Sept. 13, 1949. L. A. THOMPSON 2,482,039

SECRET COMMUNICATION EMPLOYING SIGNAL SEQUENCE SWITCHING

Filed Sept. 6, 1945

2 Sheets-Sheet 1

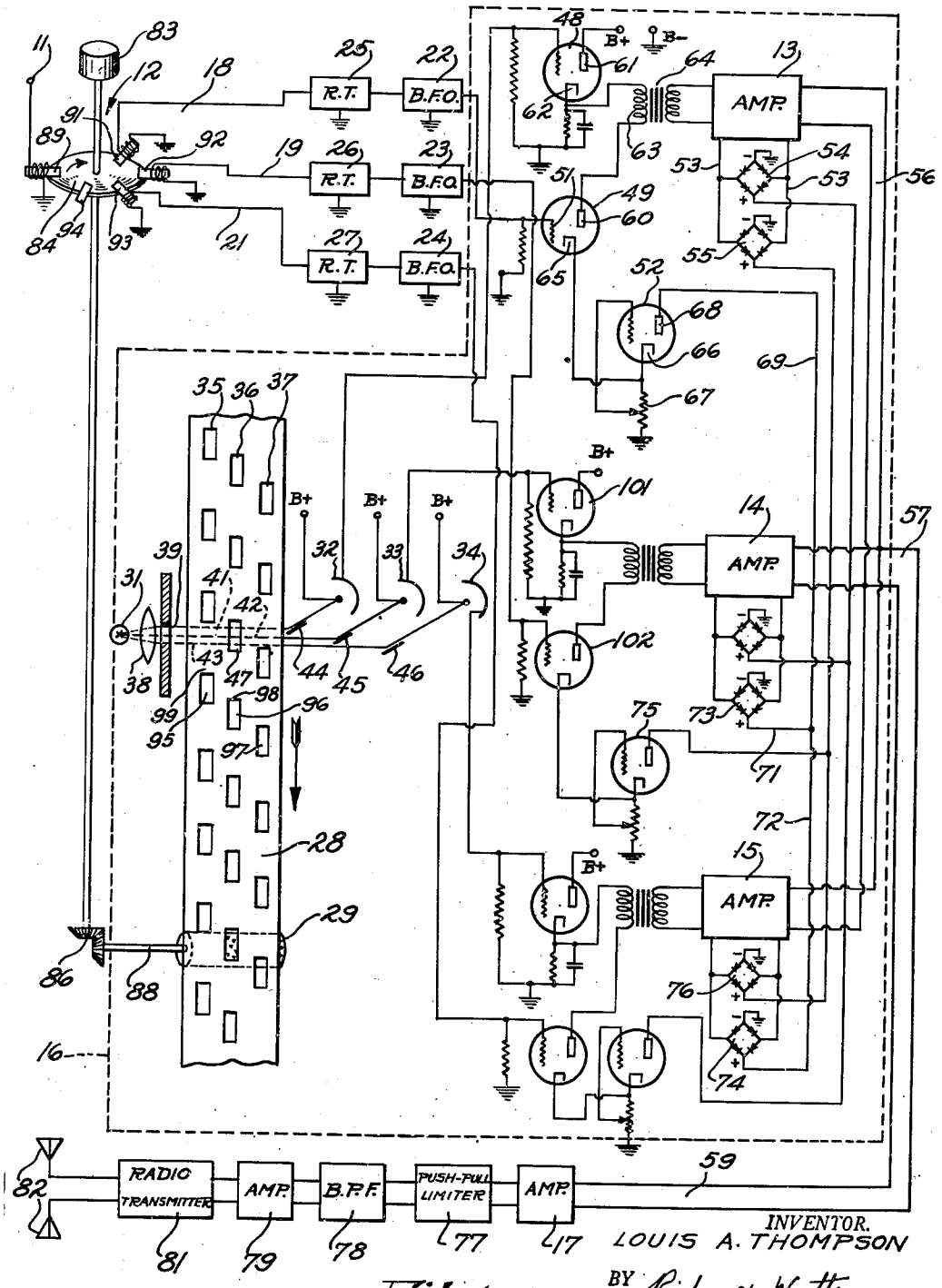

Fig. 1

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2 Sheets-Sheet 2

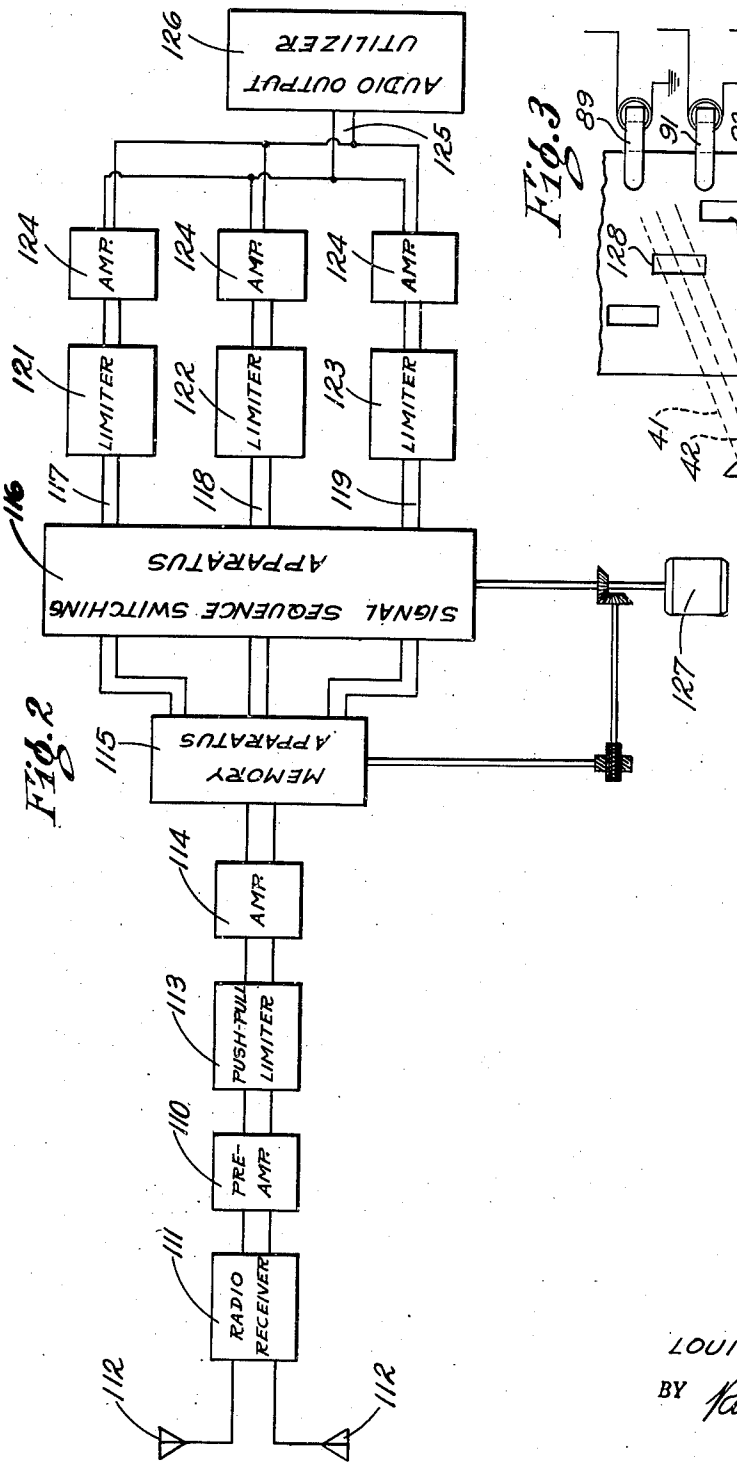

FIG. 2

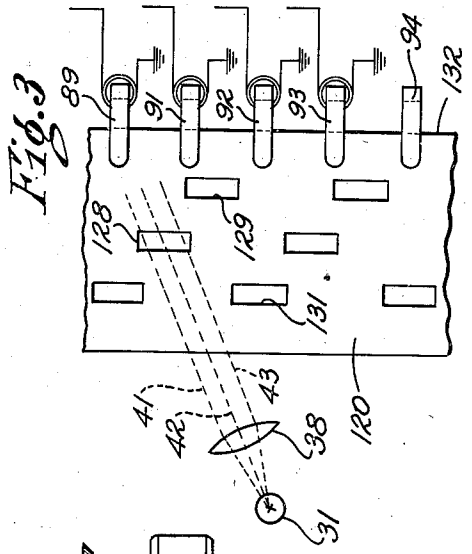

FIG. 3

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UNITED STATES PATENT OFFICE

2,482,039

SECRET COMMUNICATION EMPLOYING SIGNAL SEQUENCE SWITCHING

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Application September 6, 1945, Serial No. 614,772

6 Claims. (Cl. 179—1.5)

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My invention relates to switching apparatus, particularly sequence switching for signal transmission.

It is an object of my invention to provide improved methods and apparatus for signal transposition and the security transmission of information.

A further object of my invention is to avoid transients or effects recognizable as transitions or transfer points in the electrical transmission of intelligence.

A further object is to provide electrical continuity between unrelated signal segments. Still another object of my invention is to transfer electrical signals back and forth between circuits with high precision so as to avoid any overlap between signals and to avoid also any period during which no energy is present in the system.

Still another object of my invention is to control signal switching photo-electrically.

