

[54] **ASYNCHRONOUS DATA TRANSMISSION APPARATUS AND METHOD**
[76] Inventor: **Harry Fein**, 832 Quarter Mile Road, Orange, Conn. 06103
[22] Filed: **Dec. 19, 1969**
[21] Appl. No.: **886,802**

Related U.S. Application Data

[63] Continuation of Ser. No. 568,008, July 26, 1966, abandoned.
[52] U.S. Cl.**325/38, 328/145, 333/14**
[51] Int. Cl.**H04b 1/64**
[58] Field of Search**328/145; 332/1, 37, 52; 333/14; 329/107, 109; 325/38, 46**

References Cited

UNITED STATES PATENTS
2,959,641 11/1960 Hufnagel333/14 X

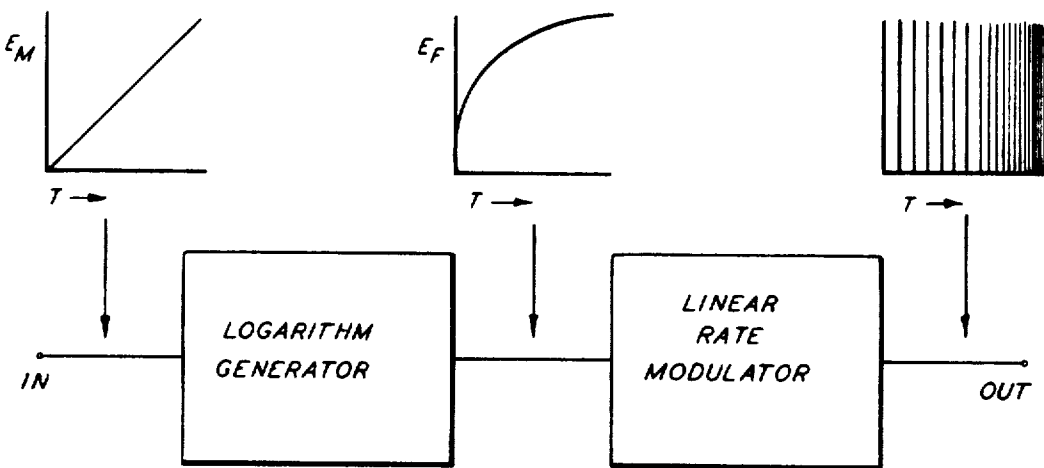
3,377,559	4/1968	Stewart.....	333/14 X
3,379,839	5/1968	Bennett.....	333/14 X
3,444,469	5/1969	Miyagi.....	333/14 X
3,500,206	3/1970	Kaneko et al.....	333/14 X
3,518,578	6/1970	Oppenheim et al.....	328/145 X
3,160,816	12/1964	Gunningham et al.....	328/145 X
3,440,414	4/1969	Miller.....	328/145 X
3,466,392	9/1969	Calfee et al.....	325/46
2,410,489	11/1946	Fitch.....	325/46

Primary Examiner—Donald J. Yusko
Attorney—Fishman and Van Kirk

[57] **ABSTRACT**

The generation of an asynchronous information bearing signal comprised of a series of pulses wherein the pulse repetition rate is proportional to a preselected non-linear function of the instantaneous magnitude of the modulating signal.

