Feb. 20, 1968 D. L. SCIDMORE 3,370,126

COMMUNICATION APPARATUS

Filed Sept. 23, 1964 2 Sheets-Sheet 1

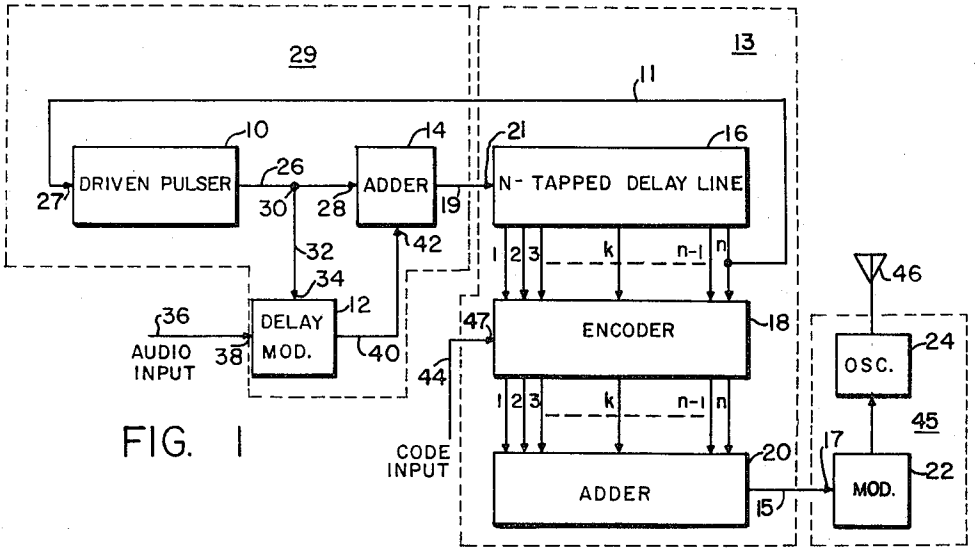


FIG. 1

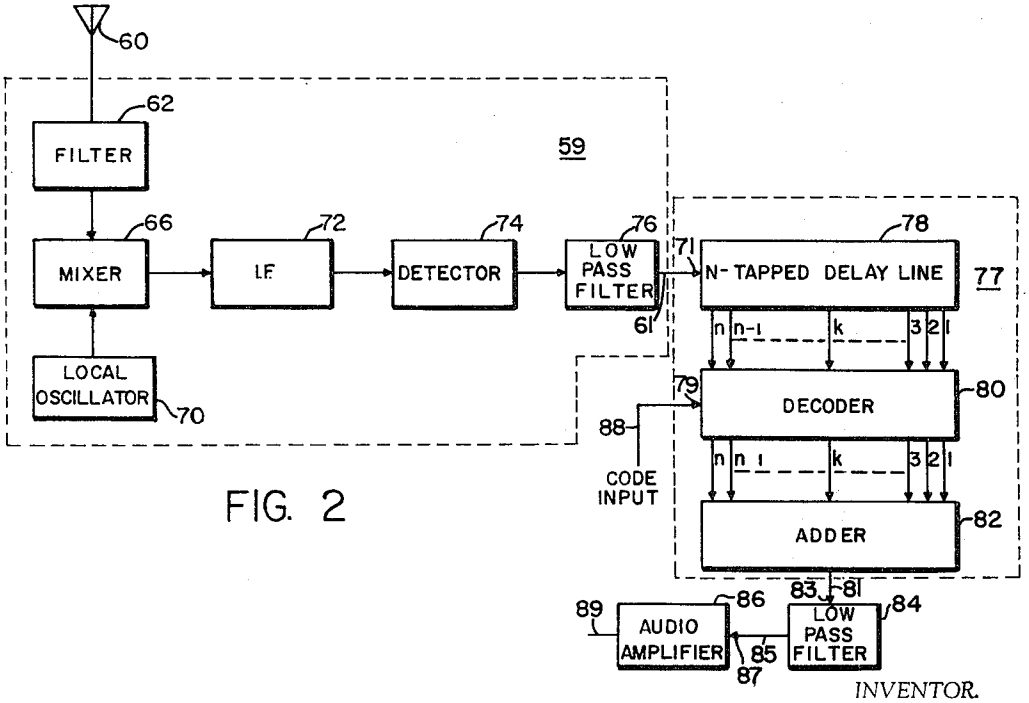


FIG. 2

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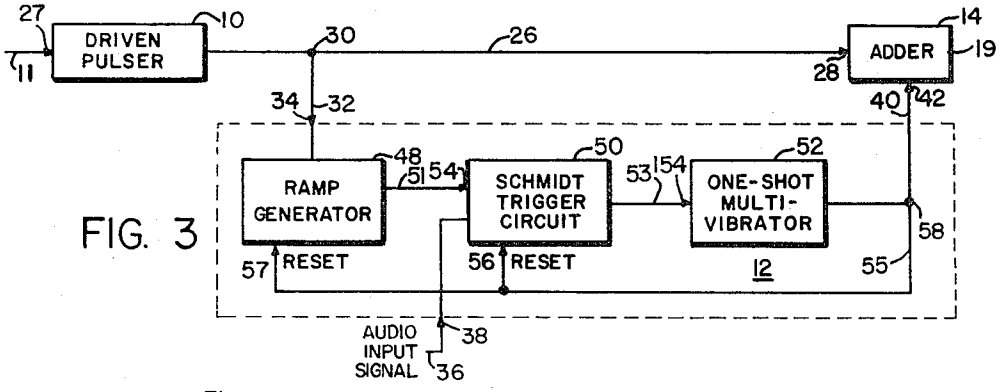