Further object of my invention is to control selection of channels for signal transmission by selectively blocking various channels.

Other and further objects, features and advantages of my invention will become apparent as the description proceeds.

In carrying out my invention in accordance with a preferred form thereof, I provide a punched tape in conjunction with a source of light and a photo-electric tube for producing channel energization and blocking voltages in accordance with the pattern of slots punched in the tape, which is caused to travel at a uniform rate of speed preferably synchronized with other apparatus. A plurality of circuits is provided each controlled by a photo-electric tube associated with one of the rows of the slots in the moving tape. There may be a plurality of connections through which input signals are received where several signals are to be transposed among the various channels for security purposes. For the sake of simplicity however, the invention will be explained in connection with an arrangement in which different signal elements or segments of a single signal differing in time relation are transposed by means of the apparatus for the purpose of making the signal unintelligible to an unauthorized receiver. Preferably in this case memory apparatus synchronized with the moving tape is employed for the purpose of providing different segments of the same signal differing in time of occurrence.

Means are provided for causing signal output to be transmitted from one of the circuits at a time and preferably means are provided for con-

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verting the input signals into frequency variations to simplify the elemination of transition or transfer effects. The frequency modulated output signal is amplified and severely limited so that no possible difference in signal level occurs at the transfer points where the circuit is switched from one channel to another. After limitation of the signal, it is filtered to reconvert the transposed signal wave to one having only sine wave components within the frequency-modulation frequency range.

The output signal is transmitted by any suitable medium such as land wire, carrier, radio or the like. For reception of the signal suitable apparatus is provided for reversing the operations performed on the signal prior to the transmission so as to rearrange the signal segments in the original order before application to an ordinary receiving device such as a telephoto exposure head, telephone, telegraph or teletype receiver or the like.

A better understanding of the invention will be afforded by the following detailed description considered in conjunction with the accompanying drawing in which Fig. 1 is a circuit diagram schematically illustrating an embodiment of my invention as used in the transmission of transposed signals. Fig. 2 is a schematic diagram of receiving apparatus adapted for use with the apparatus of Fig. 1, and Fig. 3 is a diagram of a combined switching, signal coding, and memory apparatus utilizing a punched tape for control.

