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(19) United States
(12) **Reissued Patent**
Fullerton

(10) **Patent Number: US RE41,479 E**
(45) **Date of Reissued Patent: Aug. 10, 2010**

(54) **TIME DOMAIN RADIO TRANSMISSION SYSTEM**

(75) Inventor: **Larry W. Fullerton**, Brownsboro, AL (US)

(73) Assignee: **Time Domain Corporation**, Huntsville, AL (US)

(21) Appl. No.: **10/836,861**

(22) Filed: **Apr. 30, 2004**

Related U.S. Patent Documents

Reissue of:

(64) Patent No.: **5,952,956**
Issued: **Sep. 14, 1999**
Appl. No.: **08/480,447**
Filed: **Jun. 7, 1995**

U.S. Applications:

(63) Continuation-in-part of application No. 08/335,676, filed on Nov. 8, 1994, now abandoned, which is a continuation-in-part of application No. 07/846,597, filed on Mar. 5, 1992, now Pat. No. 5,363,108, which is a continuation of application No. 07/368,831, filed on Jun. 20, 1989, now abandoned, which is a continuation-in-part of application No. 07/192,475, filed on May 10, 1988, now abandoned, which is a continuation-in-part of application No. 06/870,177, filed on Jun. 3, 1986, now Pat. No. 4,743,906, which is a continuation-in-part of application No. 06/677,597, filed on Dec. 3, 1984, now Pat. No. 4,641,317.

(51) **Int. Cl.**
G01S 13/04 (2006.01)
H04L 27/30

(52) **U.S. Cl.** **342/27**; 342/21; 375/130; 375/239; 375/256; 375/E1.001; 380/34

(58) **Field of Classification Search** 37/E1.001; 385/1, 2, 34; 455/76; 380/34; 375/130–153, 375/239, 256, 345, E1.001; 342/21, 22, 27, 342/28, 118, 120, 127, 132, 134, 145, 201; 359/237, 238, 240, 245, 265, 278, 290, 321, 359/322, 323, 326, 327, 332

See application file for complete search history.

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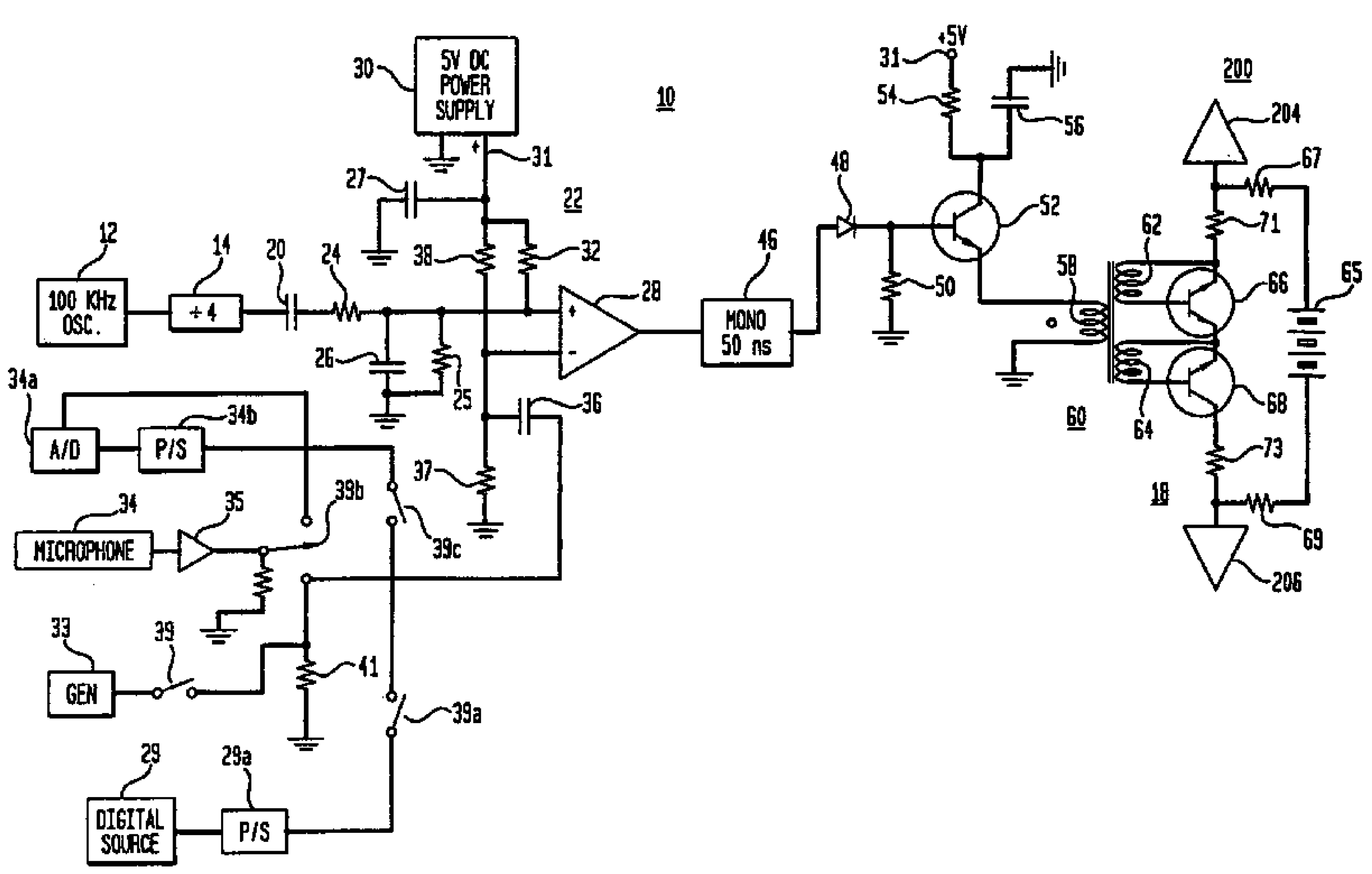
Primary Examiner—Bernarr E Gregory

(74) *Attorney, Agent, or Firm*—Venable LLP; Robert S. Babayi

(57) **ABSTRACT**

A time domain communications system wherein a broadband of time-spaced signals, essentially monocycle-like signals, are derived from applying stepped-in-amplitude signals to a broadband antenna, in this case, a reverse bicone antenna. When received, the thus transmitted signals are multiplied by a D.C. replica of each transmitted signal, and thereafter, they are, successively, short time and long time integrated to achieve detection.

19 Claims, 13 Drawing Sheets



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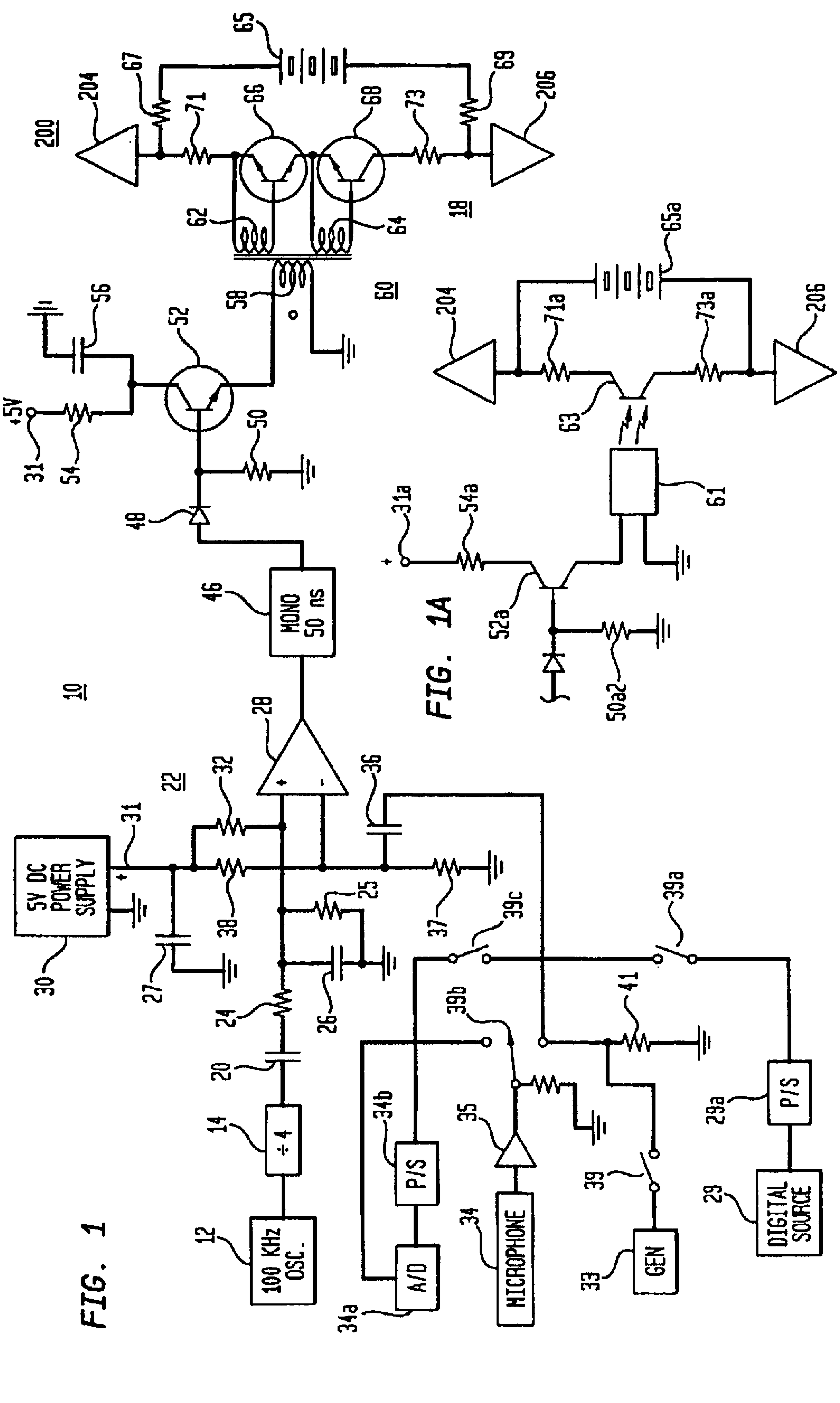
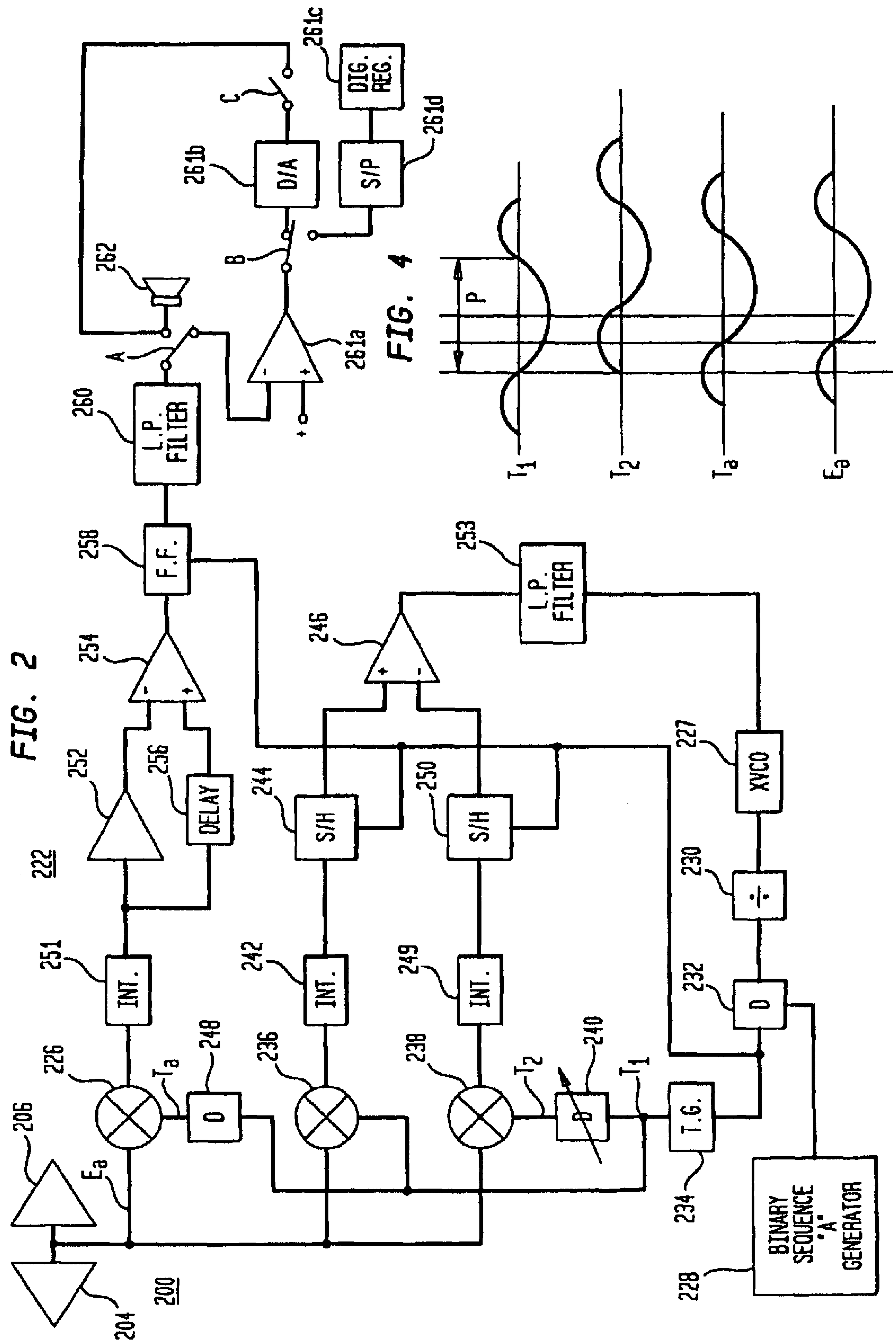