FIG. 3

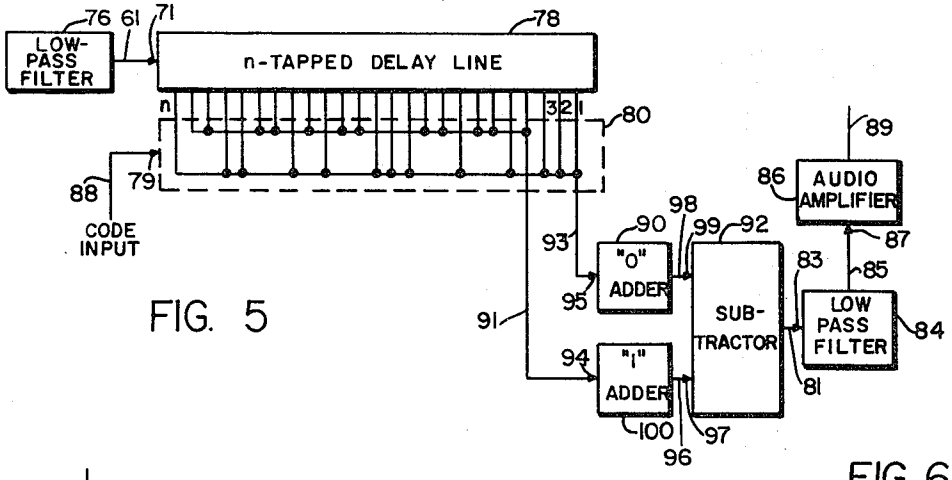


FIG. 5

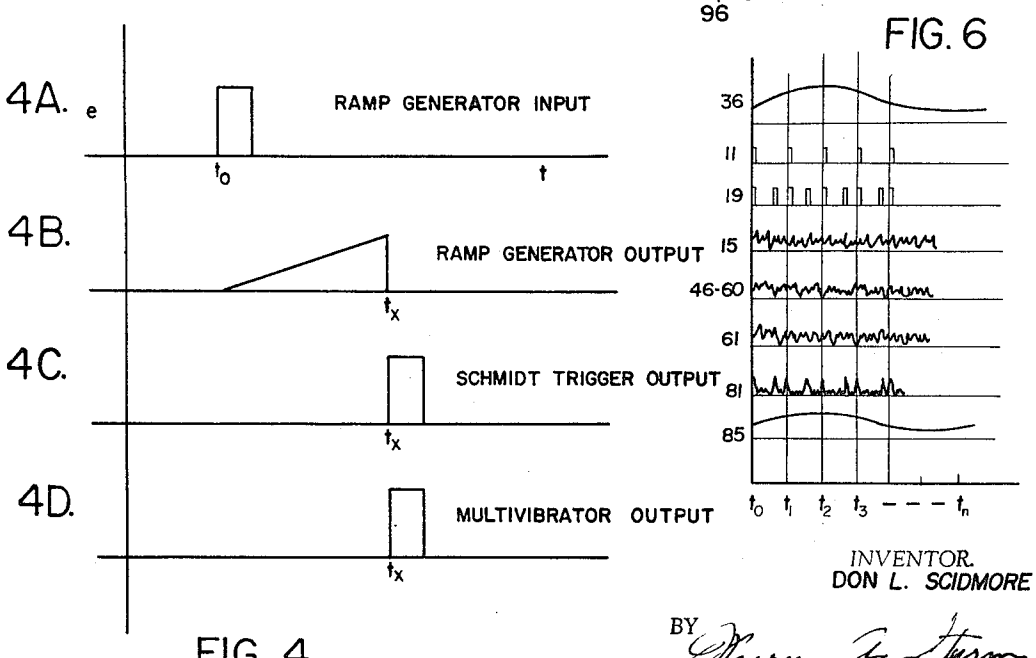


FIG. 4

FIG. 6

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United States Patent Office 3,370,126
Patented Feb. 20, 1968

3,370,126

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Filed Sept. 23, 1964, Ser. No. 398,610
7 Claims. (Cl. 179—1.5)

ABSTRACT OF THE DISCLOSURE

A security transmitting and receiving system utilizing a tapped delay line wherein predetermined taps of the delay line are added together to produce apparent noise. The apparent noise signal is received and decoded by a further delay line which provides a time inverse of the original tapped delay line. The signals transmitted are pulse position modulated and the frequency of the information is determined by the delay line characteristics.

The invention

This invention is related to data handling and communication systems and is particularly directed to systems of this general class for processing information existing in an analog state. This invention is further directed to communication systems utilizing a transmission mode, method and apparatus which is not subject to unauthorized detection and which may be operable under substandard operating conditions as might be occasioned by noise and intentional interference.

Accordingly, as will be seen from the description set forth below, I have provided data handling apparatus and a method of operation for processing data existing in an analog state which provides a high degree of security from unauthorized use of the data and a high degree of accuracy in the handling of such data whereby undesired signals whether present intentionally or unintentionally are substantially ineffective with respect to the quality of the information contained in the data being processed.

Briefly, my invention is comprised of apparatus which characterizes an analog signal for further processing or handling according to a predetermined pattern whereby selected portions of the analog signal are superimposed on the signal. A further means is utilized to decharacterize the signal whereby the original analog signal may be detected in the characterized signal to provide the original analog signal information.

It is therefore an object of this invention to provide a novel and improved communication system for processing and handling analog signals.