Referring to the drawings it is assumed that signals for transmission are applied to an input terminal 11. Suitable means such as a memory apparatus 12 are provided for recording and making available elements or segments from the input signal differing in time relation. A plurality of channels, in this case represented as three in number, are provided for passing different signal elements. These three channels are represented by amplifiers 13, 14, and 15 included in the respective channels. A signal sequence switching device 16 represented by the portion of the apparatus within the dotted lines is provided for control of the sequence of signal elements supplied to the output circuit, which includes an amplifier 17 to which the out puts of the amplifier 13, 14 and 15 are connected in parallel.

Memory apparatus is arranged to provide three signal output circuits 18, 19 and 21. Preferably means are provided for converting the signals to frequency modulated signals. For example three oscillators 22, 23 and 24 may be provided, each having reactance-tube modulating means 25, 26

and 27, respectively, interposed between the circuits 18, 19 and 21 and the oscillators 22, 23 and 24, respectively. For the sake of simplicity the oscillators 22, 23 and 24 have been shown as separate units; but preferably I employ a single fixed-frequency oscillator beating with three variable frequency oscillators, each controlled by one of the signal circuits 18, 19, and 21 and having a different average frequency. For example a frequency of 100 kilocycles may be chosen for the fixed-frequency oscillator, and the mid-range frequencies of the variable oscillators may be 101, 102, and 103 kilocycles respectively. It will be understood, of course, that these specific numerical values are given merely by way of illustration and that the invention is not limited to any specific values.

The signal switching device 16 includes a movable beam interceptor or a shutter means, a radiant beam source and a plurality of radiant energy responsive devices. The beam interceptor is illustrated as a moving tape 28, driven at a uniform rate of speed by a drum 29. The radiant beam source most conveniently takes the form of a lamp 31. The radiant-energy responsive devices preferably take the form of photoelectric tubes 32, 33, and 34. Means are provided for controlling the transmission of signals through the amplifiers 13, 14 and 15 in response to the photoelectric tubes 32, 33 and 34. The tape 28 is provided with a plurality of rows of slots in this case three rows of slots 35, 36 and 37 corresponding in number to the number of photoelectric tubes and the number of transmission channels. Preferably a beam-focusing arrangement, represented schematically by a single lens 38 and a slot 39 are provided in order to produce a thin ribbon of light spread across the tape 28, or a plurality of beams aligned transversely across the tape 28, striking the respective slots 35, 36 and 37. For the sake of simplicity of explanation it is assumed that light from the lamp 31 has been broken into three separate beams 41, 42, and 43 adapted to be reflected by mirrors 44, 45 and 46, against the photoelectric tubes 32, 33 and 34, respectively. The complete paths of all the light beams have been shown, although with the tape 28 in the position illustrated, only the light beam 42 is free to pass through the associated slot 47 in the tape 28 and to strike the associated photo-electric tube 33.

The sprocket drum 29 is driven directly or indirectly by a synchronized motor.

For controlling the channel including the amplifier 13, I provide a direct-current amplifier 48 controlled by the photoelectric tube 32, a signal relay device or signal-pickup tube 49 having a control grid 51 excited by the variable frequency oscillator 22, and a blocking tube 52. The amplifier 13 also has connections 53 tapping voltage therefrom and supplying a pair of unilateral devices such as full wave rectifiers 54 and 55. Similar devices are associated with the amplifiers 14 and 15. The output connections 56, 57 and 58 of the amplifiers are connected in parallel directly or indirectly to a common output line 59 supplying the input to the amplifier 17.

The direct current-amplifier tube 48 has an anode or plate 61 connected to a suitable source voltage represented by the symbol B+ and has a cathode 62 in series with the primary winding 63 of an input transformer 64 of the amplifier 13. Also connected in series with the winding 63 is the signal pick-up tube 49 having a cathode 65 connected to the cathode 66 of blocking tube 52. A cathode resistor 67 is connected between the cathode 66 of the blocking tube 52 and ground. The plate or anode 68 of the blocking tube 52, associated with the amplifier 13, is connected through a conductor 69 to output conductors 71 and 72 associated with the rectifiers tapped into the other amplifiers. Thus the line 71 is connected to a rectifier 73 having leads from the amplifier 14, and the line 72 is connected to the output terminal of the rectifier 74 energized from the amplifier 15. The blocking tube 75 associated with the amplifier 14 is supplied with the direct current either from the rectifier 55 associated with the amplifier 13 on the rectifier 76 associated with the amplifier 15. In like manner each amplifier is provided with a plurality of unilateral devices or rectifiers, each one supplying direct current to the blocking tube of one of the other amplifiers.