5V DC POWER SUPPLY
100 KHz OSC.
÷ 4
MONO 50 ns
+5V
A/D
P/S
MICROPHONE
GEN
DIGITAL SOURCE
P/S

FIG. 1

FIG. 1A



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261a
261b
261c
261d
262
A
B
C
INT.
D
S/H
DELAY
F.F.
L.P. FILTER
XVCO
T.G.
D/A
S/P
DIG. REG.
BINARY SEQUENCE "A" GENERATOR
E_a
T_a
T_1
T_2
P

FIG. 2

FIG. 4

FIG. 3A

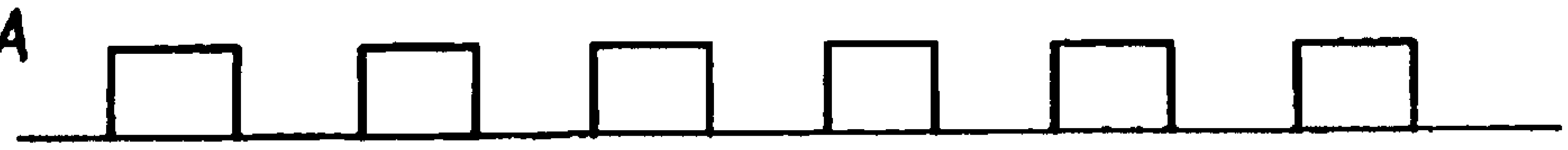


FIG. 3B

FIG. 3C

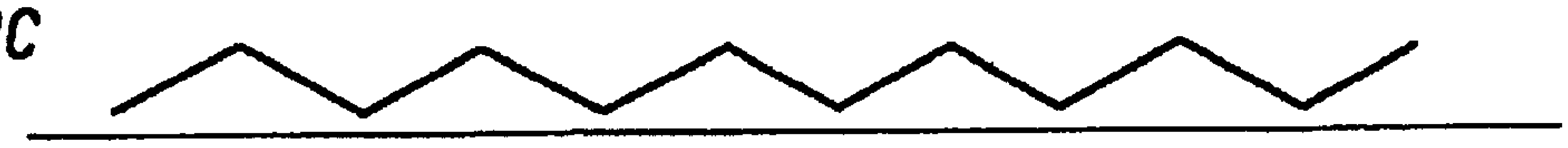


FIG. 3D

FIG. 3E

FIG. 3F

FIG. 3G

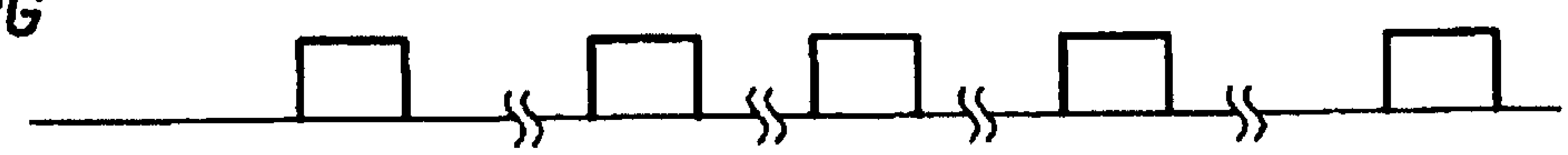


FIG. 3H

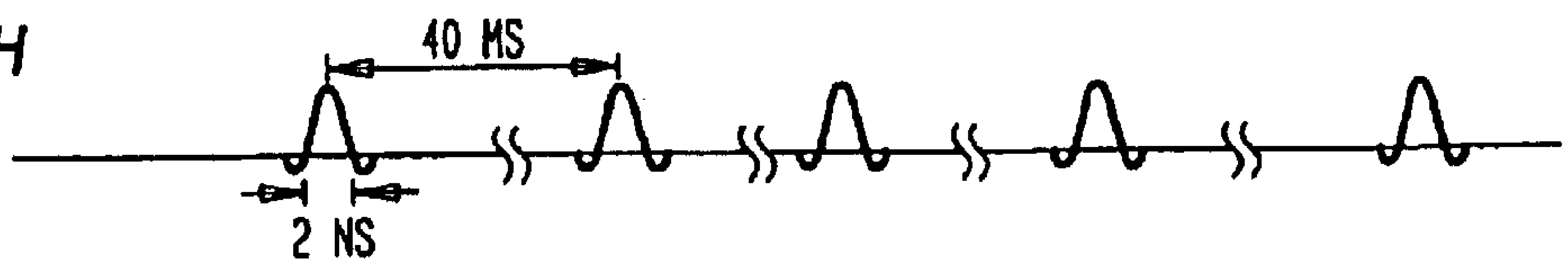


FIG. 3I

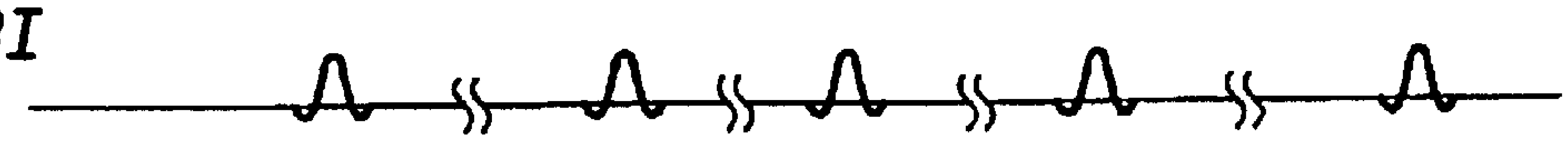


FIG. 3J

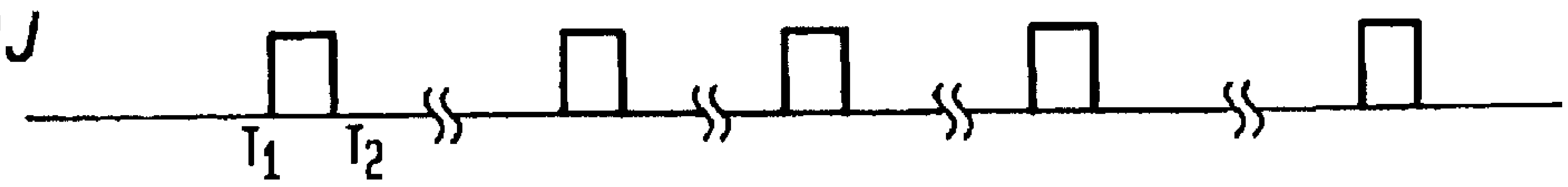


FIG. 3K

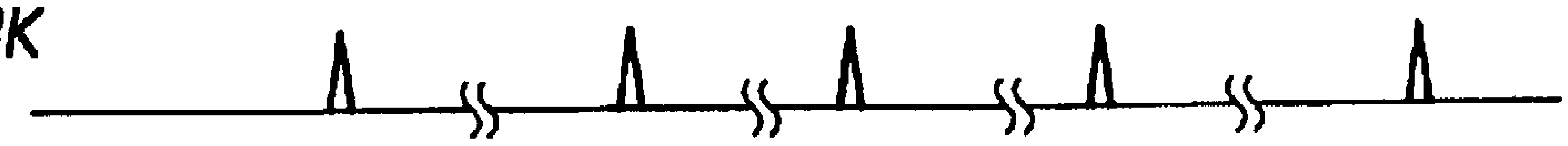


FIG. 3L

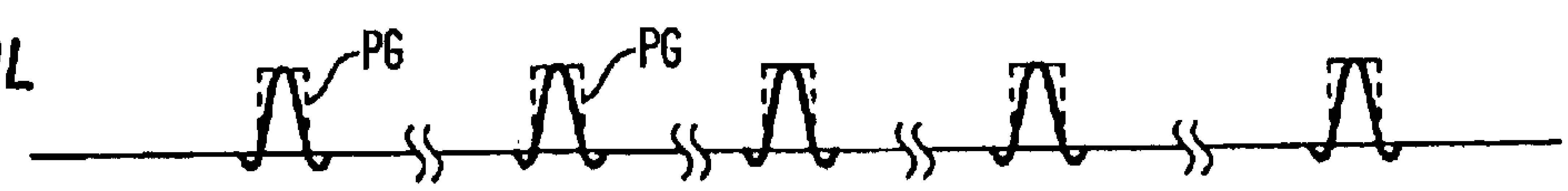
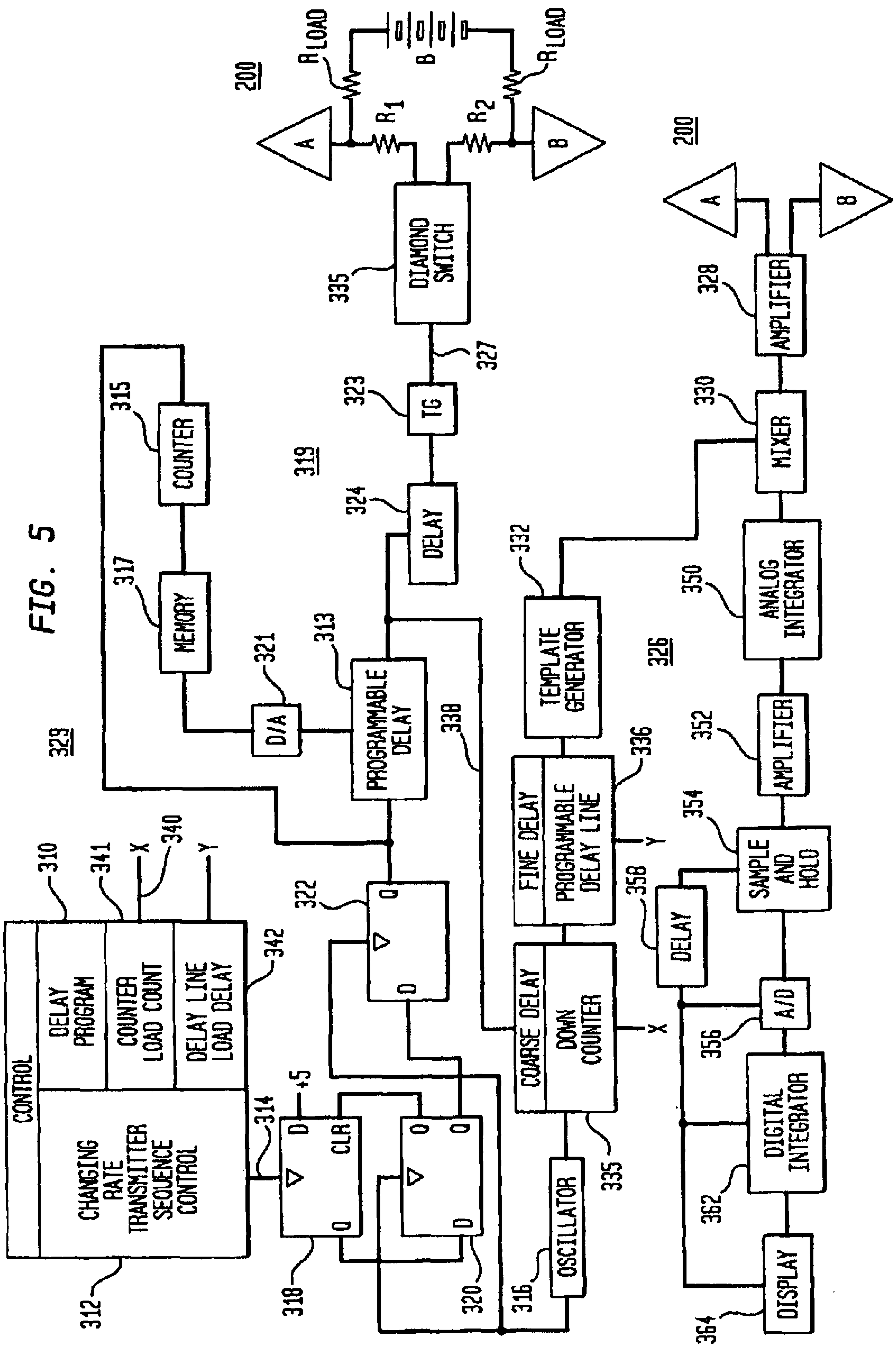


FIG. 5



200
A
B
R_{LOAD}
R_1
R_2
335
DIAMOND SWITCH
327
323
TG
324
DELAY
319
315
COUNTER
317
MEMORY
321
D/A
313
PROGRAMMABLE DELAY
338
329
332
TEMPLATE GENERATOR
326
336
FINE DELAY
PROGRAMMABLE DELAY LINE
Y
COARSE DELAY
DOWN COUNTER
X
335
OSCILLATOR
316
328
AMPLIFIER
330
MIXER
350
ANALOG INTEGRATOR
352
AMPLIFIER
354
SAMPLE AND HOLD
358
DELAY
356
A/D
362
DIGITAL INTEGRATOR
364
DISPLAY
310
341
340
342
CONTROL
DELAY PROGRAM
COUNTER LOAD COUNT
DELAY LINE LOAD DELAY
CHANGING RATE TRANSMITTER SEQUENCE CONTROL
312
314
+5
D
CLR
Q
318
320
322