9 Claims, 12 Drawing Figures



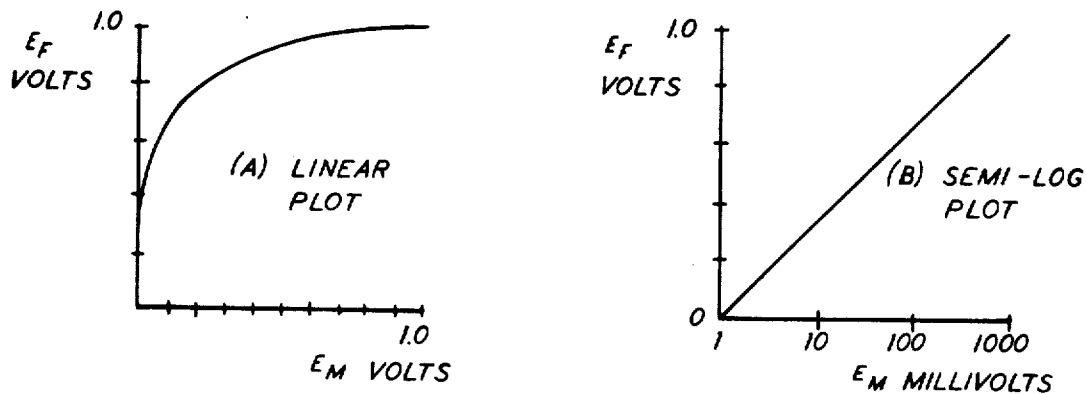


FIG - 1

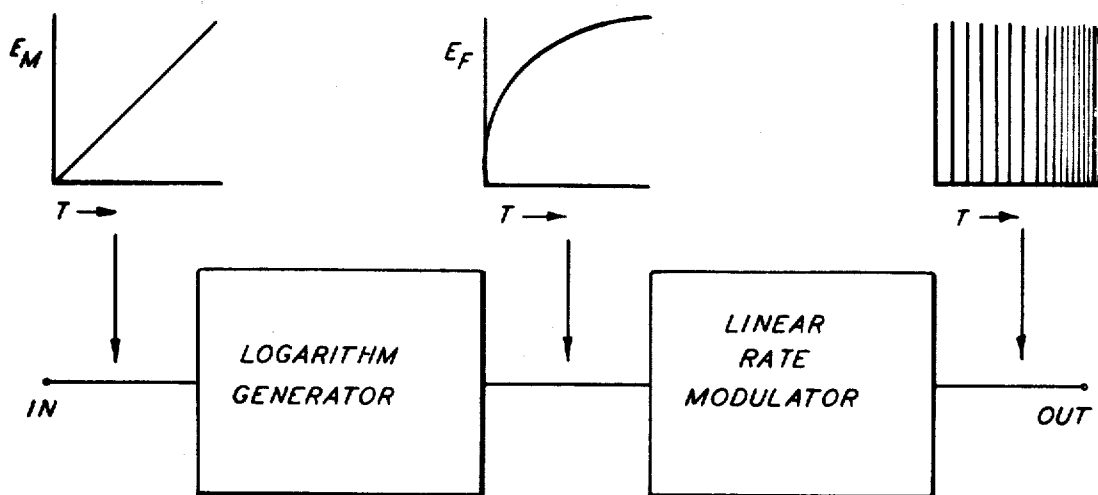


FIG - 2

INVENTOR:
HARRY FEIN
BY *Edmund L. Pantani*
Special Agent

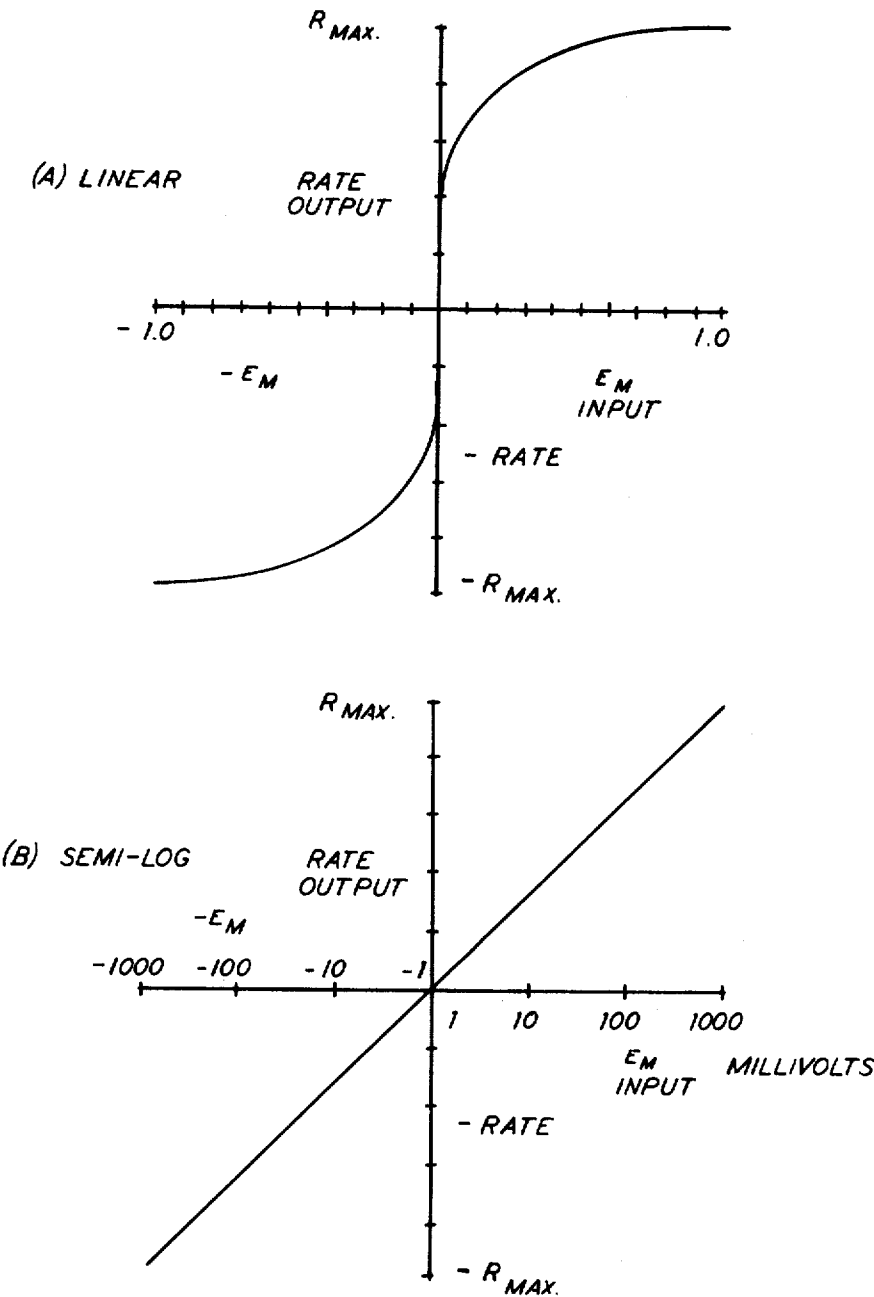


FIG-3

INVENTOR
HARRY FEIN
BY *Edmund L. Pantoni*