In order to eliminate the transient effect of variations in amplitude of transposed wave segments and to suppress any indications of the points of transposition, a push pull limiter 77 is provided in the output side of the amplifier 17 designed for severely limiting the wave. For converting the output of the limiter 77 from a rectangular wave or one having square tops, to a wave containing only sine wave components of the frequencies represented by the output of the oscillators 22, 23 and 24 a band-pass filter 78 is provided. Where the numerical values of the frequencies employed are as previously assumed, so that the output frequencies of oscillators 22, 23 and 24 average 1000, 2000, and 3000 cycles, respectively, the filter 78 has band passing frequencies lying in the region between zero and 5000 cycles, for example. Preferably an amplifier 79 is provided for amplifying the output of the band-pass filter 78 and supplying it to a suitable transmission channel, which may take the form of a wire or carrier circuits, but for the sake of illustration is represented as a radio transmitter 81 including radiator elements 82.

Preferably the tape 28 is so arranged as to be coordinated with the memory apparatus 12 so that the slot punching of the tape 28 may be employed also for controlling the transposition arrangement and coding of the memory device 12. Any suitable form of a memory apparatus may be employed. The arrangement illustrated comprises a travelling, magnetic wire, tape or disc 84 having means for synchronizing itself with the punched tape 28. This is indicated schematically in the drawings by mechanical connections consisting of the shaft 85, bevel gears 86 and 87, and a shaft 88 connected to the sprocket drum 29 driving the tape 28. The memory device 12 is provided with a signal recording electro-magnet 89, a plurality of signal pick-up electro-magnets 91, 92 and 93 or more (not shown) and an erasing magnet 94. The magnets 89, 91, 92 and 93 have electrical windings connected respectively to the input terminal 11 and the output circuit 18, 19 and 21. There may be more pick-up magnets than channels, in which case the pick-up magnets are connected in parallel. The main purpose is to pick up and use all the intelligence put on the magnetic record 84 by the recording magnet 89, before it is wiped off or erased by magnet 94. The erasing magnet 94 may be a permanent magnet or a high-frequency electromagnet. The angular spacing between the pick-up heads or electromagnets 91, 92 and 93 may be so related to the linear spacing between the trailing ends of the successive slots 95, 96 and 97 of the tape 28 that

either the same length of time is required for the magnetic disc 84 to move through a unit spacing as for the tape 28, or the time ratio is an integral number. For the sake of simplicity of explanation, a simplified pattern or arrangement of slots is shown but it is to be understood that in practice a more complicated code may be and preferably is employed. The slots punched in the tape 28 may be of the same lengths or different lengths and the spacing of successive slots may be different in accordance with the code employed. It is unnecessary however to employ great accuracy in the length of the slots, the determining factor is the space from the trailing end of one slot to the trailing end of the next, for example, from the end 98 of the slot 96 to the end 99 to the slot 95. Preferably, as indicated, trailing ends of the slots overlap for reason which will be explained. The amount of overlapping and any variations therein have no effects on the accuracy and precision of the operation of the signal transposition and sequence switching.

Since the recording heads 91, 92 and 93 of the memory apparatus 12 are operated at different angular positions, a signal occurring during a given time interval will be reproduced at successively later times by the heads 91, 92 and 93. The arrangement of the tape 28 is such that the portions of a signal occurring during successive time intervals are delivered to a channel separately as signal segments, and the signal segments are rearranged and retransmitted out of their natural order. Thus when the light beam passes through only one of the slots in the central row such as slots 96 and 47, the photo-tube 33 is illuminated causing the amplifier 14 to operate. Similarly for the other amplifiers and the channels in which they are located. However, when light beams pass through two overlapping slots, one channel blocks the other so that only one channel is effective.