A further object of my invention is to provide an improved transmitter for use in an analog data system.

Another object of my invention is to provide an improved receiver for use in an analog data handling system.

A further object of my invention is to provide improved analog signal characterizing apparatus.

A still further object of my invention is to provide an improved method of characterizing analog signal information for processing and handling.

Another object of my invention is to provide an analog data communication system wherein a pair of matched filters are utilized to characterize and decharacterize an analog signal.

A still further object of my invention is to provide an improved security communications system.

These and other objects will become apparent from a consideration of the appended specification, claims, and drawing in which:

FIGURE 1 is a block diagram of a radio communication transmitter embodying the principles of my invention;

FIGURE 2 is a block diagram of a radio communication receiver embodying the principles of my invention and which may be utilized with the apparatus of FIGURE 1 to provide a communication system;

FIGURE 3 is a block diagram of a portion of the apparatus shown in FIGURE 1;

FIGURE 4 is a family of curves illustrating the operation of the apparatus shown in FIGURE 3;

FIGURE 5 is a block diagram of a modification of the signal decharacterizing apparatus shown in FIGURE 2; and

FIGURE 6 is a family of curves illustrating typical wave forms of the signals appearing at the indicated portions of FIGURES 1, 2, 3 and 5.

Referring now to FIGURES 1, 2 and 6 of the drawing, there is shown in FIGURE 1, a pulse position modulator indicated generally by reference character **29** which is associated with a signal characterizing filter means indicated generally by the reference character **13** which is further connected to radio transmitting apparatus indicated generally by reference character **45** whereby an analog signal, for example an audio signal, may be characterized and radiated for transmission to remote locations. In FIGURE 2 a receiver, indicated generally by reference character **59**, is shown connected to a signal decharacterizing filter means indicated generally by reference character **77**, which is in turn connected to suitable means for further processing a decharacterized signal to provide a replica of the audio analog input signal to the apparatus of FIGURE 1.