Special Agent

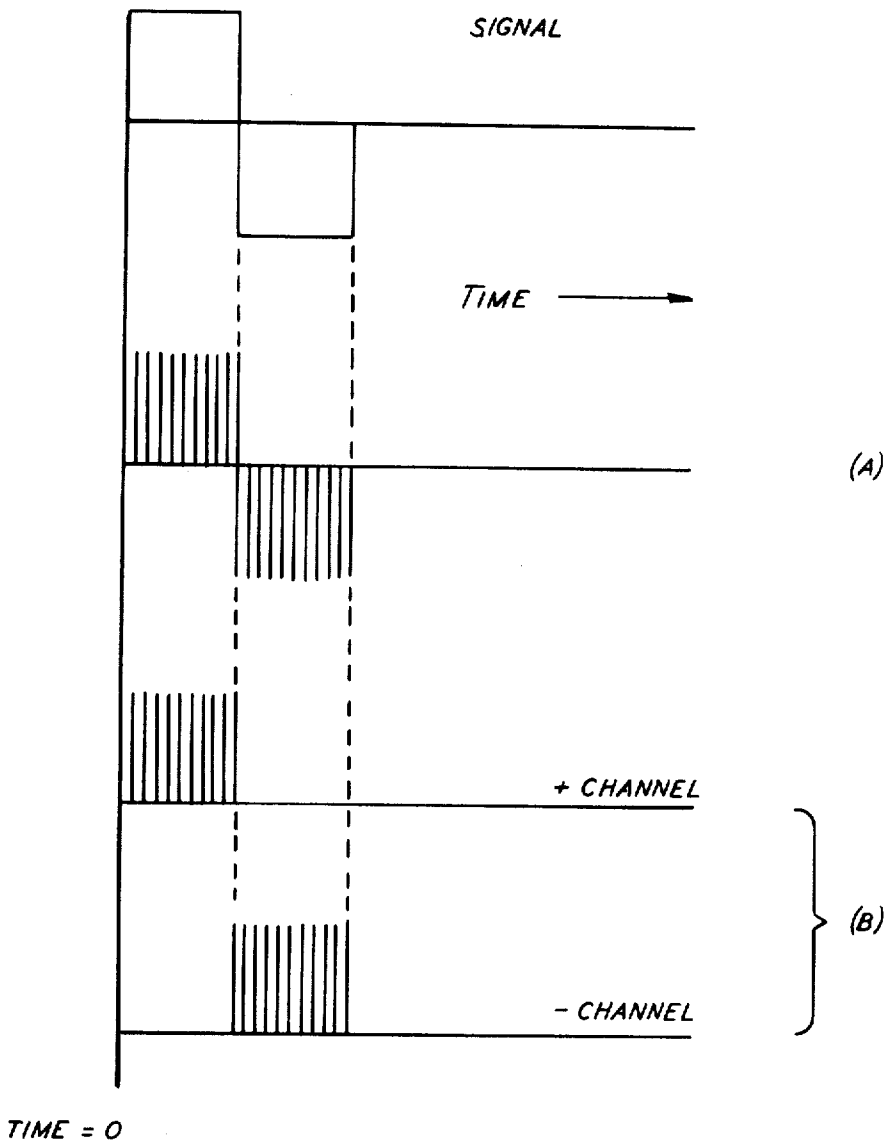


FIG-4

INVENTOR:
HARRY FEIN
BY *Edmund L. Pantani*
Special Agent

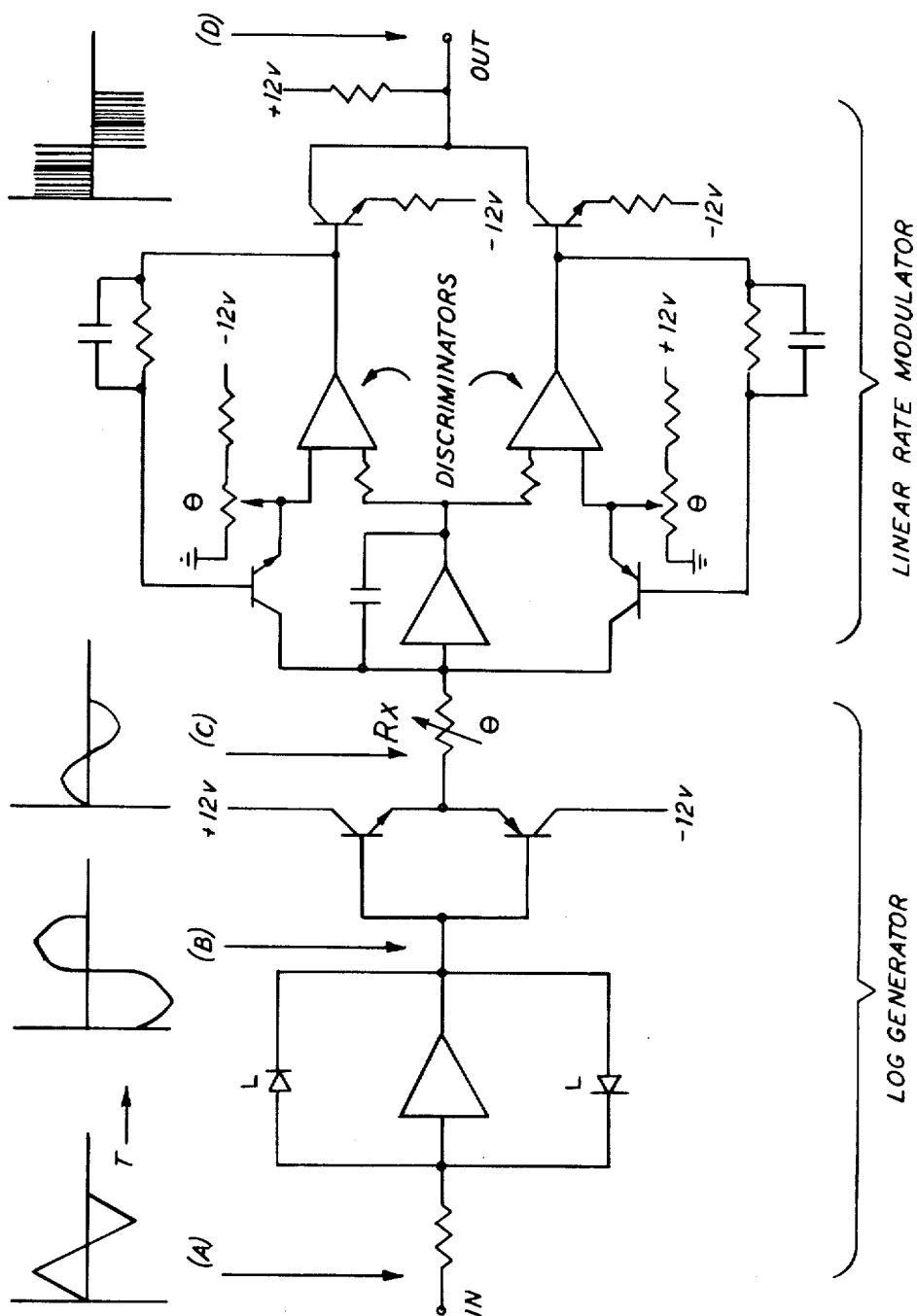


FIG-5

INVENTOR:
HARRY FEIN
BY *Edmund L. Pontani*
Special Agent

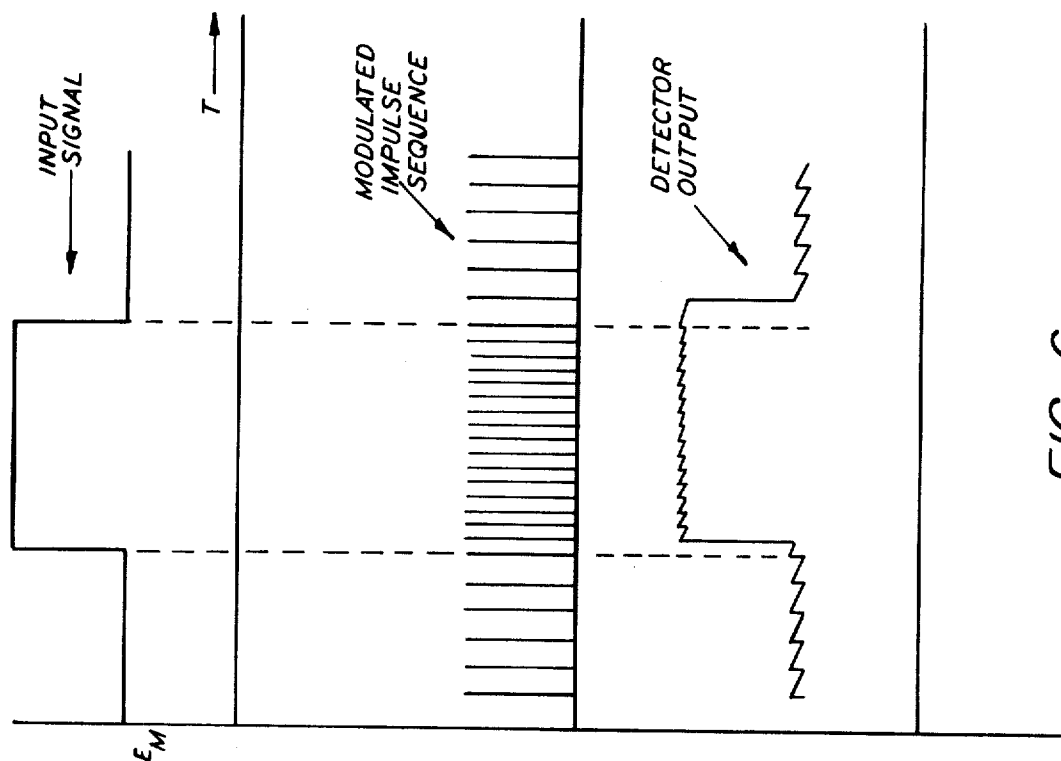


FIG-6

