connected to a point of positive potential such that ordinarily no plate current flows through the coal 61. When, however, the operator speaks into microphone 53, amplified electrical energy, rectified by diode 57 will, after suitable elapsed time, depending upon the constants of resistance 58 and condenser 59, apply positive potentials to the grid of tube 60. When tube 60 passes current, solenoid 61 will attract the armature of relay 49 against the pull of spring 52 and cause contact 51 to engage 55. Accordingly, speech energy from microphone 53 will be applied to the output leads 47 and 50 of unit 1 when speech is available and when tube 60 passes current, as hereinafter explained, and at other times random noise impulses having frequencies in the same pass band will be applied to the output terminals.

As shown in Fig. 2 the output leads 47 and 50 are connected to unit 2 and also, through branch leads 62 and 63 to unit 13. There is an additional connection between units 1 and 13 as heretofore indicated in connection with the description of Fig. 2 and this additional connection comprises a lead 64 connected at unit 1 to a second grid of tube 60 and at unit 13 to a point in the load circuit of a diode 65 (see Fig. 4). Tube 60 can pass current only when positive potential is applied to both of its grids, hence relay 49 depends for its operation not only upon the introduction of speech at microphone 53 but also upon passage of current through diode 65 of Fig. 4. The purpose of diode 65 and of its control through lead 64 of relay 49 will be apparent as the description proceeds.

As shown in Fig. 4, unit 13 includes a relay device 66 generally similar to relay 49 and which operates to connect either unit 12 or unit 1 of Fig. 2 with unit 14. When no current flows through the solenoid winding 67 of the relay device, the spring 68 causes leads 62 and 63 from unit 1 to be connected with the output leads 69 and 70 leading to unit 14. In order to connect units 12 and 14 when scrambled signal energy is available, the diode 65 with its load circuit comprising the R.-C. network 71 is connected across the output leads of unit 12 and the positive potential across the network 71 is applied to the control grid of a tube 72 having the solenoid coil 67 in the plate circuit thereof. As there will be no potential across the output leads of unit 12 unless energy is applied to both pairs of input terminals of balanced modulator 5 (see Fig. 2) and as the cathode of tube 72 is maintained sufficiently positive to prevent current flow except when positive potential is applied to the control grid, solenoid 67 will not be energized unless scrambled signal energy is available. Hence relay 13 operates to connect unit 1 directly with unit 14 until such time as the signal sent out from station A has made the complete circuit and noise or intelligence added thereto at station B has appeared at balanced modulator 5 for scrambling the output for unit 1. At such time unit 13 automatically connects units 12 and 14. Lead 64 connecting units 1 and 13 is provided as a safety device. As scrambling of information originating at one station depends upon the receipt of keying information from the other station, a failure in the arrival of such keying information due to fading or failure of transmitting apparatus at the other station would cause operation of unit 13 to connect unit 1 directly with unit 14. This would result in radiation of unscrambled information which might fall upon immediate unauthorized ears. To avoid this possibility, the rectified potential across network 71 of unit 13 is connected to the second grid of tube 60 of unit 1 so that plate current through tube 60 is shut off or substantially reduced when no current flows through diode 65, indicating that scrambled intelligence is not available. Cessation of plate current in tube 60 causes spring 52 of relay 49 to move the armature into position to substitute noise for intelligence and thus prevent the broadcasting of unscrambled intelligence. Tube 60 in unit 1 can pass plate current only when positive potentials are applied to both grids. Units 1 and 13, as illustrated in Figs. 3 and 4 and as above described, are arranged to prevent transmission at any time of unscrambled intelligence; the initial signal thus being noise not intelligence. If desired, however, the system could readily be arranged for transmission of unscrambled intelligence (speech, code, or the like) at the will of the operator. For this purpose, it would only be necessary to provide a suitable manually operated switch in unit 1 for connecting the output of microphone 53 and amplifier 54 with the output leads 47 and 50. Then, when scrambling is not desired, the operator can, by operation of the usual volume control on the receiver 19, insure that insufficient energy will be received at the scrambling unit 5 to operate relay 66 of control unit 13. In this manner, unscrambled intelligence may be transmitted when desired.