Pulse position modulator **29** includes a driven pulser **10** having an input terminal **27**. The output of driven pulser **10** is connected to an input terminal **28** on an added **14** through conductor **26** and to an input terminal **34** on a delay modulator **12** through conductor **32** and terminal **30** on conductor **26**. Delay modulator **12** has a further input terminal **38** adapted for connection to a suitable source of analog signal (indicated as an audio signal, not shown) through conductor **36**. The output of delay modulator **12** is connected to a further input terminal **42** on adder **14** through conductor **40**.

Signal characterizing means **13** includes an N-tapped delay line **16** having an input terminal **21** connected to the output of adder **14** through conductor **19**. Delay line **16** is provided with a predetermined number of taps, e.g. 1, 2, 3–k–(n—1), n. The last tap, n, in the delay line is connected to input terminal **27** on driven pulser **10** through conductor **11**. An encoder **18** is shown having a plurality of input and output terminals corresponding in number to the number of taps (n) on delay line **16**. Encoder **18** may be provided with means (not shown) for providing continuity between selected corresponding input and output terminals, for example an electronic switch responsive to a code input (not shown) which may be supplied to encoder **18** through conductor **44** and code input terminal **47**. The electronic switches may conveniently be considered as single pole single throw switches connected intermediate corresponding input and output terminals. It may thus be seen that selected signals appearing on predetermined taps of delay line **16** will appear at the output of encoder **18** according to the status of the switches. In one embodiment of my apparatus, approximately half of the switches were closed so that a so-called pseudo random coded output appeared on the output terminals of encoder **18**. Each of the output terminals of encoder **18** is shown connected through suitable conductors to an adder **20**. Adder **20** may be comprised of a plurality of parallel summing resistors connected to provide an output on conductor **15**. The signals applied to the predetermined summing resistors in adder **20** appear as a serial output on conductor **15**.

Transmitter **45** is shown including a modulator **22** which is connected to an oscillator **24** which in turn is connected to an antenna **46** for radiating a signal in accordance with the signal present on conductor **15** connected to an input terminal **17**. Radio transmitter **45** may be one of many forms of transmitting equipment known to those skilled in the art.

Referring to FIGURE 2, a radio receiver **59** is shown comprised of an antenna **60** connected to a filter **62** which is in turn connected to a mixer **66** which is adapted to receive a signal from a local oscillator **70**. The output of mixer **66** is connected to conductor **61** through an IF stage **72**, a full wave detector **74** and a low pass filter **76**.

Signal decharacterizing filter means **77** is shown comprised of a delay line **78**, a decoder **80** and an adder **82**. Delay line **78** is shown having *n* taps corresponding to the taps on delay line **16** in FIGURE 1 and it may be noted that the taps are connected in an inverse manner, with respect to delay line **16**, to decoder **80** through suitable conductors. Decoder **80** may comprise apparatus as described above in connection with encoder **18** and it is desired that a coded input supplied from a source (not shown) to conductor **88** and terminal **79** provide a predetermined pattern with approximately one-half the switches closed corresponding to the pattern supplied to encoder **18**. The output of decoder **80** is supplied to adder **82** through suitable conductors and an output from adder **82** appears at conductor **81**. Adder **82** may be comprised of a plurality of summing resistors for simultaneously adding all signals appearing at its input terminals from delay line **78** connected through decoder **80**. The output of adder **82** is connected to a low pass filter **84** which includes a converter from pulse position modulation to pulse width modulation of some type such as a multivibrator or flip-flop in an input stage thereof, through conductor **81** and input terminal **83**. The output of low pass filter **84** is connected to input terminal **87** of an audio amplifier **86** through conductor **85**. An audio analog signal for use by suitable output signal utilization means appears at conductor **89** connected to audio amplifier **86**.

A family of curves on FIGURE 6 is provided to illustrate the signals appearing at various portions of the apparatus shown in FIGURES 1 and 2 and reference characters corresponding to the conductors on which the signals are present have been applied to facilitate reference to FIGURES 1 and 2.