When the tape 28 is in such a position that the light passes through both the slot 95 and the slot 96, the poto tubes 32 and 33 are illuminated. Current passes through tubes 32 and 33. Passage of current through the photo tube 32, positively biases the D.-C. amplifier 48 to render it conducting. Voltage is applied from the terminal B through the tube 48 and the input transformer 63 to the anode 60 of the signal relay device or pick-up tube 59 thereby energizing it. The latter is thereby pre-set so as to permit a signal from beat frequency oscillator 22 to affect the pick-up tube 49 as soon as it becomes conducting. The signal pick-up tube 102 had previously been rendered conducting through the action of light falling on the photo tube 33, so as to energize the amplifier 14 and supply positive voltage to the anode 68 of the blocking tube 52. Consequently the cathode 65 of the pick-up tube 49 is positively biased by the flow of current through the cathode resister 67 of the tube 52. As soon as the tape 28 moved to the point at which the edge 98 of the slot 96 cuts-off the light beam 42, the tubes 101 and 102, amplifier 14, the rectifier 73 and the blocking tube 52 lose energization. At the same instant the potential of the cathode 65 falls to zero and the tube 49 becomes responsive to pass segments to the amplifier 13. Under these circumstances the amplifier 13 is first pre-set so that the signal pick-up tube 49 and the amplifier 13 may pass current as soon as current is cut-off from blocking tube 52. In a similar manner the interception of lights at the trailing edge of each slot very precisely fixes the instant of signal transfer to the next channel. In the pattern arrangement of slots shown, in the drawing, for the sake of illustration, light beams will pass successively through the slots 97, 96 and 95 assuming that the tape 28 is traveling downward. Consequently signal segments from the memory apparatus pick-up heads 91, 92 and 93 will be sent successively through the channels 13, 14 and 15 and applied in this order to the common output line 59. However since the magnetic recording tape or disc 84 is traveling in a direction from the pick-up head 91 to 93 the signal segments actually occurring last are transmitted first so that confusion is introduced in the transmitted signal. The speed of the operation is such that very short segments are transposed and consequently the signal emitted from the radio transmitter 81 is not transcribable or decipherable. By suitable arrangements of the slots in the tape 28 other and more complicated transpositions are provided making it still more difficult to decipher the transmitted signal.

In order to receive and decode the signal it is necessary to have corresponding apparatus employing a transposition controlling and decoding tape corresponding exactly with the tape 28. A suitable receiving apparatus may comprise a radio receiver 111 having antennae 112 corresponding to the transmitter antennae 82, a pre-amplifier 110, a push pull limiter 113 for removing the fading effect, preferably an additional amplifier 114, memory apparatus 115 corresponding to the transmitter memory apparatus 112, and signal switching apparatus 116, corresponding to the transmitter signal switching apparatus 16. By limiting the output to a predetermined value independent of input strength or fading, the limiter 113 overcomes the effect of fading. The principle of operation of limiters is described in "Basic Radio," by Hoag, 1942 edition, page 274, referring to Fig. 33C and in "Ultra-High Frequency Techniques," by Brainerd et al., 1942 edition, pages 179, 267 and 283. The switching apparatus 116 is provided with three output lines 117, 118 and 119 corresponding respectively to the output lines 56, 57 and 58. Preferably the receiver includes limiters 121, 122 and 123 in lines 117, 118 and 119, and also amplifiers 124. The output terminals of the amplifiers 124 are connected directly or indirectly in parallel to a pair of conductors 125 to which a suitable device 126 is connected such as a telephoto exposure head, a teletypewriter, a telephone receiver including a detector or other reception device, depending upon the input signal to the transmitter. The memory apparatus 115 and the signal sequence switching apparatus 116 are provided with driving motor means 127 for operating the two devices 115 and 116. Suitable means (not illustrated) are provided for causing the motor 83 at the transmitter and the motor 127 at the receiver to operate synchronously and exactly in phase. Such means may take the forms of synchronizing drives or synchronizing signals such as employed in telephoto and television circuits.