Control unit 39 which connects either oscillator 38 with unit 14 and unit 17 or the output of filter 36 with unit 14 is shown in Fig. 5. The circuit of unit 39 is arranged to apply the 10 cycle timing signal to modulator unit 14 in series with the intelligence to be broadcast and at the same time to supply the 10 cycle timing signal to the modulator-oscillator 17 through filter 40 without producing cross-modulation between the two pairs of output terminals of the unit. In control unit 39 one common lead 73 forms one output lead to filter 40 and to modulator 14 and by branch leads 74 and 75 forms input leads to oscillator 38 and to filter 36 respectively. A manually operable switch 76 connects the input lead 77 of unit 39 with either of the leads 78 or 80 connected with units 38 and 36 respectively. Input lead 77 is connected through blocking condenser 81 with the grid of a tube 82, the plate circuit of which contains 10 cycle load impedance 83. The other output leads 84 and 85 to filter 40 and unit 14 respectively are connected to the plate circuit of tube 82 through a condenser 86. With the above described circuit when switch 76 connects lead 78 to input lead 77 oscillator 38 supplies 10 cycle signal

impulse to modulator 14 and to unit 17 through filter 40, and when switch 76 connects leads 77 and 80 the ten cycle timing impulse originating at the other station is delivered from filter 36 to the control unit 39.

As heretofore indicated, each station would independently employ its 10 cycle oscillator 38 for producing the timing note for adjustment of its own delay circuit 32. Any suitable advance agreement could be made between the stations when the timing oscillators would be in circuit, or, if desired, suitable automatic control of units 39*a* and 39*b* could be incorporated into the system to prevent simultaneous use of the timing means. Presumably, however, the convention would be established that whichever station initiated the communication would be the one to first employ the timing signal.

Control unit 37, which determines whether the received energy will be delivered directly from receiver 19 to the audio-frequency unit 28 and reproducer 29 or whether it will be delivered thereto through the unscrambling unit 23 and associated units, is illustated in Fig. 6. In Fig. 6 the pairs of input terminals connecting respectively with receiver 19 and filter 27 are appropriately marked with legends as is the pair of output terminals connected to units 28 and 7. The control unit includes a relay device 87, a diode 88, and a tube 89 connected similarly with the corresponding devices of unit 13 and the operation thereof will be clear from the description heretofore given in connection with Fig. 4.

Specifically, when no voltage appears across the input leads from filter 27, indicating that energy is not being supplied to one set of input terminals of the unscrambler 23, no current will flow through diode 88 and hence there will not be sufficient current in the plate circuit of tube 89 to operate the armature of relay 87 against the bias of the spring 90. As in the circuit of unit 13, one lead 91 of each pair of input leads is connected directly to an output lead and the other lead of each pair of input leads is connected to the fixed contacts of relay 87. The other output lead 92 is connected with the movable arm of a manually operable switch 93 so as to be connectable at will either with the armature of relay 87 when full automatic operation is desired, or with either of the other input leads when automatic control is to be suppressed. Thus, with the arm of switch 93 connected to the armature of relay 87, receiver 19 and units 28 and 7 are directly connected until voltages appear across the input terminals from filter 27, whereupon relay 87 operates automatically to open the circuit from receiver 19 and to connect the output of filter 27 with unit 28 and 7. If the operator so wills, he may suppress this automatic operation by means of switch 93. A switch similar to switch 93 could, of course, if desired, be included in control unit 13 and in unit 1.