It may be noted that signal characterizing filter **13** and signal decharacterizing filter **17** comprise a matched filter of the general class described by Turin in an article "An Introduction to Matched Filters," IRE Transactions on Information Theory, June 1960.

It should further be noted that the code input appearing on conductors **44** and **88** may be continuously simultaneously varied in a predetermined pattern by suitable means (not shown) to further increase the security of the data transmission.

A detailed diagram of a portion of FIGURE 1 is shown on FIGURE 3 in which the several elements of which delay modulator **12** is comprised are shown in block diagram in connection with the associated portion of the apparatus of FIGURE 1. FIGURE 4 shows a family of curves which are illustrative of the operation of the delay modulator **12** shown in FIGURE 3. In FIGURE 3, driven pulser **10** is shown having an input terminal **27** connected to conductor **11** upon which appears a train of pulses of predetermined frequency as will be set forth below. Driven pulser **10** is connected to adder **14** through conductor **26** and to a ramp generator **48** that is connected to input terminal **34** on delay modulator **12** through conductor **32**. Ramp generator **48** is connected to an input terminal **54** on a Schmidt trigger circuit **50** through conductor **51**. Trigger circuit **50** is connected to input terminal **154** on a one shot multivibrator **52** through conductor **53**. The output of multivibrator **52** appears on conductor **55** which is in turn connected to reset terminals **57** and **56** on ramp generator **48** and trigger circuit **50** respectively. Conductor **55** has a further terminal **58** that is connected to conductor **40** which is in turn connected to input terminal **42** on adder **14**. A further input terminal **38** on delay modulator **12** is shown connected to conductor **36** which may be energized from a suitable source of analog data indicated as an audio input signal. As may be seen from a consideration of the family of curves in FIGURE 4, delay modulator **12** provides, in combination with the train of pulses supplied by driven pulser **10** and adder **14**, an analog to digital conversion of the analog signal appearing on conductor **36**. In FIGURE 4A a pulse indicated at time T_o is supplied from driven pulser **10** and passes through adder **14** to conductor **19** and is simultaneously applied to ramp generator **48** which initiates a sweep as indicated on curve **4B**. At the time the amplitude of the sweep voltage generated in generator **48** reaches the amplitude of the analog audio signal supplied to trigger circuit **50**, an output pulse indicated by t_x on FIGURE 4C is provided and is applied to one shot multivibrator **52**. The output thereof is indicated by curve **4D** and is a pulse of substantially constant amplitude and duration. The output of multivibrator **52** then passes through adder **14** and appears as a serial pulse following the pulse from driven pulser **10** which is displaced in time in accordance with the analog audio signal amplitude supplied to trigger circuit **50**. Simultaneously, the ramp generator **48** and trigger circuit **50** are reset to the initial condition and, upon reception of a further pulse from driven pulser **10**, the operation described above will be repeated.

Operation

Referring now to FIGURES 1, 2, 3, 4 and 6, the operation of the illustrated embodiment will be described. Operation with no analog signal input to conductor **36** will first be considered. It may be seen, at this time, that a pulse from driven pulser **10**, as indicated on curve **11** (FIGURE 6) is circulated through a circuit including conductor **26**, adder **14**, delay line **16** and conductor **11**. Additionally, each output of driven pulser **10** causes the delay modulator **12** to derive and supply a similar pulse, only delayed in time, to tapped delay line **16** through conductor **40** and adder **14**. The time delay of delay line **16** may be selected to be equal to or less than the inverse of twice the highest frequency which may be present in an analog signal. For example, an audio signal of 5 kilocycle spectral content would indicate a time delay line of 100 microseconds. It therefore follows that the total delay time for time delay line **16** should be equal to or less than 100 microseconds for an analog signal of this spectral content. The delay time between the taps may be equally divided. The number of equally spaced taps on delay line **16** is determined by the spectral bandwidth desired in the characterized signal. In the example noted above, a one microsecond time delay between taps in the 100 microsecond delay line was observed to be sufficient to maintain an adequate signal to noise ratio for satisfactory processing of an analog signal of the indicated frequency. The nominal width of the individual pulses must be somewhat less than the time interval between the taps on delay line **16**. Hence, with no signal applied to conductor **36**, a continuous train of equally spaced pulse pairs of a predetermined frequency is supplied to signal characterizing filter means **13** and a repetitive train of serial pulses is transmitted from radio transmitter **45**. The pulse train configuration appearing on output conductor **17** of signal characterizing filter means **13** as a result of each input pulse on conductor **21** is determined by the status of the individual electronic switches in encoder **18** in determining which of the output taps of delay line **16** are connected to adder **20**. As a pulse passes through delay line **16** from tap 1 to tap *n*, a corresponding pulse is produced at the output of adder **20** to provide a spectrum spreading effect. Since the input