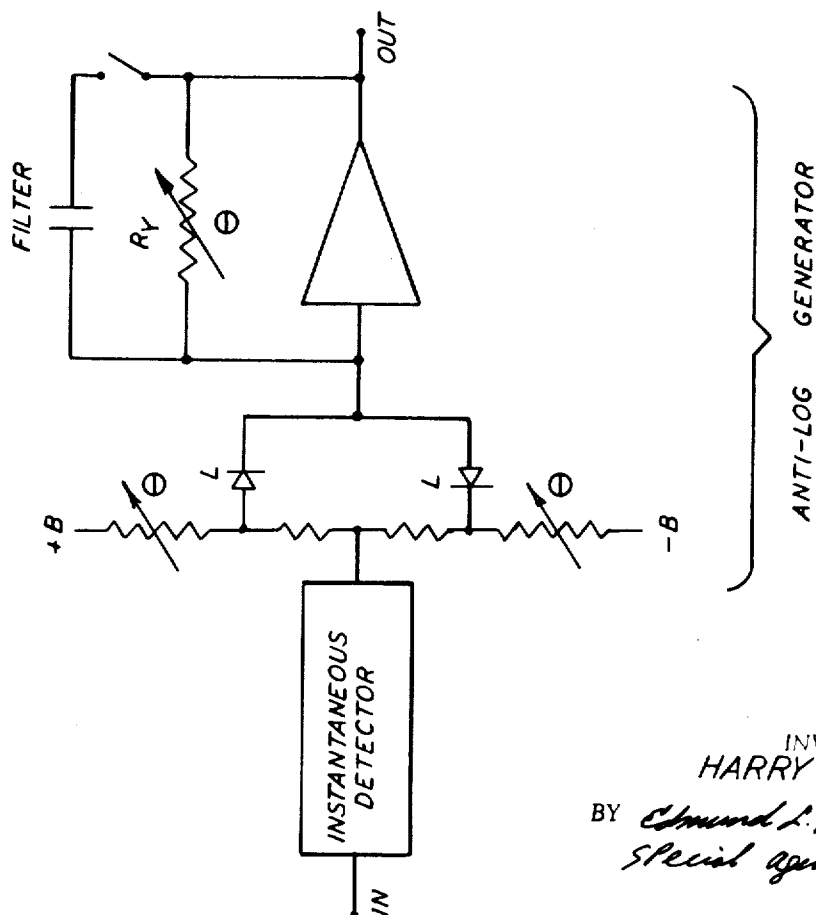


FIG-7

INVENTOR
HARRY FEIN
BY *Edmund L. Pantani*
Special Agent

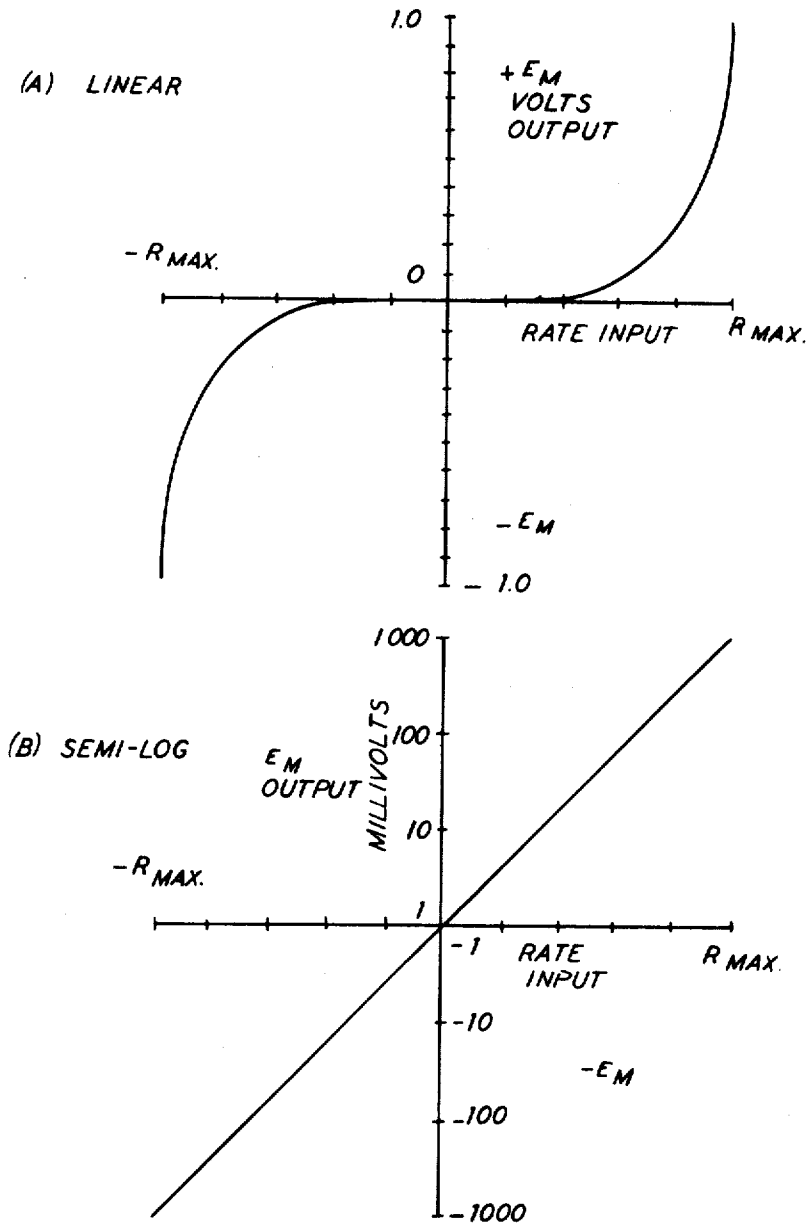


FIG - 8

INVENTOR:
HARRY FEIN
BY *Edward L. Pantani*
Special Agent

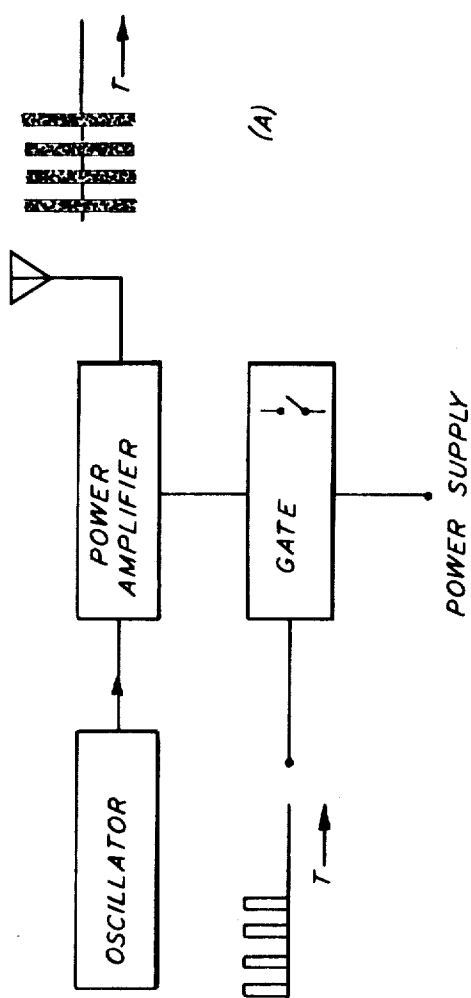
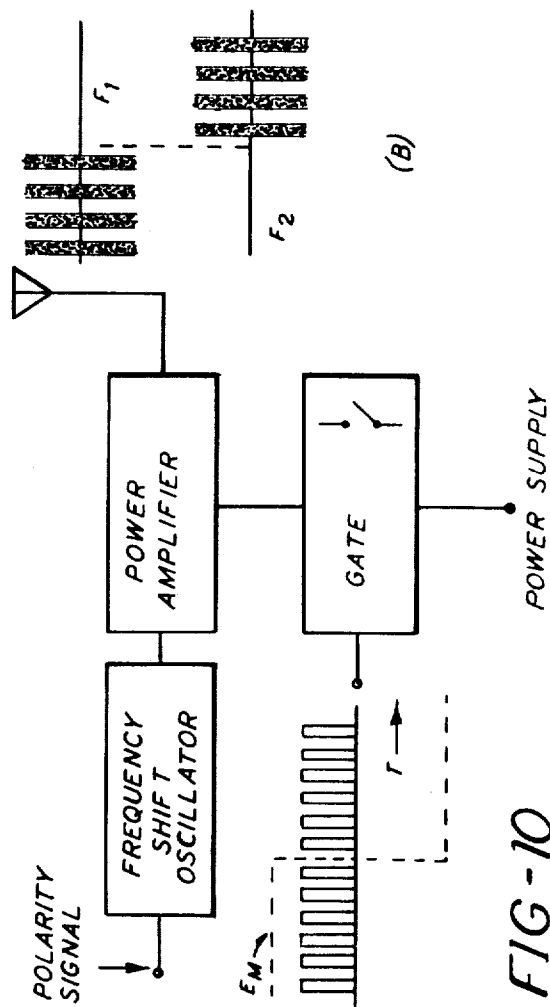