As indicated in Fig. 2, units 2, 5, 10, 20, 23 and 25 are balanced modulators. These units could be of the conventional type wherein two triodes are used with push-pull input and output connections and the center tap of the input circuit contains the secondary of a third transformer in order that the grids of the tubes may be excited in parallel simultaneously with push-pull excitation. With such conventional circuit, potentials from the push-pull input connections are not canceled and accordingly frequency selective means would need to be provided to insure cancellation of these potentials, that is the energy in the push-pull input circuit would have to have its frequencies outside the pass band of the output circuit. Such stringent frequency selective requirements are avoided if the circuits of the balanced modulators of the system are not of the conventional form but are as illustrated in Fig. 7. In the circuit of Fig. 7 two multi-element tubes 94 and 95 are employed and their anodes are tied directly together and connected in parallel to a common load impedance 96. One input voltage is applied in push-pull through a transformer 97 having its secondary connected to a grid of each tube and the other input voltage is similarly applied in push-pull to another grid in each tube through a transformer 98. With this arrangement neither of the input energies can produce any output potentials across the impedance 96 when acting alone. Interaction between the input energies results in the production of the sum and difference frequencies as heretofore described.

The invention has now been described in connection with a single embodiment thereof. Obviously the system herein described could be incorporated in various forms of apparatus and more or less parts of the apparatus described could be made automatic, depending upon the skill of the operators. For example, where two-way speech is being transmitted, the timing mechanism, that is the oscillator 17, could be adjusted by a skilled operator without the use of the special apparatus described, as he could vary the delay of the replica signal to the unscrambler until intelligible speech was heard in the reproducer. Thus units 33, 34, 35, 36, 38, 39 and 40 could be dispensed with. Alternatively other means for timing or measuring the distance between stations could be employed and other means for varying the period of delay in response to such measurements could be provided. In the specific embodiment of this invention hereinbefore described, scrambling is effected by balanced modulators feeding into filters passing only sum frequencies whereas unscrambling is effected by balanced modulators feeding into filters passing only difference frequencies. Obviously other types of scrambling and unscrambling devices could be employed, and when balanced modulators and filters are used the difference frequencies could be passed by the filters of the scrambling units and the sum frequencies by the filters of the unscrambling units if desired.

As heretofore indicated, the invention in its broadest aspects is directed to a point-to-point communication system in which scrambling of a message from one station is controlled by energy introduced at another station, the input at each station making a complete circuit before elimination. It will be apparent that the system above described meets the strictest tests of secrecy as all scrambling is completely unpredictable and at the whim of the operators. Thus it would be impossible for an unauthorized person to tune in to either station and obtain anything intelligible or decodable.

I claim:

1. A secret signalling system for communication between two stations comprising in combination signal energy input means at each station, signal transmitting and receiving means at each station, means at each station for separating from the received signal the signal energy introduced at the other station and means at each station for utilizing such separated energy to scramble the transmitted signal.

2. In a secret signalling system for communica-

tion between two stations, apparatus at each station including a transmitter, a receiver, signal energy input means, signal energy reproducing means, a device between the energy input means and the transmitter for scrambling the signal energy delivered to the transmitter, a device between the receiver and the reproducing means for unscrambling the signal energy received by said receiver, and circuit connections between said devices for utilizing the energy delivered by the unscrambling device to scramble the energy to be delivered to the receiver.

3. In a secret signalling system for communication between two stations, apparatus at each station including a transmitter, a receiver, energy input means, energy reproducing means, a device between the energy input means and the transmitter for scrambling the signal energy delivered to the transmitter, a device between the receiver and the reproducing means for unscrambling the signal energy received by said receiver, and circuit connections between said devices for utilizing the energy delivered by the unscrambling device to scramble the energy to be delivered to the receiver, including means for delivering energy from said input means to said unscrambling device and means for delaying the passage of energy through said last mentioned means whereby signal energy from said input means can be delivered to said unscrambling device at the same station after a period of time equivalent to that taken for energy from said input device to be scrambled, delivered to the transmitter, sent to the other station, unscrambled, scrambled, transmitted at the other station, received at the first station and delivered to the unscrambling device of that station.