The signal switching apparatus 116 is indicated in block form but is preferably identical with the arrangements shown within the dotted line 16 of Fig. 1. It includes tape such as the tape 28 of Fig. 1 which is identical there with same punching arrangement. In case the receiving apparatus indicated in Fig. 2 should be located in such a position that it may fall in enemy hands during military use or there is danger that unauthorized operators of the signal transmission circuits may obtain access thereto during com-

mercial use, the tape of the receiving apparatus is removed before leaving the receiving apparatus unguarded. Without the proper tape serving as a key to the transposition it is not possible for an unauthorized person even with similar receiving apparatus to obtain signals which convey intelligence. Even if received signals should be recorded and should be examined by decoding experts allowed a considerable period of time, decoding would be impossible because the points of transition are not detectable. The signal segments into which the original segment was cut fit together without revealing transition points since only frequency changes are involved and operates very precisely in starting the transmission of signal segment over one channel at the instant of termination of the transmission over another channel. There are no transition or decay effects by which a person attempting to decode the recorded signal can observe the points of transition.

The only way of decoding the signal segment in the original order is to employ a tape in the switching apparatus 16 at the receiver which is identical with the tape 28 at the transmitter. Consequently the simple operation of removing such a tape renders it impossible for unauthorized persons to receive signals even though they may obtain access to the receiver. Thus the apparatus may safely be employed for security purposes even if those operating the receiver should find it impossible to retain control thereof and should not even have time to destroy the receiver. The tape may be composed of inflammable material or of metal, but even if composed of metal it is readily destroyed since thin metal would be employed. Even though the light metal tape may not be consumed by fire it will be destroyed by the heat. For example it may also be destroyed by passage of electrical current to heat it to glowing temperatures. This will serve to damage it to such an extent that it will not operate and that the slot coding is not reproducible.

Thin metal tape has the advantage of maintenance of accuracy of slot spacing independently of humidity conditions.

In order to simplify the precise synchronization of the moving elements of the memory apparatus 12 and the moving tape 28 of the signal sequence device 16, a tuning fork drive or a moving light interceptor may be employed as the common moving element for both devices. For example a slotted motion picture film having sound tracks at the edge may be employed for the operation of both the photo-electric cells 22, 23 and 24 and for energizing the memory device units photo-electrically. Preferably a steel tape is employed for the sake of accuracy. As indicated in Figure 3, a tape 120 is employed composed of steel having slots 128, 129 and 131 cut therein with slot spacing corresponding to the spacing of the magnetic pick-up heads 91, 92 and 93 arranged along the edge 132 of the tape 127. It should be understood that the recording head 89 is arranged in advance of the pick-up heads 91, 92 and 93 and that an erasing magnet 94 may be provided as previously described.

While I have described my invention as embodied in concrete form and as operating in a specific manner in accordance with the provisions of the patent statutes it should be understood that I do not limit my invention thereto, since various modifications thereof will suggest themselves to those skilled in the art without departing from the spirit of my invention, the scope of which is set forth in the annexed claims.

I claim:

1. Signal sequence switching apparatus comprising in combination a plurality of transmisison channels, a plurality of blocking devices, each one adapted to block one of said channels when energized, means providing a plurality of light beams, a moving tape arranged to intercept said light beams with each beam striking a different distance from the edge of the tape, said tape having longitudinal rows of slots, each row of slots passing through one of said light beams, whereby said light beams are intermittently passed and intercepted as the tape moves, said slots being arranged according to a fixed pattern and each slot longitudinally overlapping a slot in another row, a plurality of photo-electric responsive devices beyond said tape with respect to said light providing means, direct current amplifiers actuated by said photo-electric devices, and connections from each one of said amplifiers to one of said channels for energizing the same, unilateral means between each of said amplifiers and all of the blocking devices except the one associated with the channel energized by the same amplifier, said unilateral means being connected to said respective blocking devices for energizing the same in response to amplifier output, memory apparatus for recording the input to each blocked channel and for subsequently transferring the recorded signals to said channels.