FIG. 14

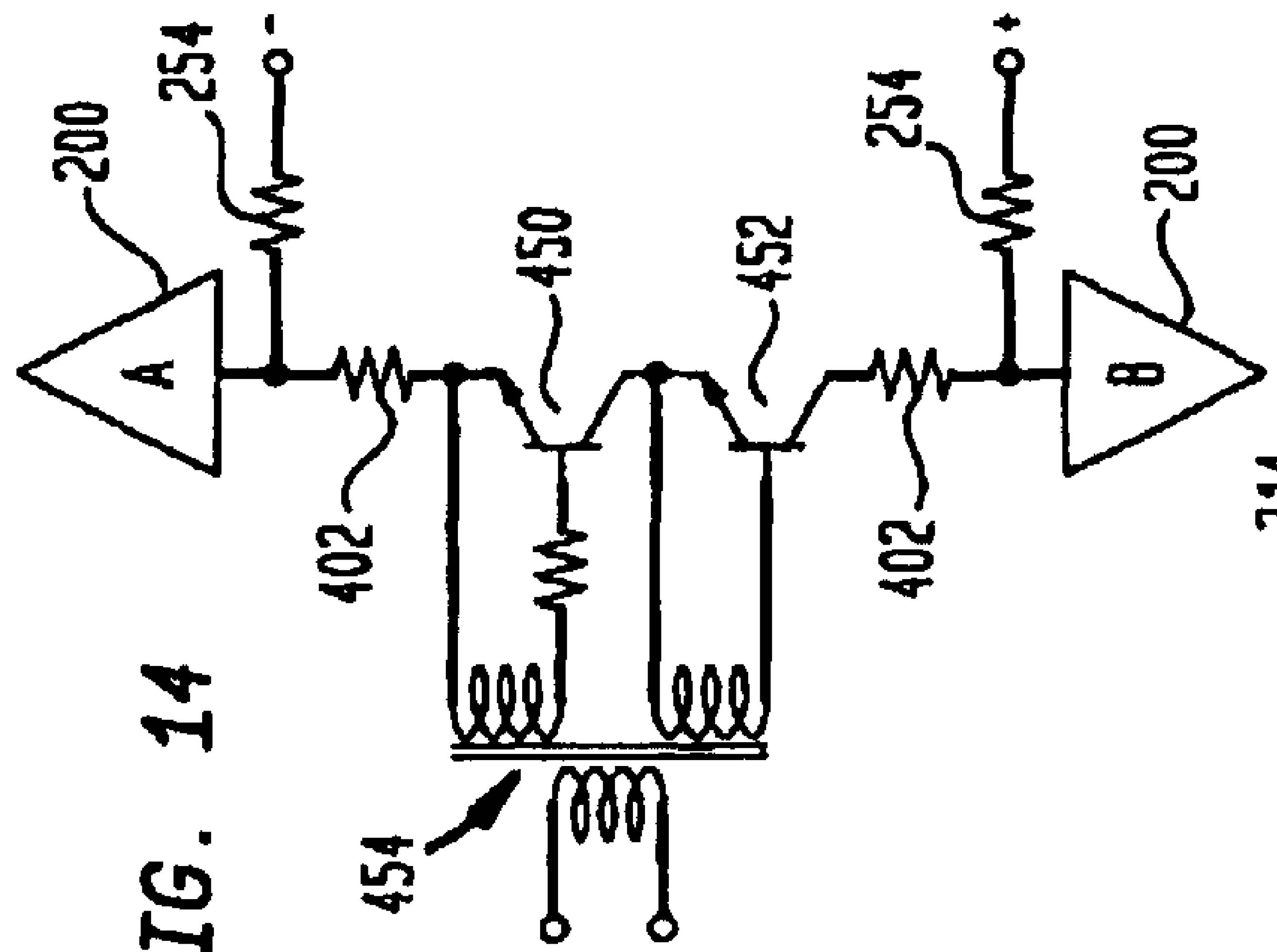


FIG. 15

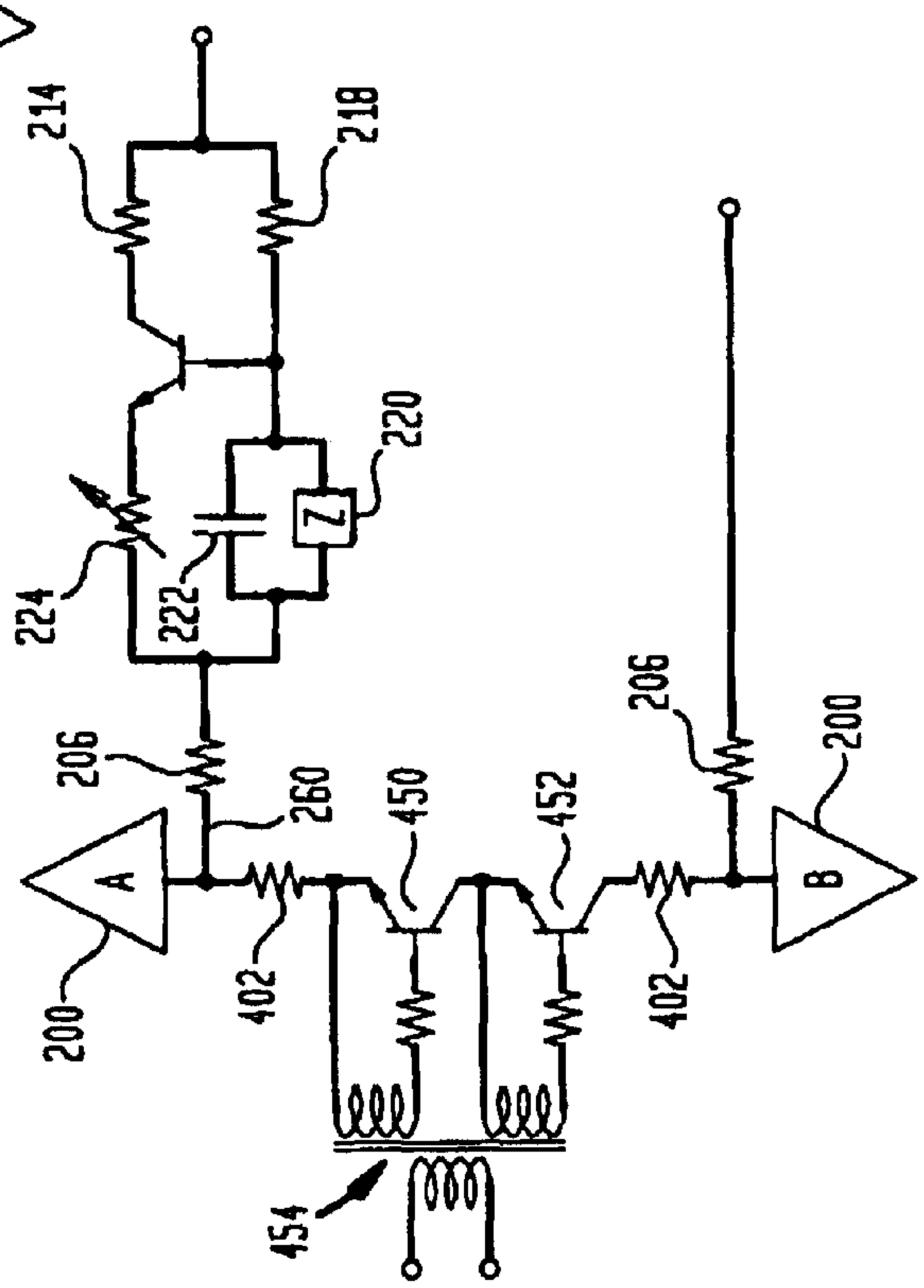


FIG. 6A

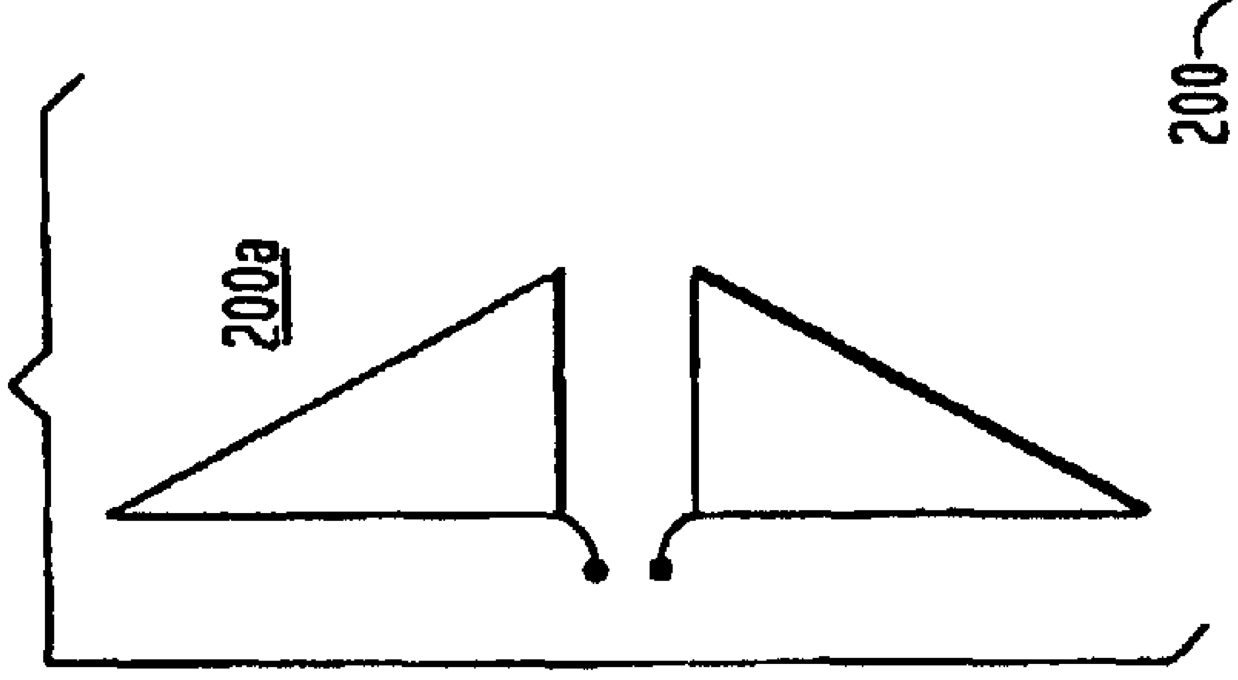
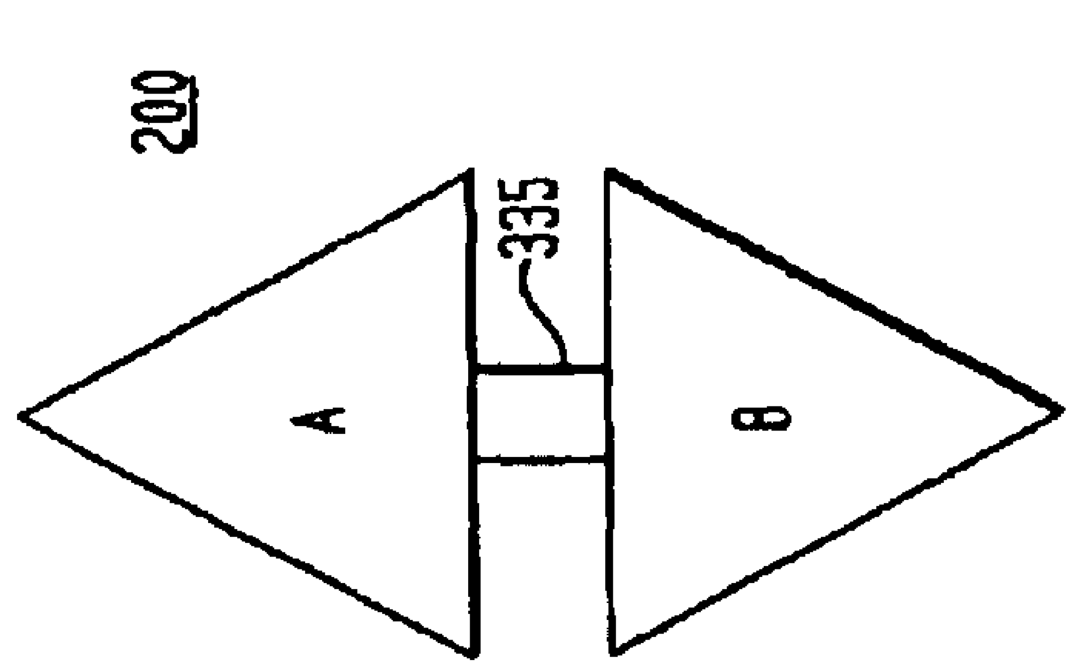