4. In a secret signalling system for communication between two stations, apparatus at each station including a transmitter, a receiver, energy input means, energy reproducing means, a device between the energy input means and the transmitter for scrambling the signal energy delivered to the transmitter, a device between the receiver and the reproducing means for unscrambling the signal energy received by said receiver, and circuit connections between said devices for utilizing the energy delivered by the unscrambling device to scramble the energy to be delivered to the receiver, including means for by-passing said scrambling device for delivering unscrambled signal energy from said input means to said transmitter, and means for by-passing said unscrambling device for delivering signal energy from said receiver directly to said scrambling device.

5. In a secret signalling system for communication between two stations, the combination comprising signal energy input means, a transmitter, a scrambling device interposed between said input means and said transmitter, a receiver and an unscrambling device connected between said receiver and said scrambling device whereby energy separated by said unscrambling device from the signal energy received by said receiver may be utilized to scramble the energy from the input means delivered to the transmitter.

6. In a secret signalling system for communication between two stations, the combination comprising energy input means, a transmitter, a scrambling device interposed between said input means and said transmitter, a receiver and an unscrambling device connected between said receiver and said scrambling device whereby energy separated by said unscrambling device from the signal energy received by said receiver may

be utilized to scramble the energy from the input means delivered to the transmitter, said scrambling device having two pairs of input terminals and one pair of output terminals and including means for by-passing said scrambling device to permit passage of the energy from said input means directly to said transmitter and means responsive to potentials at the output terminals of said scrambling device, indicating that energy is being supplied to both pairs of input terminals, for opening said by-pass.

7. In a secret signalling system for communication between two stations, the combination comprising energy input means, a transmitter, a scrambling device interposed between said input means and said transmitter, a receiver and an unscrambling device connected between said receiver and said scrambling device whereby energy separated by said unscrambling device from the signal energy received by said receiver may be utilized to scramble the energy from the input means delivered to the transmitter and including means for optionally by-passing said unscrambling device whereby signal energy received by said receiver may be delivered directly to said scrambling device for scrambling the outgoing signal energy.

8. In a secret signalling system for communication between two stations, the combination comprising energy input means, a transmitter, a scrambling device interposed between said input means and said transmitter, a receiver and an unscrambling device connected between said receiver and said scrambling device whereby energy separated by said unscrambling device from the signal energy received by said receiver may be utilized to scramble the energy from the input means delivered to the transmitter and including means for by-passing said scrambling device, said energy input means including a device for the introduction of intelligence and a source of noise, means responsive to delivery of energy by said scrambling device for opening said by-pass and means for rendering inoperative said device for the introduction of intelligence when said by-pass is closed.

9. In a secret signalling system for communication between two stations, the combination comprising energy input means, a transmitter, a scrambling device interposed between said input means and said transmitter, a receiver and an unscrambling device connected between said receiver and said scrambling device whereby energy separated by said unscrambling device from the signal energy received by said receiver may be utilized to scramble the energy from the input means delivered to the transmitter, said unscrambling device having two pairs of input terminals and one pair of output terminals, and a delay circuit connecting said energy input means with one pair of said input terminals, whereby energy delivered at the output terminals of said unscrambling device and used for scrambling the outgoing signal energy corresponds to the signal energy received by the receiver and delivered to the other pair of input terminals less that delivered by the input device to said unscrambling device through said delay circuit.

10. In a secret signalling system for communication between two stations, the combination comprising signal energy input means, a transmitter, a scrambling device interposed between said input means and said transmitter, a receiver and an unscrambling device connected between said receiver and said scrambling device

whereby energy separated by said unscrambling device from the signal energy received by said receiver may be utilized to scramble the energy from the input means delivered to the transmitter, said scrambling device and said unscrambling device each comprising a balanced modulator and a filter for receiving signal energy therefrom, each balanced modulator comprising a pair of multielement tubes having one of their elements tied together, one push-pull input connection to another element of each tube and a second push-pull input connection to another element of each tube whereby signal energy is delivered by the balanced modulator to its filter only when signal energy is supplied to both push-pull input connections.