2. A signal sequence switching apparatus comprising in combination a plurality of transmission channels, a plurality of blocking devices, each one adapted to block one of said channels when energized, means providing a plurality of light beams, moving tape arranged to intercept said light beams with each beam striking a different distance from the edge of the tape, said tape having longitudinal rows of slots, each row of slots passing through one of said light beams whereby said light beams are intermittently passed and intercepted as the tape moves, said slots being arranged according to a fixed pattern and each slot longitudinally overlapping a slot in another row, a plurality of photo-electric responsive devices beyond said tape with respect to said light providing means, direct current amplifiers connected to said photo-electric devices, connections from each of said amplifiers to one of said channels for energizing the same, and simultaneously energizing each of said blocking devices except the one associated with the channel energized by said amplifier.

3. A signal sequence apparatus comprising in combination a plurality of transmission channels, a plurality of blocking devices each one adapted to block one of said channels when energized, means providing a plurality of light beams, moving shutter means arranged to intercept said light beams with each beam striking a different distance from the edge of the shutter means, said shutter means having rows of slots, each row passing through said light beam whereby said light beams are intermittently passed and intercepted as the shutter means moves, said slots being arranged according to a predetermined pattern and each slot longitudinally overlapping a slot in another row, a plurality of photo-electric responsive devices beyond said shutter means with respect to said light providing means, direct current amplifiers actuated by said photo-electric devices, and connections between said channels and said direct current amplifiers for precondi-

tioning each channel to be energized with corresponding light beams permitted to pass through said shutter means and for energizing the blocking means of the other channels simultaneously therewith, whereby each channel becomes finally energized when the channel is unblocked.

4. Signal sequence apparatus comprising in combination a signal source, a plurality of transmission channels, a plurality of blocking devices each one adapted to block said channel when energized, means providing radiant energy beams, moving shutter means arranged to intercept and pass such beams intermittently according to a predetermined pattern, each of said radiant energy beams corresponding to one of said channels, a signal relay device for each channel controlling transmission of received signals through it, each of said signal relay devices being of the type effective to permit transmission through its channel only when energized, means responsive to passage of the radiant energy beam corresponding to a given channel for simultaneously energizing the signal relay device of the corresponding channel and energizing the blocking means for the other channels, whereby the interception of the radiant energy beam terminates the blocking of a given channel, releases such channel for signal transmission, and signals are transferred in sequence from one channel to another according to the pattern of said shutter means.

5. Signal sequence apparatus comprising in combination a plurality of transmission channels, a plurality of blocking devices each associated with one of said channels, a source of radiant energy, a plurality of radiant energy responsive devices, a moving radiant energy interceptor with slots in rows each corresponding to one of said energy responsive devices, and connections from each of said energy responsive devices for energizing one of said channels and blocking the remainder, whereby signals are passed through said channels in accordance with a code determined by its slot arrangement of the said moving interceptor.

6. The method of signal transmission which comprises recording of the signal to be transmitted in segments occurring in different intervals of time, transmitting signal segments through separate channels, transposing the sequence of transmission through said channels in accordance with a predetermined code with transmission through only one channel at a time, combining the transposed signal segments to form a continuous unbroken transmission, limiting the output amplitude to suppress decay effects at the instants of transfer, transmitting the output of the limiter, receiving such output and recording successive signal segments, transposing the signal segments in accordance with the same transposition code employed in the transmitter for restoring the original signal sequence in different channels, limiting the output in each channel and combining all the outputs for utilization in a receiving device.

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Certificate of Correction

Patent No. 2,482,039 September 13, 1949

LOUIS A. THOMPSON

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

Column 5, line 48, for "terminal B" read *terminal B+*; line 51, for "tube 59" read *tube 49*;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 17th day of January, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

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Patent No. 2,482,039 September 13, 1949

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[SEAL]

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Assistant Commissioner of Patents.