FIG. 6



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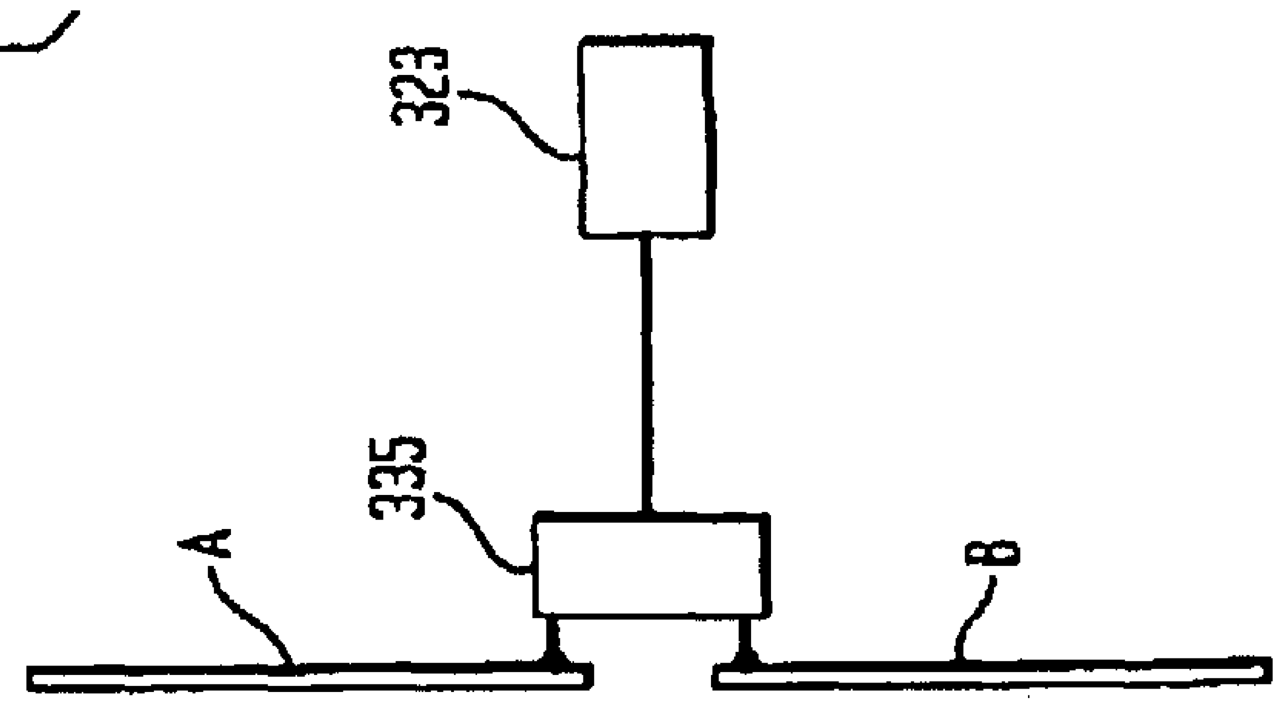