FIG-10

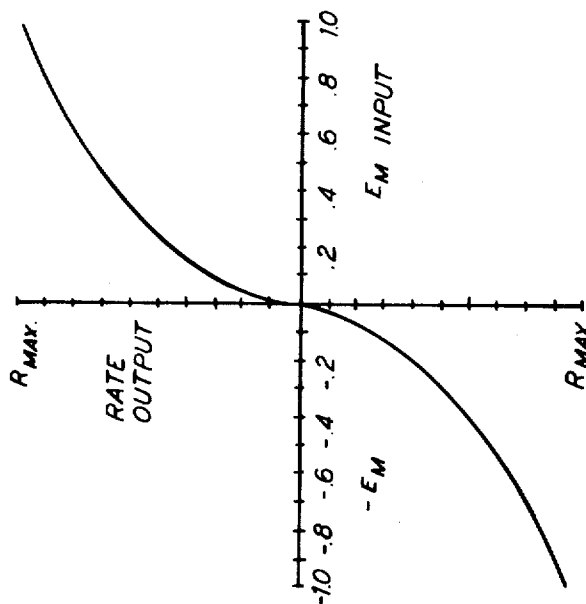


FIG-9

INVENTOR:
HARRY FEIN
BY *Edmond L. Pantoni*
Special Agent

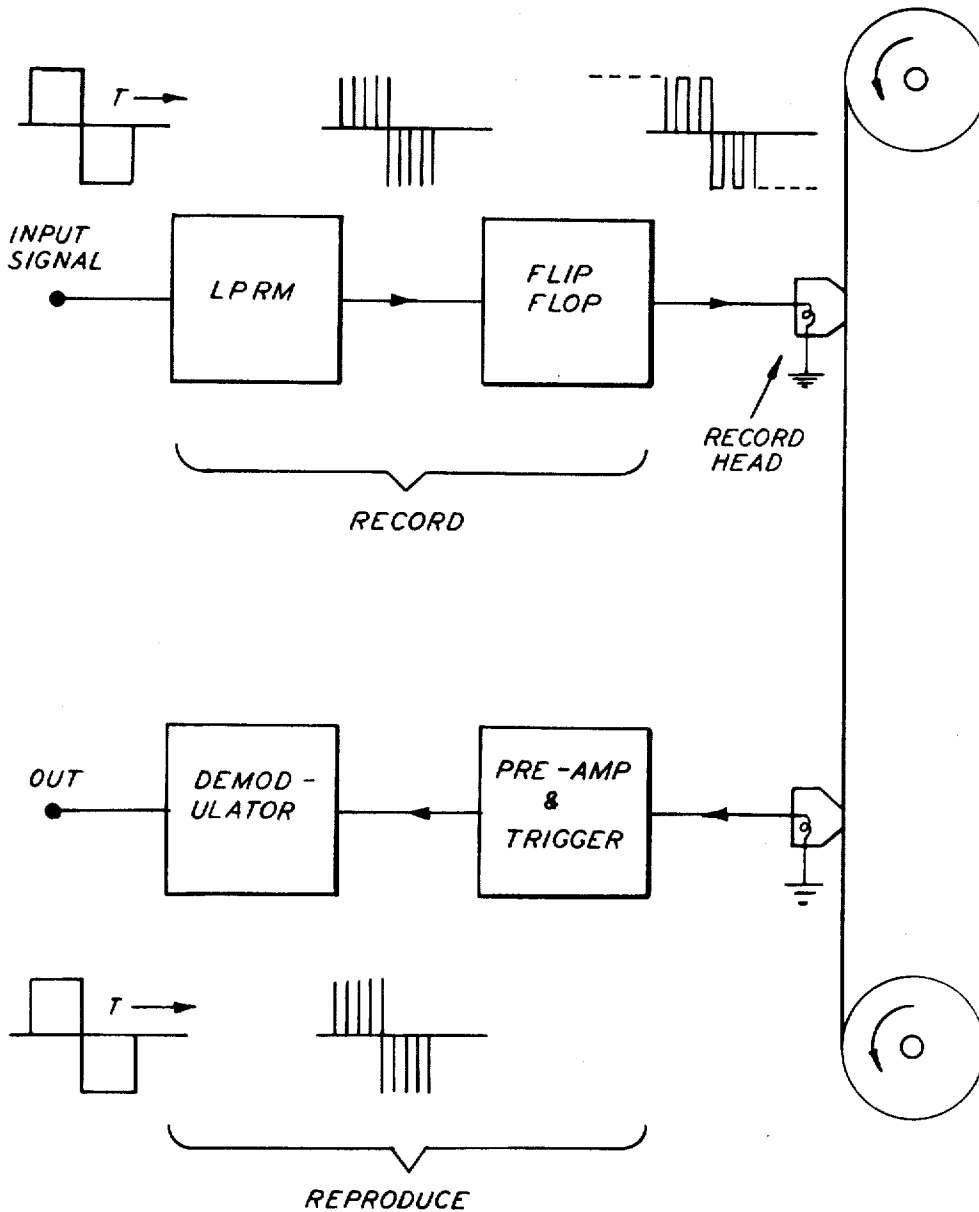


FIG-11

INVENTOR:
HARRY FEIN

BY *Edmund L. Pantoni*
Special Agent

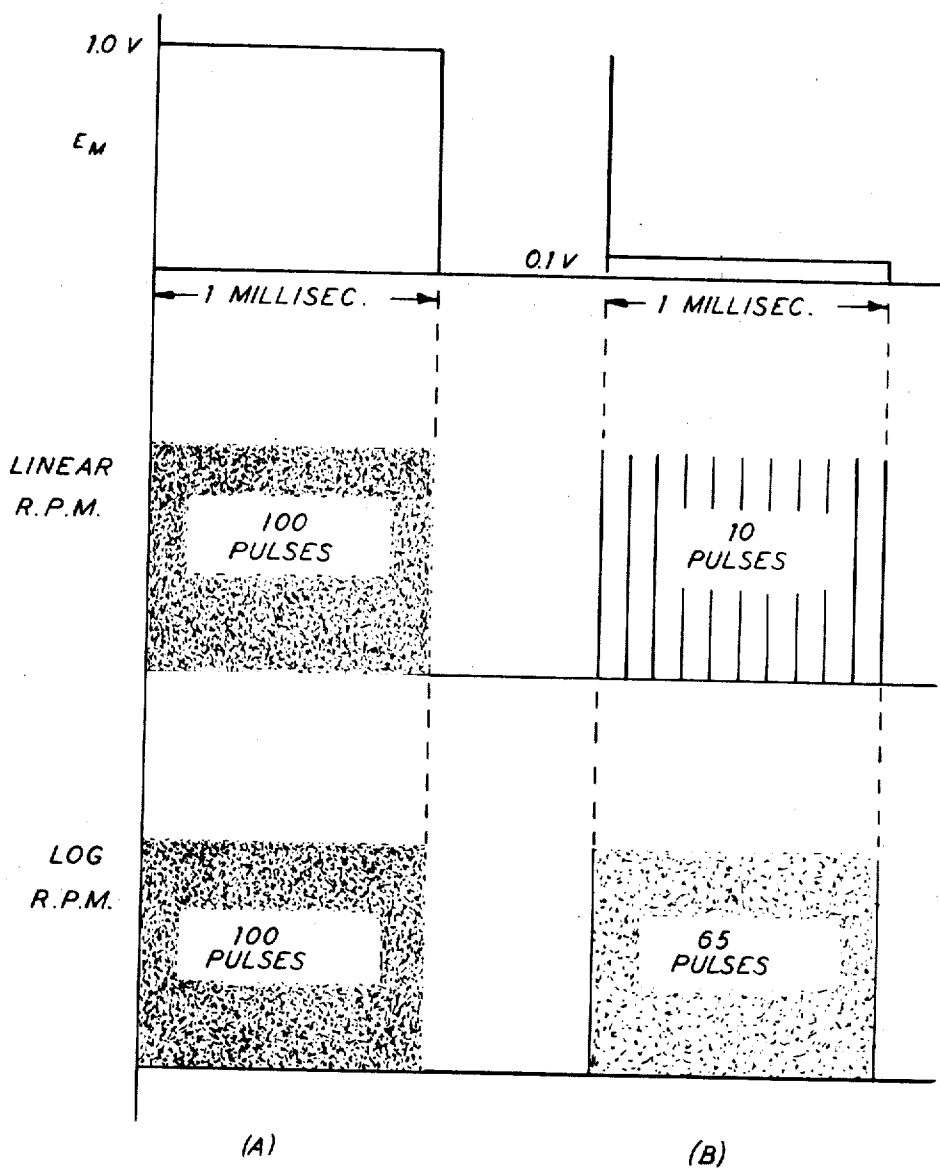


FIG-12

INVENTOR:
HARRY FEIN
BY *Edmund L. Pantani*
Special Agent

ASYNCHRONOUS DATA TRANSMISSION APPARATUS AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of application Ser. No. 568,008, filed July 26, 1966, now abandoned and entitled "System of Logarithmic and Non-Linear Pulse Rate Modulation and Demodulation."

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to imposition of information on electrical signals and the detection of the thus modulated signals. More specifically, the present invention is directed to the conversion of time varying voltages or currents to an asynchronous series of short electrical impulses whose instantaneous repetition rate is proportional to a preselected non-linear function of the instantaneous value of a modulating signal. Accordingly, the general objects of the present invention are to provide novel and improved methods and apparatus of such character.