11. A secret signalling system for communication between two stations comprising in combination energy input means at each station, signal transmitting and receiving means at each station, means at each station for separating from the received signal the energy introduced at the other station, means at each station for utilizing such separated energy to scramble the transmitted signal, said means for separating from the received signal the energy introduced at the other station comprising a balanced modulator having two pairs of input terminals and one pair of output terminals, said receiver being connected with one pair of input terminals, a delay circuit connecting said energy input means with the other pair of input terminals, and a filter connected to said output terminals.

12. A secret signalling system for communication between two stations comprising in combination energy input means at each station, signal transmitting and receiving means at each station, means at each station for separating from the received signal the energy introduced at the other station, means at each station for utilizing such separated energy to scramble the transmitted signal, said energy input means including a device for the introduction of audio-frequency intelligence, a source of audio-frequency noise, output terminals for said means and a relay device normally connecting said source with said output terminals and responsive to introduction of intelligence to said device for connecting said device with the output terminals and disconnecting said source therewith.

13. A secret signalling system for communication between two stations, energy input means at each station, a transmitter and a receiver at each station, a scrambling device at each station connected between the input means and the transmitter, an unscrambling device at each station connected between the receiver and the scrambling device, means at one station for generating a timing signal and for delivering the same to the transmitter for transmission with the scrambled energy delivered to the transmitter by the scrambling device, means at the other station cooperating with the receiver and transmitter at the other station for returning said timing signal to the first station and a delay circuit controlled by said timing signal and connecting said energy input means with the unscrambling device whereby the time of transit of energy from said input means to said unscrambling device may be made equal to the time of transit of energy from said input means, through said scrambling device and transmitter to the other station, through the receiver, devices and transmitter at the other station and back through the receiver at the first station.

14. A secret system for communication between two stations, the combination comprising signal transmitting and receiving means, means for introducing signal energy at one station for transmission to the other station by said transmitting means and means for scrambling said signal energy with signal energy received by said receiving means and originating at the other station.

15. The method of secret signalling between two stations which comprises scrambling an outgoing signal at one station with signal energy introduced at the other station and transmitted thereby to the first station and detecting at the other station the energy introduced at the first station by cancelling from the received scrambled energy the signal energy corresponding to that previously introduced at such station.

16. The method of secret signalling between two stations A and B which comprises introducing signal energy at station A and causing such energy to travel to station B and back to station A, introducing signal energy at station B and mixing it with the signal energy received from station A and returned by station B to station A, then separating at station A the signal energy introduced at station B, adding additional signal energy thereto and causing such mixed signal energy to travel to station B whereby signal energy introduced at each station makes a complete circuit of the two stations and signal energy introduced at one station is utilized for scrambling the signal energy introduced at the other station.

17. The method of secret signalling between two stations A and B which comprises introducing signal energy at station A and causing such energy to travel to station B and back to station A, introducing signal energy at station B and mixing it with the signal energy received from station A and returned by station B to station A, then separating at station A the signal energy introduced at station B, adding additional signal energy thereto and causing such mixed signal energy to travel to station B whereby signal energy introduced at each station makes a complete circuit of the two stations and signal energy introduced at one station is utilized for scrambling the signal energy introduced at the other station, including delaying at station A a replica of the signal energy transmitted to station B for an interval of time equal to that taken by energy to make the round trip from station A to station B and back to station A and utilizing such delayed replica to separate out from the signal energy received at station A from station B the signal energy introduced at station B.

18. The method of secret signalling between two stations A and B which comprises initially transmitting unscrambled signal energy from station A to station B, scrambling at station B the signal energy received from station A, transmitting such scrambled signal energy to station A, separating from such scrambled signal at station A the energy introduced at B, introducing additional signal energy at station A, scrambling such additional energy with the energy so separated from the scrambled energy received from station B, transmitting this latter scrambled energy to station B and there separating the additional energy introduced at station A.

19. A secret system for communicating between two stations comprising means for transmitting signal energy originating at one station

to the other station, means at the other station for introducing signal energy and scrambling the same with the energy originating at the first station, means at the last mentioned station for transmitting the scrambled signal energy to the first station and means at the first station for unscrambling the signal energy received from the other station.

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