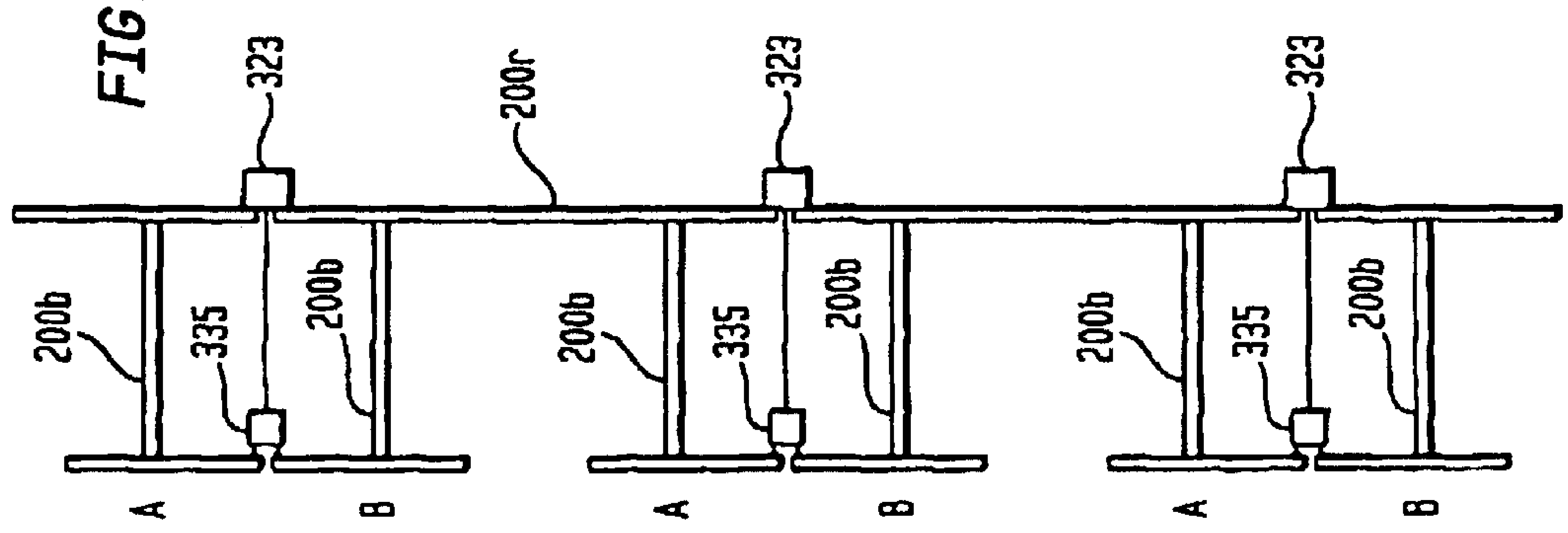


FIG. 8A

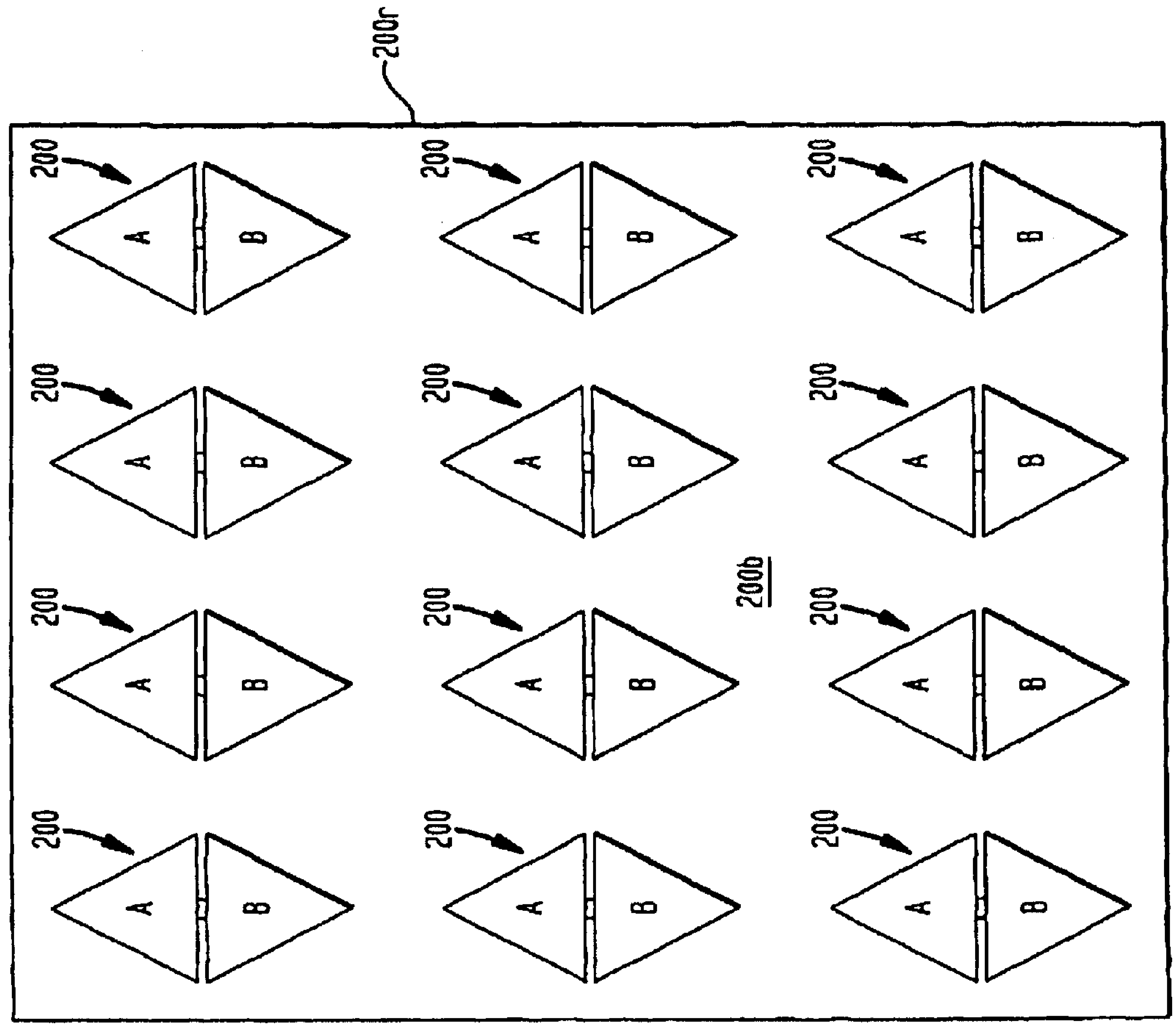


FIG. 8B

FIG. 17

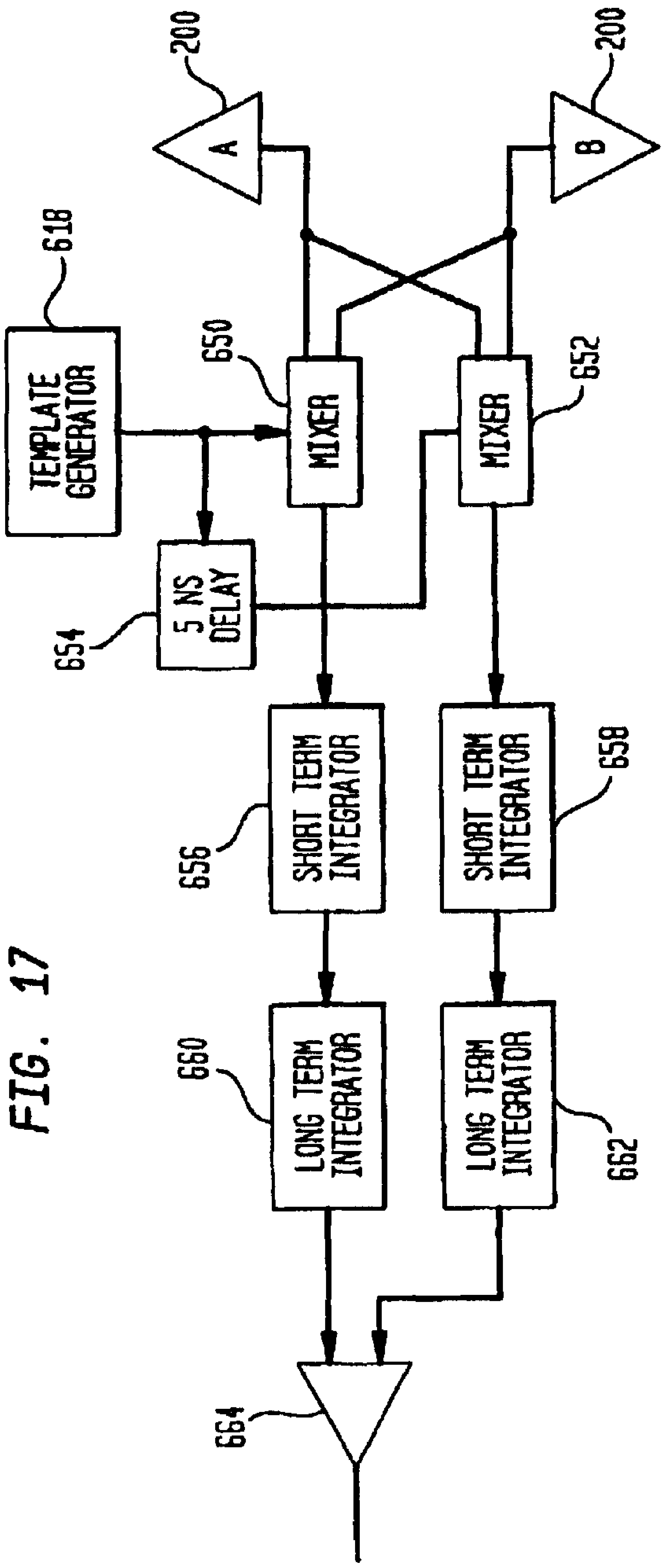


FIG. 9B

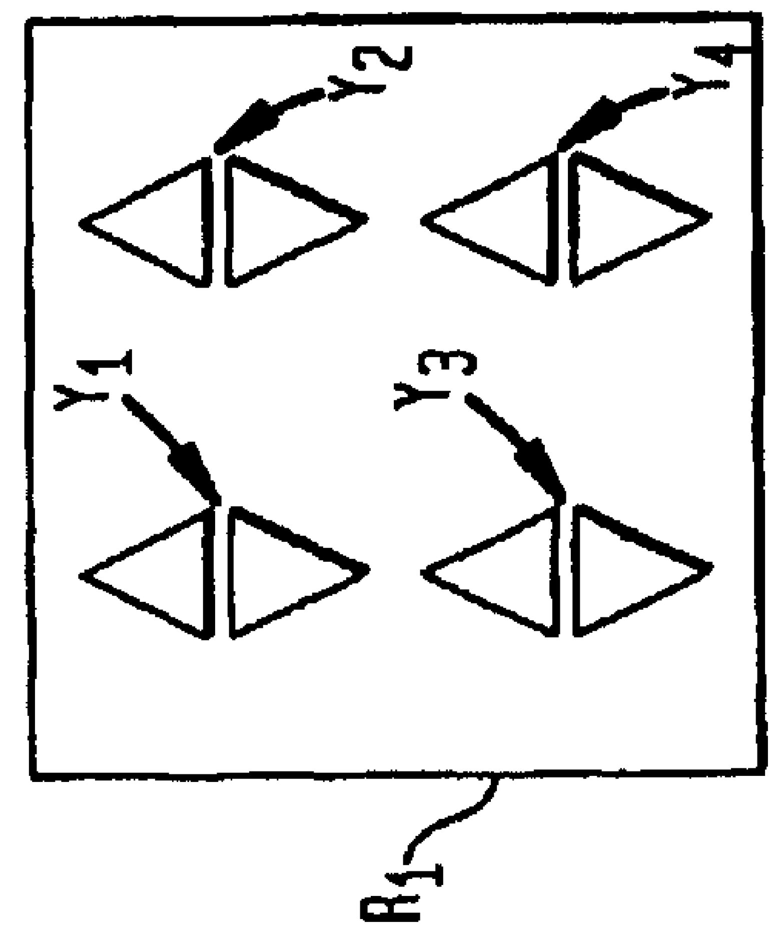
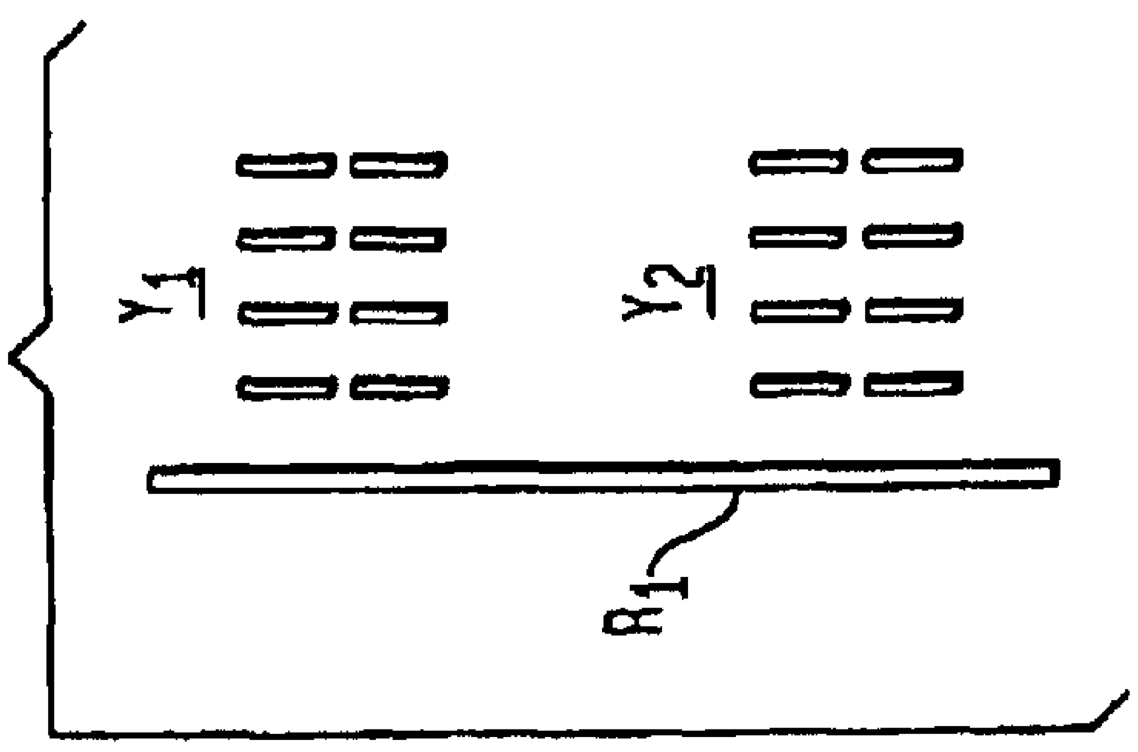
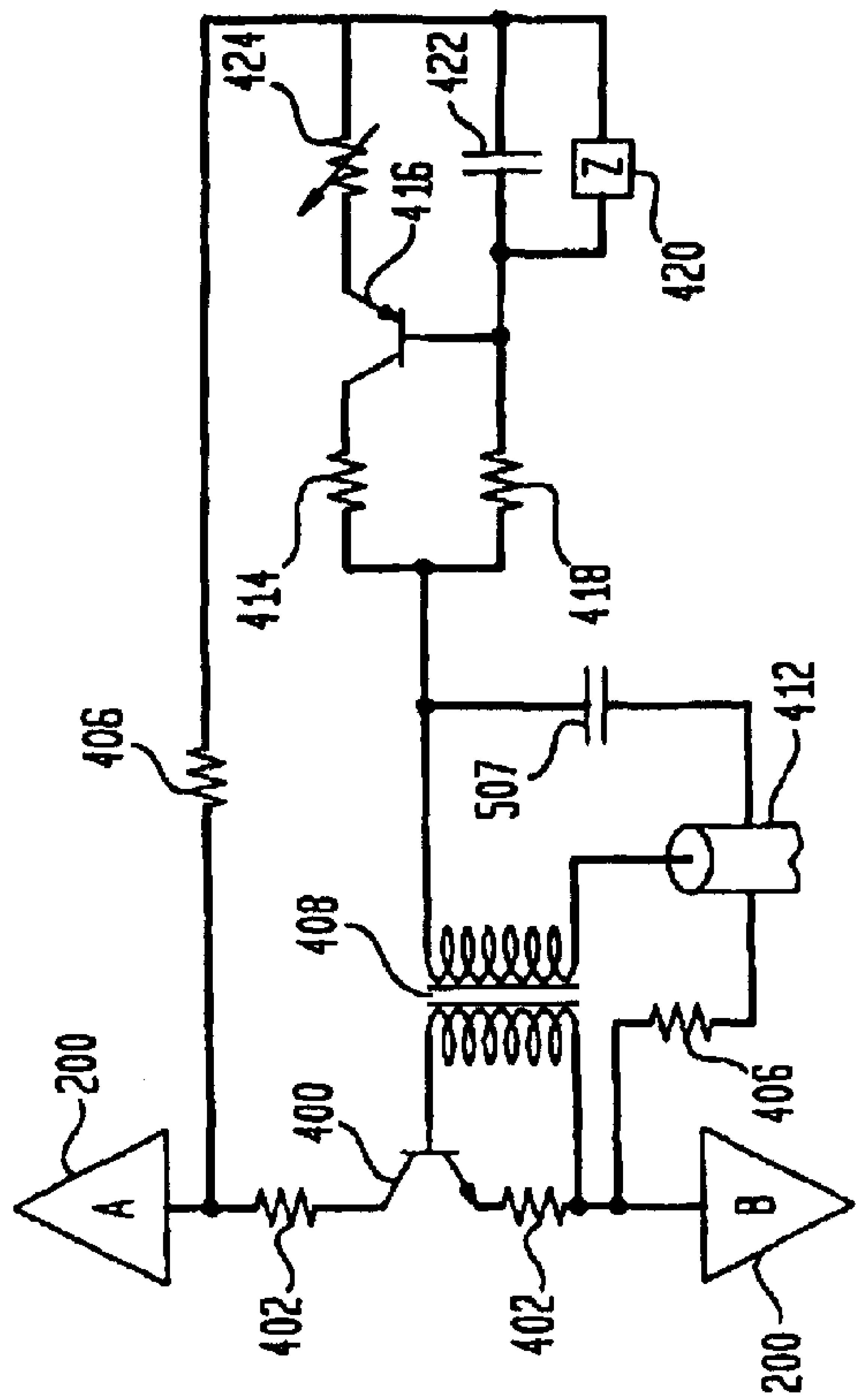


FIG. 9A





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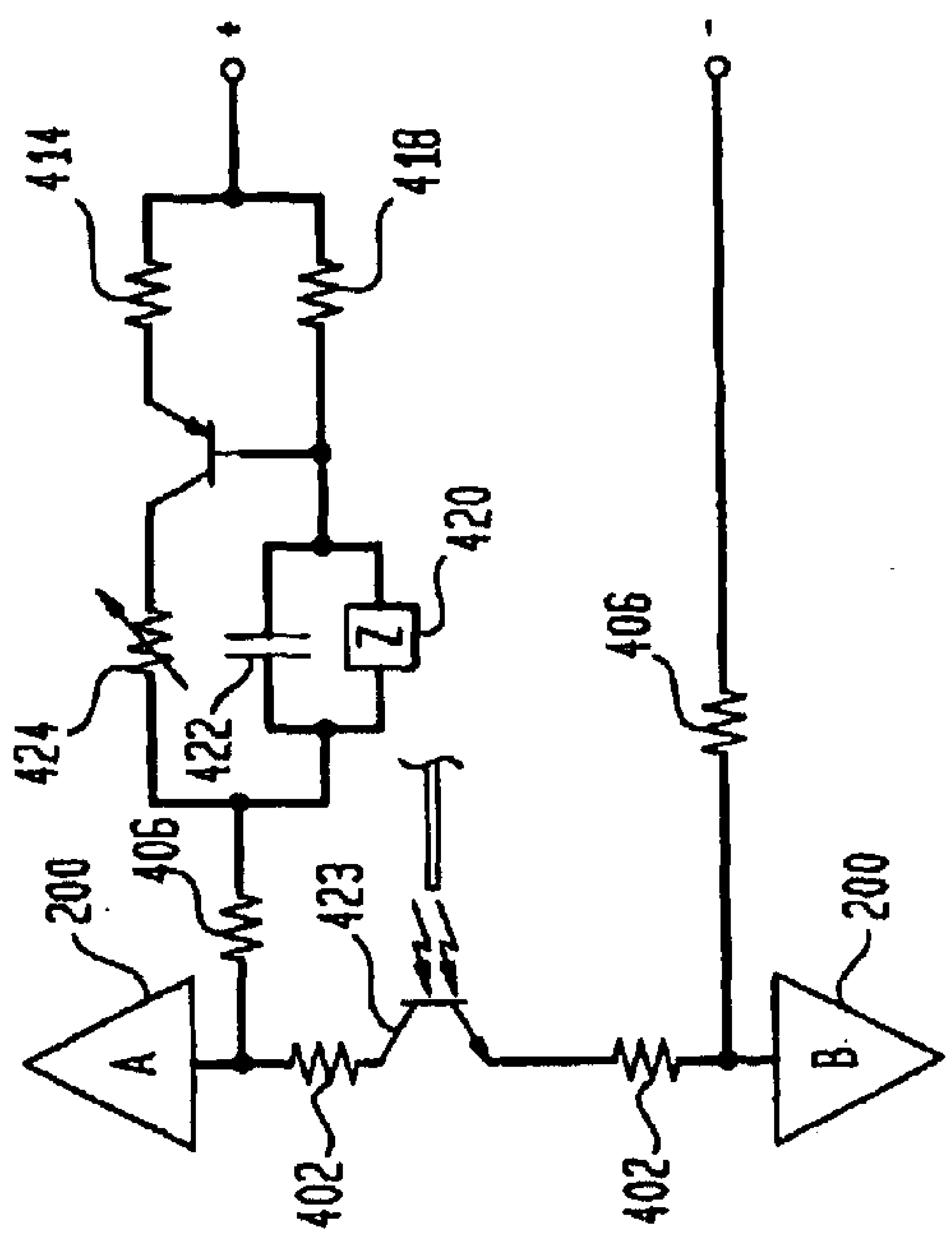

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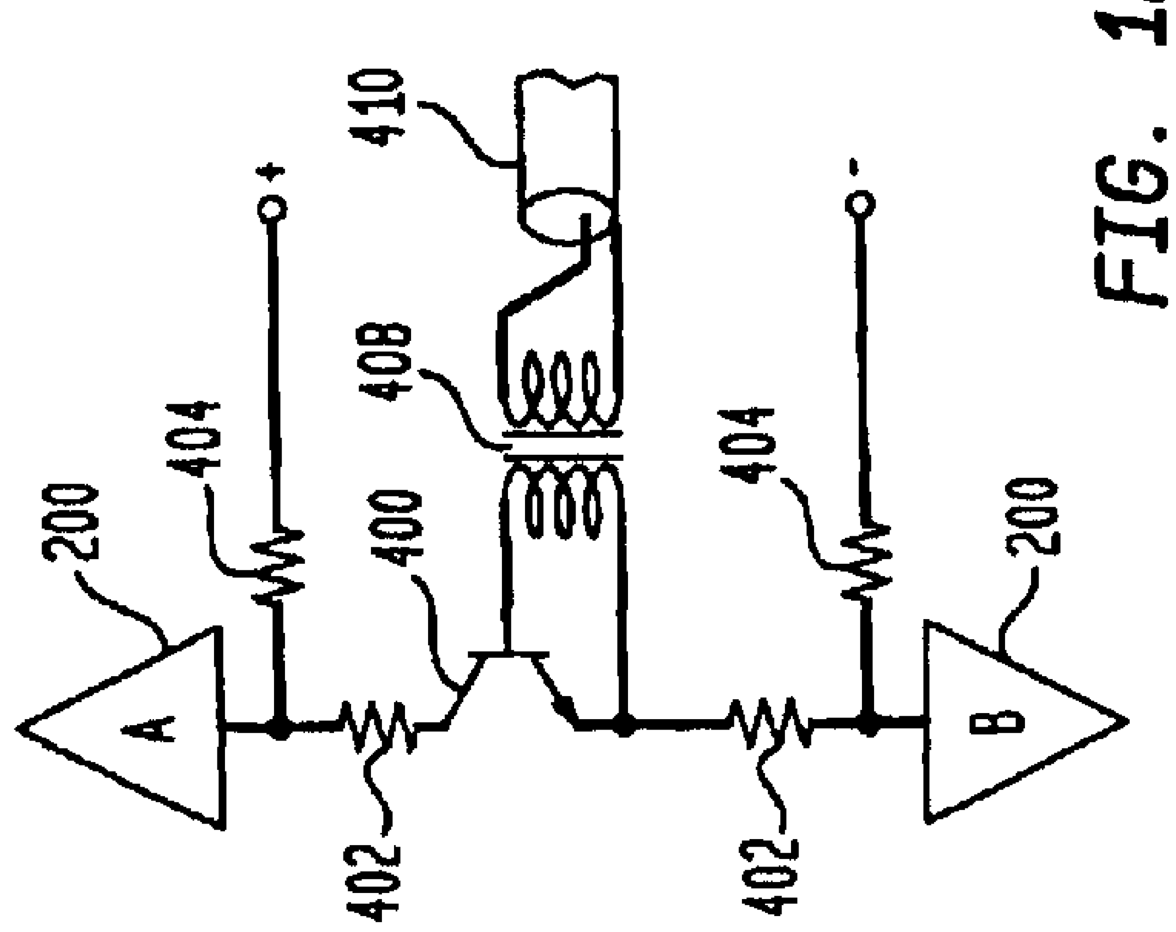