2. Description of the Prior Art

A number of pulse modulation schemes have been proposed, and in some cases implemented, in the prior art. These previous pulse modulation schemes include pulse position modulation (P.P.M.), pulse amplitude modulation (P.A.M.), pulse width modulation (P.D.M.), pulse time modulation (P.T.M.) and pulse code modulation (P.C.M.). All of these prior pulse modulation systems are characterized by inherent deficiencies or limitations. Thus, for example, all of the prior art pulse modulation apparatus are inherently synchronous systems. Synchronous systems are wasteful of transmitter power since a marker channel or other synchronizing information must be sent to the receiver. Also, in a synchronous system, it is necessary that clocks and comparison circuitry be provided at the receiver and such circuitry adds to the cost and complexity of the prior art pulse modulation systems.

Considering specifically linear pulse rate modulation, prior art techniques of this type are characterized by poor information content for small magnitude signals. Restated, the band width of prior art linear pulse rate modulation systems for small input signals is very limited. This characteristic has resulted in linear pulse rate modulation being considered unacceptable for communication purposes.

SUMMARY OF THE INVENTION

The present invention overcomes the above-discussed and other disadvantages of the prior art by providing a novel and improved system for the modulation and subsequent demodulation of pulse coded signals. As employed herein the term "modulation" is used in a generic sense and refers to the variation of a characteristic of a signal in the interest of conveying information. This may be contrasted to the more limited meaning conventionally employed in the electronics arts where modulation is commonly used to indicate the variation of a characteristic of a carrier to impose information thereon. Similarly, as employed herein the term "information" is employed in the context of the intelligence bearing signal which is transmitted; i.e.,

when there is no information there is no transmission. In accordance with the present invention, a pulsating signal having an instantaneous repetition rate which is varied as a non-linear function of the amplitude of information bearing input signals are generated to provide asynchronous information bearing signals. In accordance with a preferred embodiment of the invention, the input signals are modified in amplitude substantially in accordance with a logarithmic function and the thus modified input signals are applied to the input of a linear pulse rate modulator.

At the receiver, rate detector circuitry is employed to reconvert the received asynchronous pulse train to an analog or continuous signal and the thus detected signal is thereafter applied to a complementary function generator to provide an analog signal commensurate with the original input signal. In the preferred embodiment, the complementary function generator provides an output signal which is the antilogarithm of the detected pulse train.

Also in accordance with the present invention, the transmitter is permitted a low duty cycle since no marker or clock pulses are sent to the receiver and, in the absence of a modulating input signal, no information and thus no signal will be transmitted. The present invention also enables a much higher information content when compared to prior art systems of like character.

BRIEF DESCRIPTION OF THE DRAWING

The present invention may be better understood and its numerous objects and advantages will become apparent to those skilled in the art by reference to the accompanying drawing wherein like reference numerals refer to like elements in the several figures and in which:

FIGS. 1a and 1b are respectively linear and semi-log plots of the input-output voltage relationship of a function generator which may be employed in the present invention;

FIG. 2 is a block diagram of a preferred embodiment of a non-linear pulse rate modulator in accordance with the present invention;

FIGS. 3a and 3b comprise graphical presentations of the input-output voltage relationships of the modulator of FIG. 2;

FIGS. 4a and 4b graphically represent the employment of both positive and negative going signals in accordance with the present invention;

FIG. 5 is a schematic showing of a logarithmic pulse rate modulator in accordance with the present invention;

FIG. 6 is a graphical representation of the output of a pulse rate detector in accordance with the present invention;

FIG. 7 is a block diagram of a preferred embodiment of demodulator circuitry in accordance with the present invention, the demodulator of FIG. 7 being employed in conjunction with the modulator circuitry of FIG. 2;

FIGS. 8a and 8b graphically depict, in linear and semi-log form, output signals provided by the demodulator circuit of FIG. 7;

FIG. 9 is a plot of the transfer function of detector circuitry in accordance with the present invention.

FIGS. 10a and 10b depict keying systems which may be employed in accordance with the present invention as utilized in a communications system;

FIG. 11 depicts utilization of the present invention in a recording system; and

FIG. 12 is a graphical representation of the advantages of the non-linear small signal enhancement technique of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

The present invention represents a method by which a significant improvement in the informational content of a modulated signal may be obtained. This improvement, in part, may be attributed to the fact that small signals are caused to receive magnification in accordance with the present invention. A particularly significant characteristic of the present invention resides in the fact that, in the absence of a modulating input signal, no information is transmitted. It is further to be noted, and as will be explained in greater detail below, a center frequency or marker pulses are not transmitted in accordance with the present invention.

Thus, in accordance with the present invention, a modulating voltage or signal e_m is applied to a non-linear function generator. In a preferred embodiment, the function generator is a logarithmic circuit having an input-output voltage relationship which may be expressed as follows:

$$\log_a e_m = e_f \quad (1)$$

where e_f is the logarithm of the modulating signal e_m and a , the base of the logarithm, can be any arbitrary value. Throughout the following description, a will be presumed to be 10. FIGS. 1a and 1b respectively show linear and semi-log plots of equation (1). It is to be noted that there are several methods for achieving the voltage relationship depicted in FIG. 1B and one such method will be described below.

As may be seen from FIG. 2, the voltage e_f which appears at the output of the non-linear function generator, which in the preferred embodiment is the logarithm of modulating signal e_m , is applied directly to a linear pulse rate modulator. The output of the modulator is, accordingly, a train of short electrical impulses whose instantaneous repetition rate will be proportional to the logarithm of the instantaneous value of the modulating signal. As used herein, instantaneous rate is defined as the reciprocal of the time interval between two separate successive impulses at the output of the pulse rate modulator.

The sequence of events in modulation is portrayed in FIG. 2 where e_m , shown at the input to the circuit, is assumed to be a linear function of time or a so-called ramp function. The output of the logarithm generator in FIG. 2 shows the effect of the non-linear function generator upon the input ramp signal. It may be seen that the function generator has emphasized or magnified the small values of the ramp voltage much more than the larger values. The logarithm generator output is applied to the input of the linear rate modulator and the resulting pulse signal is shown at the output of the linear rate modulator. The entire apparatus of FIG. 2 comprises a logarithmic pulse rate modulator (hereinafter referred to as L.P.R.M.). The input-output

relation of the entire modulator can be expressed as follows:

$$R = (R_{max}/N) \log_{10} (e_m) \quad (2)$$

where R is the modulator output pulse rate, N the number of decades into which the signal is arbitrarily divided, e_m is the modulating signal in millivolts and R_{max} is the maximum pulse rate output of the linear rate modulator. As illustrated in FIG. 2, N is equal to 3.

Since the input modulating signals are generally of both polarities, the overall transfer function or input-output relationship for the system of FIG. 2 may be depicted graphically as shown in FIGS. 3a and 3b.

Also in accordance with the present invention, positive and negative modulating signals may be distinguished in several ways if desired. First, signal polarity information can be conveyed by using a positive going impulse train for positive modulating signals and a negative going impulse train for negative modulating signals as shown by waveform (a) in FIG. 4. Waveform (a) of FIG. 4 shows the kind of signal which would emerge from the L.P.R.M. of FIG. 2 if a square wave which goes both positive and negative had been used as the modulating signal e_m instead of the ramp voltage illustrated. Another technique which allows distinguishing between positive and negative signals is represented by waveform (b) of FIG. 4. The result depicted at (b) in FIG. 4 is obtained when two channels are employed; one channel for the impulse sequence representing positive voltages and a second channel for impulse sequences representing negative voltages. Use of two channels offers a decided advantage in adaptability of the logarithm pulse rate modulation system comprising the preferred embodiment of the present invention.