to the signal characterization filter **13**, with no analog signal applied to audio input conductor **36**, is pulse pairs, the output appearing on conductor **15** to the modulator **22** consists of the repetitive overlapping sum of two identical pulse trains, one delayed with the respect to the other, where each individual train is that which would be developed by a single pulse input to the signal characterization filter **13**. It should also be noted at this point that driven pulser **10** may be provided with suitable inhibiting means (not shown) which are responsive to the train of pulses referred to above to inhibit driven pulser **10** during interpulse intervals so that the only frequency determining element which may affect driven pulser **10** is delay line **16**.

Assuming now that an audio analog signal is supplied to terminal **38** on delay modulator **12**, it may be seen from a consideration of FIGURES 3 and 4 that the second pulse is generated at a predetermined time after a pulse has been generated by driven pulser **10**. This pulse appears on conductor **40** and is applied to terminal **42** on adder **14** and follows the pulses circulating through delay line **16** by a time interval determined by the amplitude of the audio signal. The maximum time interval must be less than the time interval between the pulses circulating through delay line **16**. As mentioned previously with the second pulse present, as indicated by the curves **19** on FIGURE 6, two pulses separated in time are applied to delay line **16** and each time a tap that is connected through encoder **18** to adder **20** is energized by one of the pulses, a pulse output will appear on conductor **15** from adder **20** to provide a mixing of the two trains of pulses. The varying amplitude audio input signal causes this mixed output to vary continuously as a result of the varying delay in the output of the delay modulator **12**. The serial mixing of the trains of pulses results in an output signal having substantially no variation in amplitude or pulse repetition frequency despite the varying pulse train configuration as a result of the audio analog signal input and provide a composite characterized signal that may be used to modulate a transmitter. The general waveform of the characterized signal may be seen on curves **15**, **46–60** and **61** on FIGURE 6.

The signal is received in receiver **59** and the output is applied to input terminal **71** on delay line **78** in decharacterizing filter means **77**. It may be noted that the taps on delay line **78** are numbered in an inverse order with relation to the taps on delay line **16** in FIGURE 1. A signal output indicated by curve **81** on FIGURE 6, corresponding to curve **19** thereon will appear at the output of adder **82**. The "noise" appearing at a relatively constant amplitude is a result of a signal passing through delay line **78** and the sum of any pulses present on the taps connected through decoder **80** to adder **82** results in the relatively constant level of "noise" shown. When a signal which has been characterized by a code corresponding to the code present in decoder **80** is present in delay line **78** wherein each of the taps correspond in time position to pulses present in the pulse train at output **15** of the signal characterizing means **13** as a result of one pulse applied to the input **21** of signal characterizing filter means **13** in FIGURE 1, the potential appearing at each of the taps is simultaneously added in adder **82** and a relatively large pulse will appear at the output as indicated by curve **81**. Pulse pairs with varying spacing will appear at the output **81** as a result of the dual pulse position modulation input to signal characterization means **13**. This signal is then applied to a low pass filter which serves to convert the pulse position modulation output to an analog output indicated by curve **85** on FIGURE 6 corresponding to the analog input represented by curve **36** on FIGURE 6. It has been noted that distortions of a characterized signal may occur which will destroy some of the pulses generated by signal characterizing filter means **13** without substantially impairing the operation of the apparatus as the amplitude of the pulses, as shown on curve **81**, will merely be reduced.

While I have described the operation of my apparatus as utilizing a coding arrangement wherein approximately half of the switches are closed to provide a pseudo random signal, other forms of coding may occur to those skilled in the art upon becoming familiar with the principles of my invention.