FIG. 10

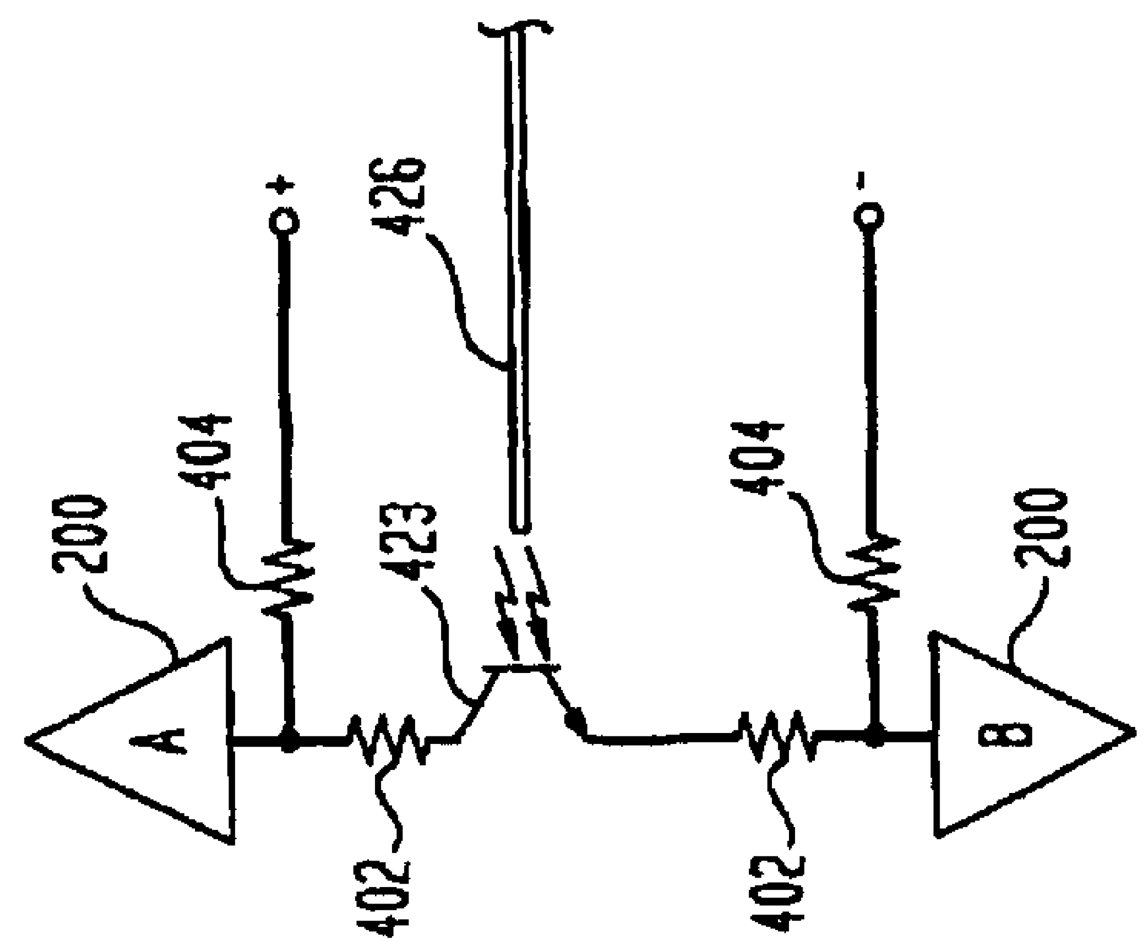


FIG. 12

FIG. 16

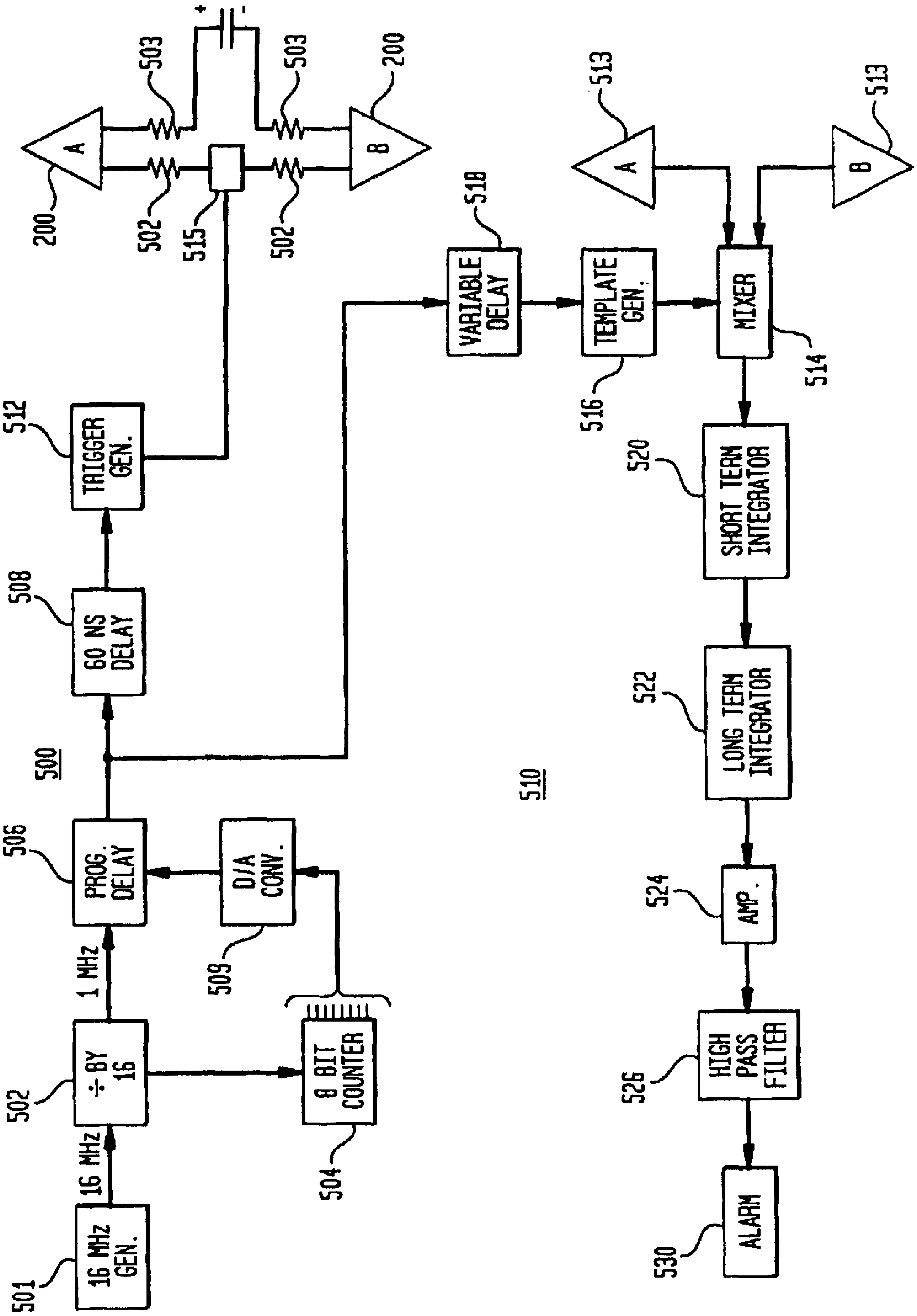

500
501
16 MHz GEN.
16 MHz
502
÷ BY 16
1 MHz
504
8 BIT COUNTER
509
D/A CONV.
506
PROG. DELAY
508
60 NS DELAY
512
TRIGGER GEN.
515
502
503
200
A
B
518
VARIABLE DELAY
516
TEMPLATE GEN.
514
MIXER
513
520
SHORT TERM INTEGRATOR
522
LONG TERM INTEGRATOR
524
AMP.
526
HIGH PASS FILTER
530
ALARM
510