A logarithmic pulse rate modulator which may be used in the practice of the present invention is shown in detail in FIG. 5. The circuit of FIG. 5 demonstrates a practical way to achieve symmetrical positive and negative logarithmic pulse rate modulation. In FIG. 5, the "log generator" comprises a logarithmic amplifier employing non-linear elements. The log generator operates on the input signal (a), shown as a triangular waveform, so as to generate the logarithm (b) of the input signal. The generation of the logarithmic function is achieved through the use of non-linear elements, diodes L, which exhibit a voltage drop which is a logarithmic function of the current therethrough. The upper and lower of diodes L are respectively operative for positive and negative input signals. While the non-linear elements are shown as junction diodes L, it is to be understood that operational amplifiers which employ proper components in the feedback path of a high gain d.c. amplifier may also be employed to generate the logarithmic function.

Assuming a triangular modulating input waveform, as shown in FIG. 5, the logarithmic generator provides an output signal (c) which is applied to the linear rate modulator via an amplifier circuit comprising a pair of opposite conductivity type transistors. This essentially logarithmic output signal can be properly weighted or controlled by varying R_x to give the overall input-output function of equation (2).

The linear rate modulator may be comprised of an operational amplifier configured as an integration circuit with a time constant $R_x C$; this time constant being

much smaller than any meaningful time intervals in the modulating waveform. The integration circuit will thus charge quickly and linearly to a maximum voltage, either positive or negative depending upon the polarity of the input voltage, until one of a pair of discriminators is triggered. The triggering of a discriminator circuit will discharge the integrating capacitor and allow a new cycle to begin. The pulses appearing at the output terminals of the discriminator circuits are amplified by respective transistor amplifiers and mixed so as to produce the bi-polar signal (d). It is to be noted that the linear rate modulator may take several other forms such as, for example, the "Voltage to Frequency Converter" disclosed in U.S. Pat. No. 3,040,273 issued to A. F. Boff on June 19, 1962.

The series of impulses which represents the modulated output signal may be transmitted to receiving equipment in any conventional manner. At the receiving equipment, the pulse train must be demodulated. It should be noted that, in order to achieve demodulation, the converse of the particular non-linear function which is employed in the modulation process must be utilized. Thus, if the non-linear modulation function is the logarithm of the information bearing input signal, the demodulator must employ an antilogarithm function.

Before considering in detail the demodulation steps, it is to be noted that, considering the incoming sequence of impulses at a rate of $R_{max}/2$ as shown in FIG. 6, if the pulse rate is suddenly changed to R_{max} the new pulse rate cannot be registered by the demodulator until at least one period at the new pulse rate has been received. The foregoing results from the quantal nature of the modulated signal. Thus, a new bit of information must be received before any change can be effected in the received signal. Considering for example the case where the new pulse rate is slower than the previously received rate, an inherent characteristic of pulse rate detectors will be encountered. This inherent characteristic is that the rise time for a step change in frequency will generally be faster for the leading or rate increasing edge than for the trailing or rate decreasing edge. Accordingly, it may be seen that a system which increases the modulated impulse rate over the impulse rate that would be obtained for a linearly modulated impulse sequence has substantial advantages. By logarithmically or functionally enhancing the effect of modulating signals, the average pulse rate will be as high as possible and faster detection for all changes within an amplitude range over that which a linear pulse rate modulation system could operate will be achieved.

To continue with the description of the demodulation process in accordance with the present invention, signal detection is essentially a two-step process. That is, the received pulse train is converted to an analog or continuous signal by suitable rate detector circuitry and the detected signal is thereafter applied to a function generator which, in the case of the preferred embodiment, will be an anti-logarithm generator.

Circuitry which will perform the above-described demodulation function is shown in FIG. 7 and comprises a rate detector and function generator. The detector may, for example, comprise a device such as a cardio-tachometer; such devices being well known and

being used to measure the heart rate from beat to beat rather than averaging over lengths of time. Thus, an instantaneous pulse rate detector is a device which converts any sequence of electrical impulses into a continuous signal having an amplitude which is proportional to the inverse of the time interval between separate successive pulses. One of several methods for accomplishing the foregoing is to generate a voltage proportional to the length of time of each pulse interval such as, for example, by initiating generation of a linear ramp voltage upon the receipt of an impulse. When the next impulse arrives, the voltage to which the ramp has risen is stored by a holding circuit. The ramp voltage generator is immediately reset and allowed to recharge whereby a series of voltage steps which are proportional to the time interval between the receipt of the leading edge of each input pulse is provided. The output of the holding circuit is applied to a reciprocal function generator which may consist merely of a resistor network with shunting diodes. Such function generator circuitry, which is well known in the art, will generate an output voltage inversely proportional to the applied signal. Accordingly, the reciprocal of the output of the instantaneous pulse rate detector will be measured at the output terminal of the reciprocal function generator and this output voltage will be the reciprocal of a signal proportional to each successive time interval in the pulse sequence. For further discussion of instantaneous pulse rate detectors, reference may be had to an article entitled "Electronic Device for Measuring Reciprocal Time Intervals," by MacNichol and Jacobs which appeared in Volume 26, Number 12 of *The Review of Scientific Instruments*, pages 1176-1180, December 1955.

As noted above, it is not sufficient to merely detect the modulated impulse train. Thus, the output of the instantaneous rate detector must be demodulated by application to a complementary function generator. The complementary function generator must decode the original modulating equation. Thus, considering the preferred embodiment being explained, for the original equation (2), it is necessary to take the anti-logarithm which yields:

$$e_m(\text{in millivolts}) = 10(RN/R_{max}) \quad (3)$$

Equation (3), which is the input-output equation for the anti-logarithm demodulator of FIG. 7, is plotted in FIG. 8 and both a linear and semi-log plot of the transfer functions are shown. A linear plot of FIG. 8(a) is, of course, a function plotted on linearly coordinate axis whereas the semi-log plot is a function plotted on semi-log coordinates. The anti-log generator of FIG. 7 represents a technique for using an operational amplifier to achieve an anti-logarithm of a voltage from a signal generator of low source impedance. A feature of the circuit shown is that it comprises a balanced and symmetrical method for taking the anti-logarithm of positive and negative voltages. The oppositely poled diodes L of FIG. 7 are, as in the case of diodes L of FIG. 5, devices that provide a voltage drop which is the logarithm of the current passed therethrough. Restated, the current flow through these diodes, or through similar non-linear devices, is an exponential function of the applied voltage. Thus, when the output voltage of the instantaneous rate detector is applied to

either of diodes L of FIG. 7, the operational amplifier with its feedback resistor R_f will generate an output voltage which is an exponential function of the rate detector output voltage. It will be obvious to those skilled in the art that diode L will be individually conductive depending on the polarity of the detector output signal.

As previously noted, the above described L.P.R.M. does not depend solely for its uniqueness of operation upon the use of the logarithm as the transfer function in the modulation process and the anti-logarithm, its converse, in the demodulation process. A logarithmic function is presented merely as a matter of choice since, in addition to the square root function, the logarithmic function presently appears to be the best mode of operation of the present invention. However, there is an entire class of functions which would achieve the desired effect of magnifying the pulse rate output of the modulating system for small modulating signals in relation to large modulating signals. That is, there are many functions which, for example, will operate whereby a 10 millivolt increase in signal amplitude at low input signal levels will produce a higher percentage change in output pulse rate than would the same 10 millivolt change in signal amplitude at larger signal levels. As plotted in FIG. 3(a), a symmetrical effect is achieved for both positive and negative modulating signals and the function could be generally said to be "S" shaped. In the context of the present application, an "S" shaped or contoured signal may be defined as a class of input-output functions wherein output pulse rate is a non-linear function of the modulating signal voltage e_m such that the following conditions hold true:

$$|dR/de_m| > |R_{max}/(e_m)_{max}| \quad (4)$$

at $e_m=0$. That is, the absolute value of the rate of change of pulse rate, R , at e_m equal to or near 0 volts is greater than

$$|R_{max}/(e_m)_{max}|.$$

The rate $f(e_m)$, that is the non-linear transfer function, increases monotonically with increasing e_m and decreases monotonically for increasingly negative e_m ; and