The apparatus of FIGURE 5 is an embodiment in which the signal to noise ratio of the output of decharacterizing filter means **77** is increased. In this embodiment, the taps corresponding to the predetermined code are connected in common to a conductor **91** that is connected to an input terminal **94** of a "1" adder **100**. The signal appearing at the output of adder **100** is substantially the same as indicated by reference character **81** on FIGURE 6. The remainder of taps in decoder **80** are connected in common to a conductor **93** that is connected to an input terminal **94** on a "0" adder **90**. A signal, substantially the "mirror" image of curve **81** on FIGURE 6 with reduced amplitude of the large pulses appears at the output of "zero" adder **90**. Adder **90** is connected to an input terminal **99** on a subtractor **92** through conductor **98** and adder **100** is connected to an input terminal **97** on subtractor **92** through conductor **96**. The signals from adders **90** and **100** are subtracted and appear on conductor **81** which is connected to terminal **83** on low pass filter **84**. The subtraction of the two signals results in a substantial reduction of the "noise" in the intervals between the "correlated" signal pulses.

While I have shown and described a preferred embodiment of my invention, it is to be understood that my invention is limited only by the terms of the appended claims.

I claim:

1. Data handling apparatus for providing security coded signals comprising in combination:

(1) a source of pulse position modulated signals;

(2) signal characterizing filter means, including tapped delay line means with a period greater than the period between adjacent pulses from said source of signals operable to simultaneously add delayed selected portions of said signal from prior time periods to itself by summing the signal outputs of predetermined taps of said delay line to provide a resultant output having random characteristics with respect to said signal; and

(3) output means connected to said filter means and adapted to be connected to output utilization means.

2. Data handling apparatus for transmitting analog data between remotely disposed locations comprising, in combination:

(1) a source of pulse position modulated signals;

(2) signal characterizing means including tapped delay line means with a period greater than the period between adjacent pulses from said source of signals, connected to be energized by said source of signals, and operable to add delayed selected portions of said signal from prior time periods to itself by summing signals appearing on predetermined taps of said delay line to provide a resultant output having random characteristics with respect to said pulse position modulated signals;

(3) transmitter means connected to said signal characterizing means and being adapted to transmit a further signal representative of the output of said signal characterizing means to remotely disposed locations;

(4) at least one remotely disposed receiving means operable to provide an output in response to said further signal;

(5) signal decharacterizing means connected to the output of said receiver means; and

(6) signal utilization means connected to the output of said signal decharacterizing means.

3. In apparatus of the class above described, a filter for detecting a coded signal representative of analog data comprising, in combination:

(1) an n tap delay line having an input terminal adapted for connection to a source of coded signal;

(2) first and second adders;

(3) circuit means connecting code determining selected taps on said delay line to said first adder;

(4) circuit means connecting the remainder of the taps on said delay line to said second adder; and

(5) subtracting means connected to said first and second adders.

4. Data handling apparatus for processing analog data comprising, in combination:

(1) a source of analog data;

(2) a first signal characterizing filter means, including an n tap delay line, an adder and circuit means connecting predetermined taps on said delay line to said adder;

(3) a source of signal pulses having a frequency the inverse of which is greater than the time period delay between adjacent taps of said delay line;

(4) means, connected to said source of analog data, said first filter means and said source of signal pulses, for providing a further signal, the frequency of which is determined by said first filter means, comprised of a plurality of pairs of pulses, one of each of said pairs of pulses being proportionally displaced in time from the other of said pulses in accordance with the magnitude of said analog data;

(5) circuit means connecting said last named means to the delay line in said first filter means;

(6) means responsive to the output of the adder in said first filter means for propagating the output of first filler means to at least one receiving means;

(7) a second signal decharacterizing filter means including an n tap delay line, an adder and circuit means connecting like predetermined taps on said delay line to said adder, said filter means being adapted to extract said further signal from the output of said receiving means;

(8) signal converting means connected to the output of said second filter means, said signal converting means being adapted to provide a signal proportional to said analog data to an output utilization means.

5. The apparatus of claim 4 in which the circuit means connecting the predetermined taps on the delay lines to the adders in said first and second filter means are comprised of n switching means.

6. The apparatus of claim 5 in which means responsive to a common source of coding signal are operative to control the switching means to provide a predetermined pattern.

7. The apparatus of claim 5 in which at least $n/3$ and less than $n/6$ of the taps on the delay lines are connected to the adders in the first and second filter means.

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