FIG. 18

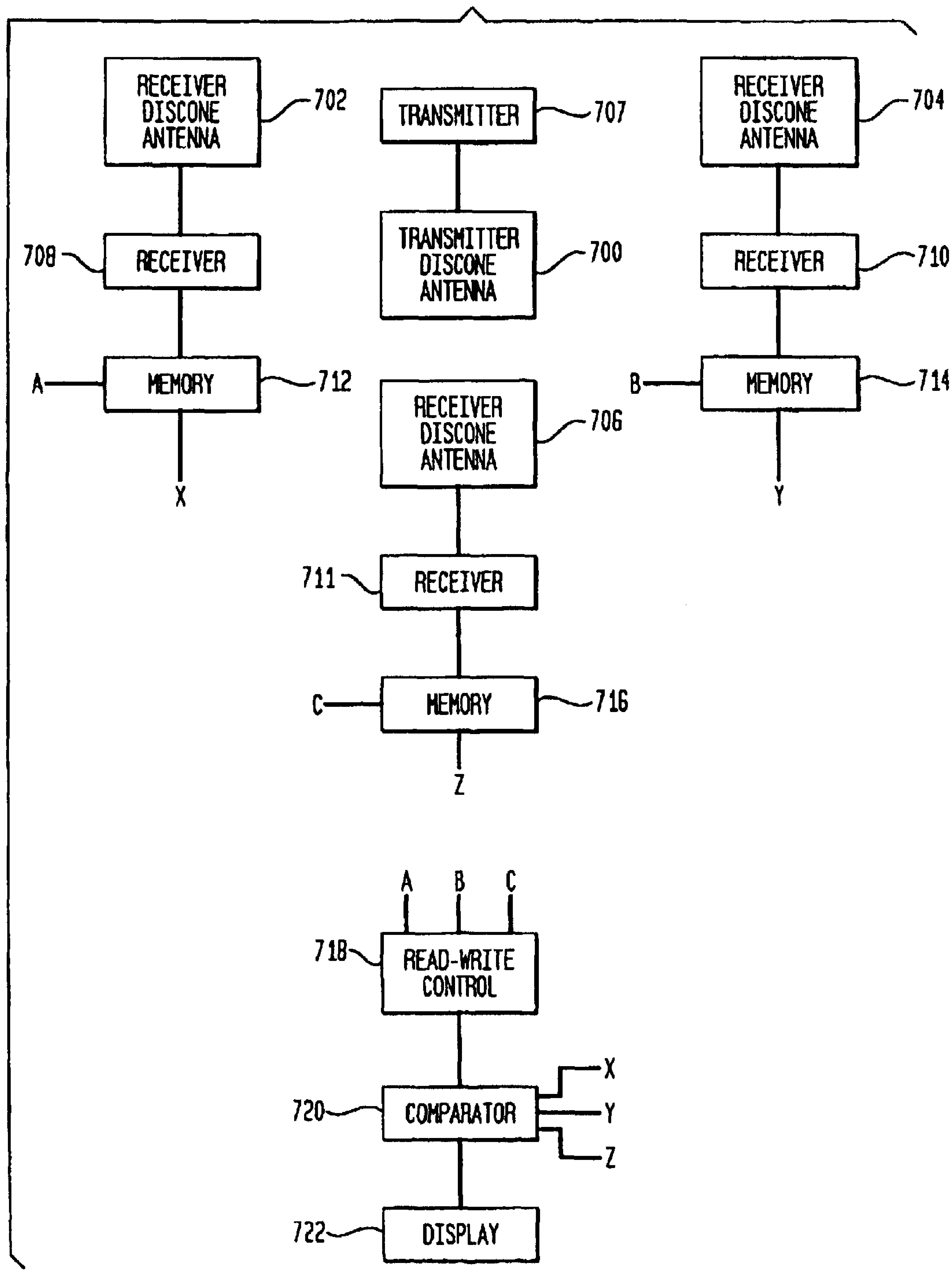
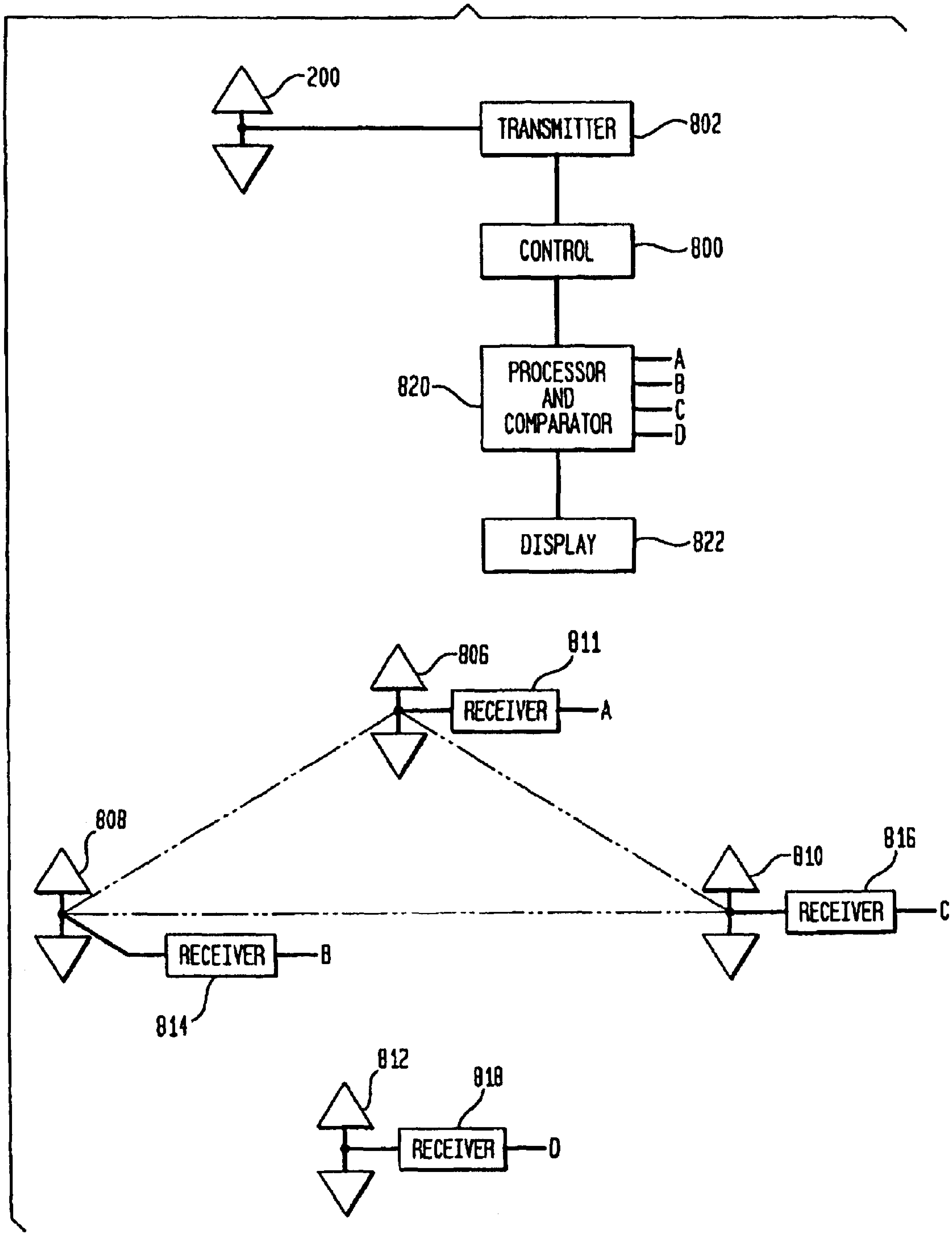
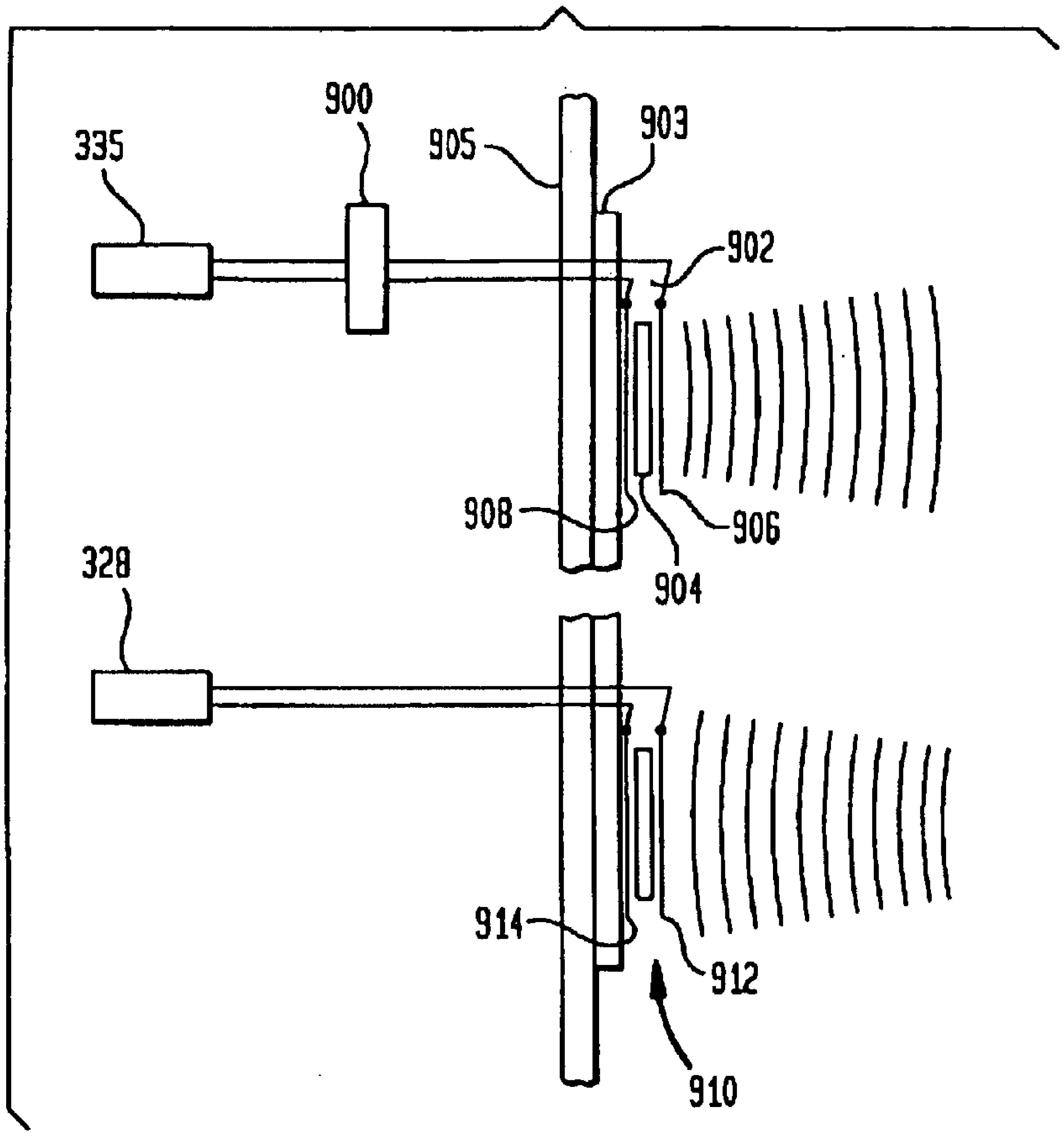

RECEIVER DISCONE ANTENNA
702
TRANSMITTER
707
RECEIVER DISCONE ANTENNA
704
708
RECEIVER
TRANSMITTER DISCONE ANTENNA
700
RECEIVER
710
A
MEMORY
712
B
MEMORY
714
RECEIVER DISCONE ANTENNA
706
X
Y
711
RECEIVER
C
MEMORY
716
Z
A
B
C
718
READ-WRITE CONTROL
720
COMPARATOR
X
Y
Z
722
DISPLAY

FIG. 19



200
TRANSMITTER
802
CONTROL
800
820
PROCESSOR AND COMPARATOR
A
B
C
D
DISPLAY
822
806
811
RECEIVER
A
808
810
816
RECEIVER
C
RECEIVER
B
814
812
818
RECEIVER
D

FIG. 20



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900
905
903
902
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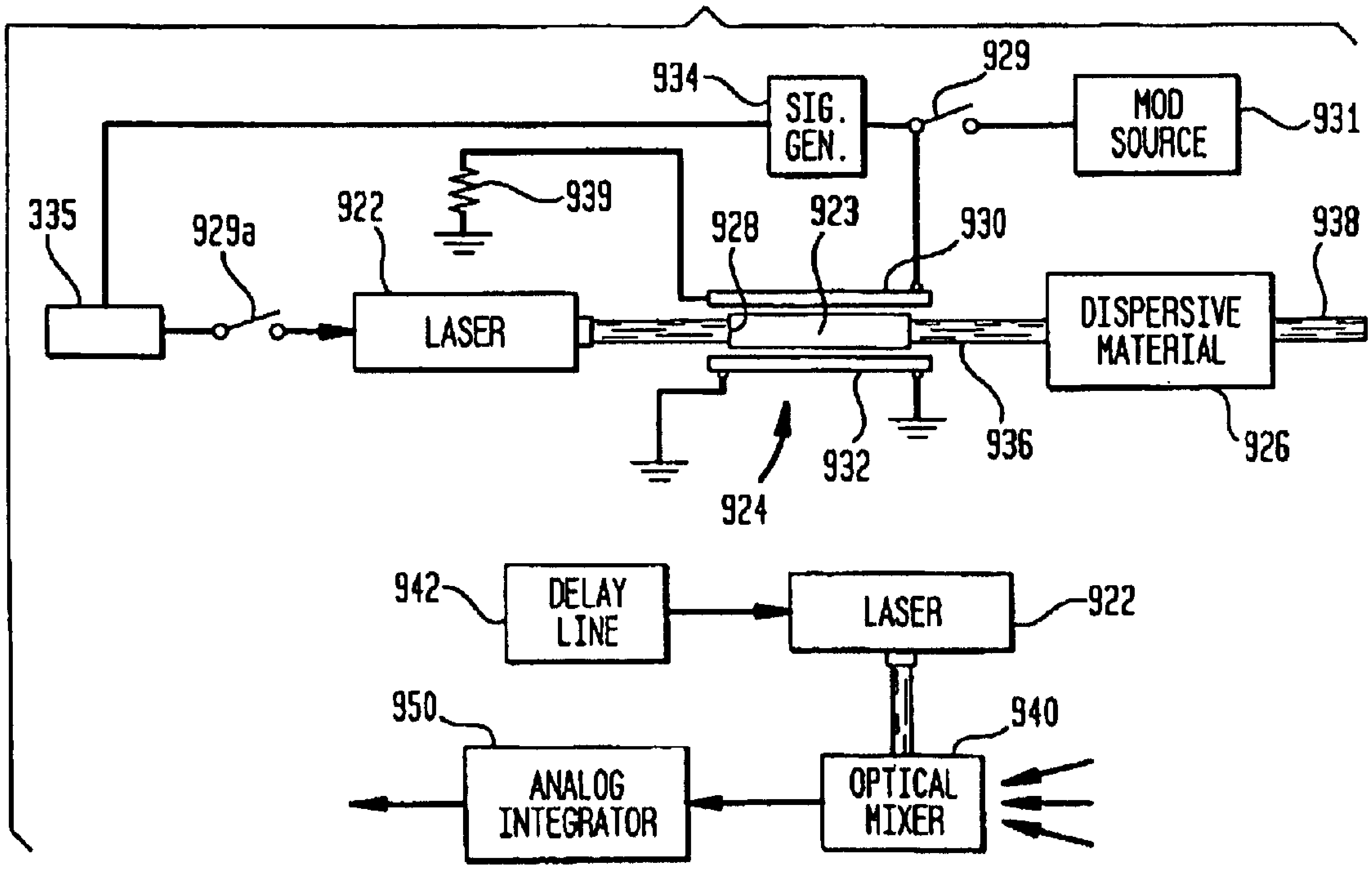
328
914
912
910