The slope $|dR/de_m|$ decreases gradually from its initial value at $e_m=0$, but is greater than 0 for all values of e_m which are within the working range of the modulator. The above class of equations defines that group of functions which are considered essential to the present invention. The square root function is a member of the above class and can also be used with great facility as a modulating function generator. The square root function is similar in shape in effect to the logarithmic transfer function. For example, as expressed in equation form:

$$\text{Instantaneous rate} = \pm R_{max} \sqrt{e_m} \quad (5)$$

Considering further the square root function, the instantaneous output pulse rate is directly proportional to the square root of the instantaneous magnitude (absolute value) of the modulating voltage e_m . The transfer function of equation 8 is plotted in FIG. 9 and is seen to be similar in shape to the plot presented in FIG. 3(a). This form of modulation can be produced by a very similar method to that described above and can be readily generated employing operational amplifiers. As

in the case of the logarithmic function, demodulation of the square root function involves detection and subsequent squaring of the pulse rate detector output waveform. This demodulation may be expressed as follows:

$$e_m = \pm [R/R_{max}]^2 \quad (6)$$

Practical circuits which implement the square and square root parts of equations 8 and 9 are well known in the analog computing art. Such circuits may be found, for example, in a book entitled "Applications Manual for Computing Amplifiers" published by Philbrick Research Inc., 2nd edition, June 1966, pages 52 and 93. Thus, the process of non-linear pulse rate modulation employing square root functions is a two-step process which employs a square root function generator, as mentioned above, in tandem with the aforementioned linear pulse rate detector. Demodulation is accomplished by a two device tandem arrangement of an instantaneous pulse rate detector whose output is applied to a square function generator so that a replica of the original modulating function is obtained.

As will be obvious to those skilled in the art from the foregoing detailed description, a simple and efficient method of pulse modulation having wide dynamic range in addition to many other advantages has been described. The present invention is a system which delivers a high information content since pulse rate modulation inherently encodes an original signal into a quantized series of events. In addition, the present invention has a low duty cycle in which no marker pulses or clock pulses are needed. In the absence of a modulating signal, no information is transmitted. Further, the present invention contains a basic feature common to all pulse modulation systems in that it is relatively immune to the effects of noise introduced in the communications or signal pathway.

As a result of the combined, above stated advantages, the present invention has a wide range of applications and uses in communications, recording and other types of electronic systems. The two following illustrations employing the present invention will demonstrate some of these potential uses.

A radio communication system can be effected if the sequence of electrical impulses which represents the output of the L.P.R.M. is applied to standard radio transmission systems such as the one shown in FIG. 10(a). In FIG. 10(a) the modulated pulse train is applied to a gate or keying device which applies power to the power amplifier resulting in the emission of pulses of radio frequency waves. High efficiency can be achieved since the duty cycle or the ratio of the transmitter "on" time to total time is always small. The simple keying system described and shown in FIG. 10(a) does not, of course, provide polarity information. However, by modifying the system of FIG. 10(a) to that of FIG. 10(b), polarity information can be provided. This is accomplished by the use of a frequency shift oscillator which operates on one frequency for impulse sequences representing positive modulating signals and on a second frequency for impulse sequences representing negative modulating signals. It is obviously necessary that the oscillator frequency must be sufficiently high to allow adequate resolution of the

pulses. The oscillator output must also allow sufficient channel width or side band to encompass the required band width demanded by the L.P.R.M. system for adequate pulse transmission and reproduction. Reception of the frequency shift signal involves standard super heterodyne reception followed by two selective filters in the intermediate frequency stage. Thus, two information channels are presented and each channel is equipped with separate but conventional detection circuitry. The output of the detection circuitry is demodulated in the manner described above and the output of the two demodulators linearly mixed or added to recreate a facsimile of the original modulating signal.

A second utilization of the present invention is in magnetic tape recording apparatus. In the tape recorder application, the impulses provided by the modulator may be employed to control a bistable multivibrator circuit which will change state upon the receipt of each impulse. In this manner the recorded information can convey the signal information in its rising and falling phase rather than in its absolute value. The foregoing has a significant advantage in that it widens the minimum time interval between events and this, in turn, allows a reduction in the necessary upper band limit of the recording system to resolve the pulse spacing at the maximum rate, r_{max} . A block diagram of a recording system in accordance with the present invention is shown in FIG. 11. The polarity of the modulating signal may be indicated in several ways. One method of indicating polarity would be to record all modulated information on one channel while recording polarity signal information on another channel. Another method would be to use two channels, one for positive signal impulse sequences and another for negative signal impulse sequences. A third method of providing polarity information would be to signal polarity by using the RZ or return to zero method of tape recording. Using the latter method, positive modulating signals magnetize square pulse recording flux in one direction while negative modulating signals magnetize the recording flux in the opposite magnetic sense. It is the latter method which is depicted in FIG. 11.

While a preferred embodiment has been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the present invention. Accordingly, the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. An asynchronous information transmission method comprising the steps of:
 - generating a first signal which varies in amplitude commensurate with input information to be transmitted;
 - modifying the amplitude of said first signal in accordance with a first non-linear function;
 - varying the repetition rate of pulse generator means in accordance with the modified signal; and

transmitting only pulses provided by the pulse generator means and commensurate with input information to a receiver only when information to be transmitted is present.

2. The method of claim 1 further comprising:
 - detecting only transmitted pulses commensurate with input information to provide an analog signal commensurate with pulse repetition rate; and
 - modifying the thus detected signal in accordance with a non-linear function which is complementary to the first non-linear function to recreate the first signal.
3. The method of claim 1 wherein the first non-linear function is the logarithm of the amplitude of the first signal.
4. The method of claim 2 wherein the first non-linear function is the logarithm of the amplitude of the first signal.
5. An information transmission system comprising:
 - means for providing a signal having an amplitude which varies in accordance with information to be transmitted;
 - non-linear function generator means responsive to said amplitude varying signal for non-linearly altering said signal to generate a control signal;
 - linear pulse rate signal generator means responsive to said control signal for providing an output pulse train wherein the instantaneous pulse repetition rate is commensurate with the amplitude of the non-linearly altered information containing signal;
 - means responsive to the output of said signal generator means for transmitting said pulse train;
 - instantaneous rate detector means for receiving the transmitted pulse train and for providing a signal commensurate with the repetition rate of the transmitted pulses; and
 - means responsive to the signal provided by said rate detector means for providing an analog output signal commensurate with the signal having an amplitude which varies in accordance with the information to be transmitted.
6. The apparatus of claim 5 wherein said means for providing an output signal having an amplitude commensurate with the amplitude of the signal which varies in accordance with the information to be transmitted comprises:
 - complementary function generator means responsive to the output of said rate detector means.
7. The apparatus of claim 5 wherein said function generator means comprises:
 - a logarithmic function generator.
8. The apparatus of claim 6 wherein said function generator means comprises:
 - a logarithmic function generator.
9. The apparatus of claim 8 wherein said pulse rate signal generator comprises:
 - integrator means; and
 - a pair of discriminator means, said discriminator means providing a bi-polar output signal.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,708,752 Dated January 2, 1973

Inventor(s) Harry Fein

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

IN THE SPECIFICATION:

Column 3, lines 34 and 35, "a" should be --"a"--

Column 4, lines 3 and 4, equation (2) should read as follows:

$$R = \frac{R_{\max}}{N} \log_{10} (e_m) \quad (2)$$

Column 6, line 46, equation (3) should read as follows:

$$e_m \text{ (in millivolts)} = 10^{\frac{RN}{R_{\max}}} \quad (3)$$

Column 9, line 26, " $r_{\max}$ " should be -- $R_{\max}$ --

IN THE CLAIMS:

Claim 5, at column 10, line 41, after "to" insert --be--

Signed and sealed this 10th day of July 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

Rene Tegtmeyer
Acting Commissioner of Patents