FIG. 21



934
SIG. GEN.
929
MOD SOURCE
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LASER
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DISPERSIVE MATERIAL
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DELAY LINE
LASER
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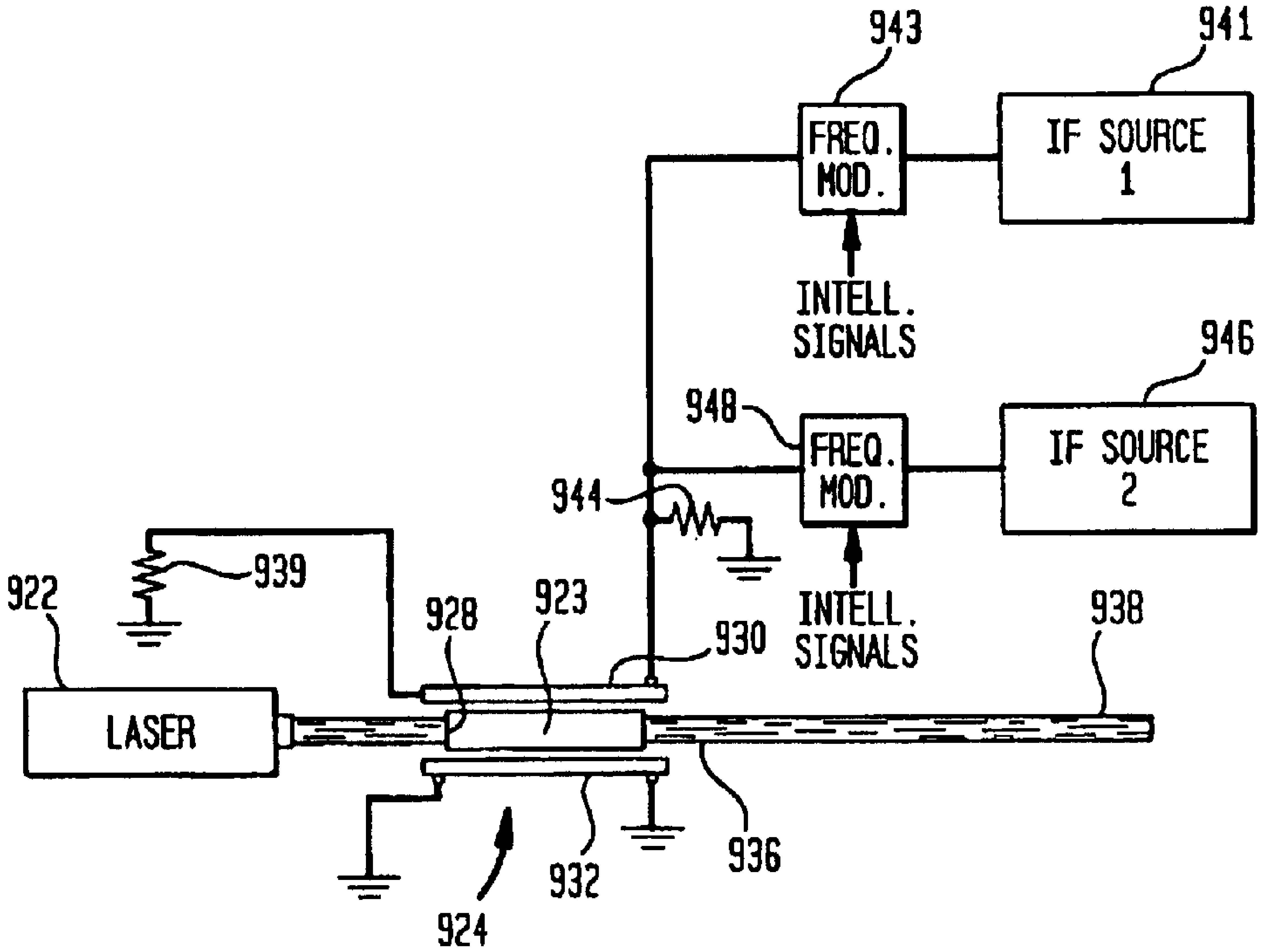
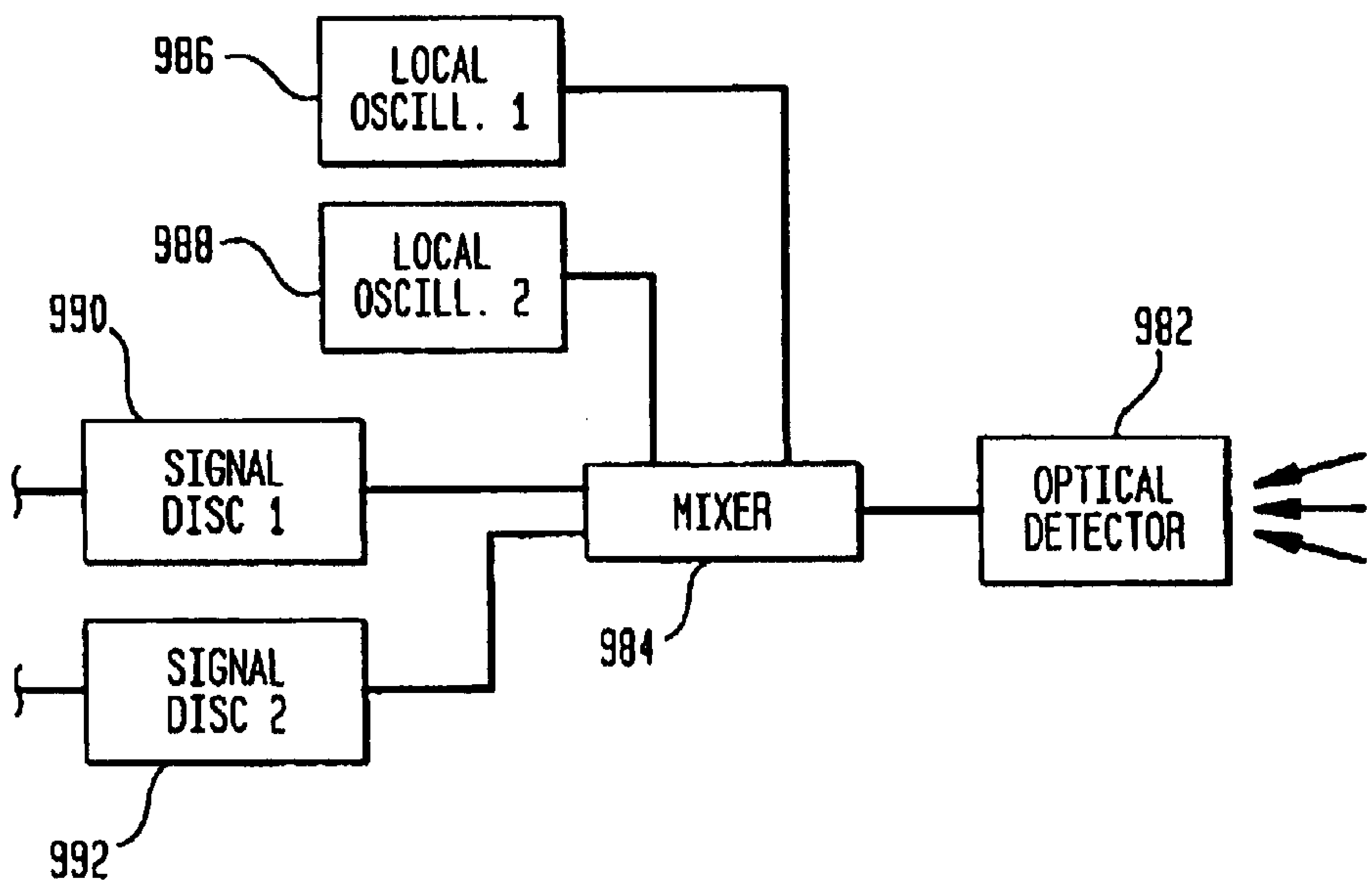
950
940
ANALOG INTEGRATOR
OPTICAL MIXER

FIG. 22



943
941
FREQ. MOD.
IF SOURCE 1
INTELL. SIGNALS
946
948
FREQ. MOD.
IF SOURCE 2
944
INTELL. SIGNALS
939
922
928
923
930
938
LASER
936
932
924

FIG. 23



986
LOCAL OSCILL. 1
988
LOCAL OSCILL. 2
990
982
SIGNAL DISC 1
MIXER
OPTICAL DETECTOR
984
SIGNAL DISC 2
992

TIME DOMAIN RADIO TRANSMISSION SYSTEM

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS-REFERENCE OF RELATED APPLICATIONS

This application is a *Reissue application of application Ser. No. 08/480,447, filed on Jun. 7, 1995, now U.S. Pat. No. 5,952,956, which is a* continuation-in-part of application Ser. No. 08/335,676, filed on Nov. 8, 1994, now abandoned, which is a continuation-in-part of application Ser. No. 07/846,597, filed on Mar. 5, 1992, now U.S. Pat. No. 5,363,108, which is a continuation of application Ser. No. 07/363,831, filed on Jun. 20, 1989, now abanbonded; which is a continuation-in-part of application Ser. No. 07/192,475, filed on May 10, 1988 now abandoned; which is a continuation-in-part of application Ser. No. 06/870,177, filed on Jun. 3, 1986, now U.S. Pat. No. 4,743,906; which is a continuation-in-part of application Ser. No. 06/677,597, filed on Dec. 3, 1984, now U.S. Pat. No. 4,641,317.

[This application is also a continuation-in-part of International Application No. PCT/US90/01174, filed on Mar. 2, 1990, which is a continuation-in-part of International Application No. PCT/US89/01020, filed on Mar. 10, 1989. Said PCT Application No. PCT/US89/01020 is also a continuation-in-part of U.S. application Ser. No. 07/010,440, filed on Feb. 3, 1987, now U.S. Pat. No. 4,813,057.**]**

This above-named prior patent applications and patents are hereby incorporated by reference.

FIELD OF THE INVENTION

This invention relates generally to radio systems wherein time-spaced, essentially monocycle-like signals are created from DC pulses and transmitted into space wherein the resulting energy bursts are disposed in terms of frequency to where the spectral density essentially merges with ambient noise, and yet information relating to these bursts is recoverable.

BACKGROUND OF THE INVENTION

Radio transmissions have heretofore been largely approached from the point of view of frequency channelling. Thus, coexistent orderly radio transmissions are permissible by means of assignment of different frequencies or frequency channels to different users, particularly as within the same geographic area. Essentially foregoing to this concept is that of tolerating transmission which are not frequency limited. While it would seem that the very notion of not limiting frequency response would create havoc with existing frequency denominated services, it has been previously suggested that such is not necessarily true, and that, at least theoretically, it is possible to have overlapping use of the radio spectrum. One suggested mode is that provided wherein very short (on the order of one nanosecond or less) radio pulses are applied to a broadband antenna which ideally would respond by transmitting short burst signals, typically comprising three or four polarity lobes, which comprise, energywise, signal energy over essentially the upper portion (above 100 megacycles) of the most frequently used radio frequency spectrum, that is, up to the mid-gigahertz region. A basic discussion of impulse effected radio transmission is contained in article entitled "Time Domain Electromagnetics and Its Application," Proceedings of the IEEE, Volume 66, No. 3, March 1978. This article particularly suggests the employment of such technology for baseband radar, and ranges from 5 to 5,000 feet are suggested. As noted, this article appeared in 1978, and now, 16 years later, it is submitted that little has been accomplished by way of achieving commercial application of this technology.

From both a theoretical and an experimental examination of the art, it has become clear to the applicant that the lack of success has largely been due to several factors. One is that the extremely wide band of frequencies to be transmitted poses very substantial requirements on an antenna. Antennas are generally designed for limited frequency bandwidths, and traditionally when one made any substantial change in frequency, it became necessary to choose a different antenna or an antenna of different dimensions. That is not to say that broadband antennas do not, in general, exist; however, applicant has reviewed many types including bicone, horn, and log periodic types and has determined that none provided a practical antenna which will enable impulse radio and radar usage to spread beyond the laboratory. Of the problems experienced with prior art antennas, is to be noted that log periodic antennas generally produce an undesired frequency dispersion. Further, in some instances, elements of a dipole type antenna may be configured wherein there is a DC path between elements, and such is not operable for employment in applicant's transmitter.

A second problem which has plaqued advocates of the employment of impulse or time domain technology for radio is that of effectively receiving and detecting the presence of the wide spectrum that a monocycle burst produces, particularly in the presence of high levels of existing ambient radiation, presently nearly everywhere. Ideally, a necessary antenna would essentially evenly reproduce the spectrum transmitted, and the receiver it feeds would have special properties which enable it to be utilized despite the typically high noise level with which it must compete. The state of the art prior to applicant's entrance generally involved the employment of brute force detection, i.e., that of threshold or time threshold gate detection. Threshold detection simply enables passage of signals higher than a selected threshold level. The problem with this approach is obvious that if one transmits impulse generated signals which are of sufficient amplitude to rise above ambient signal levels, the existing radio services producing the latter may be unacceptably interferred with. For some reason, perhaps because of bias produced by the wide spectrum of signal involved, e.g., from 50 mHz to on the order of 5 gHz or ever higher, the possibility of coherent detection has been thought impossible.

Accordingly, it is an object of this invention to provide an impulse or time domain (or baseband) transmission system which attacks all of the above problems and to provide a complete impulse time domain transmission system which, in applicant's view, eliminates the known practical barriers to its employment, and, importantly, its employment for all important electromagnetic modes of radio, including communications, telemetry, navigation and radar.

SUMMARY OF THE INVENTION

With respect to the antenna problem, applicant has determined a truly pulse-responsive antenna which translated an applied DC impulse into essentially a monocycle. It is a dipole which is completely the reverse of the conventional bat wing antenna and wherein two triangular elements of the dipole are positioned with their bases closely adjacent but DC isolated. They are driven at near adjacent points on the bases bisected by a line between apexes of the two triangular elements. This bisecting line may mark a side or height dimension of the two triangular elements.

As a further consideration, power restraints in the past have been generally limited to the application of a few hundred volts of applied signal energy to the transmitting antenna. Where this is a problem, it may be overcome by a transmitter switch which is formed by a normally insulating crystalline structure, such as diamond material sandwiched between two metallic electrodes, which are then closely coupled to the elements of the antenna. This material is switched to a conductive, or less resistive, state by exciting it with an appropriate wavelength beam of light, ultraviolet in the case of diamond. In this manner, no metallic triggering communications line extends to the antenna which might otherwise pick up radiation and re-radiate it, adversely affecting signal coupling to the antenna and interfering with the signal radiated from it, both of which tend to prolong the length of a signal burst, a clearly adverse effect.

With respect to a radio receiver, a like receiving antenna is typically employed to that used for transmission as described above. Second, a locally generated, coordinately timed signal, to that of the transmitted signal, is either detected from the received signal, as in communications or telemetry, or received directly from the transmitter, as, for example, in the case of radar. Then, the coordinately timed signal, typically including a basic half cycle, or a few, up to 10 half cycles, of signal, is mixed or multiplied by a factor of 1 (as with sampling or gating of the received signals), or ideally, as where the coordinately locally generated signal is curved, the factor is greater than one, giving rise to amplification in the process of detection, a significant advantage. Thus, the modulation on a signal, or position of a target at a selected range, as the case may be, is determined. Such a detection is further effected by an integration of the detected signal, with enhanced detection being accomplished by both a short term and long term integration. In this latter process, individual pulse signals are integrated only during their existence to accomplish short term integration, and following this, the resultant short term integration signals are long term integrated by integrating a selected number of these and particularly by a method which omits the noise signal content which occurs between individual pulse signals, thereby effecting a very significant increase in signal-to-noise ratio.

It is acknowledged that coherent detection of frequency signals has been effected by the employment of coincidence detection, followed by only long term detection, but it is submitted that such coherent detection did not contemplate the local generation of a signal but contemplated storing of a portion of a transmitted signal which was then phase coordinated with the incoming signal, which on its face presents an essentially impossible task where there is the detection of a ultra wideband frequency pulse as in the present case.

Further, transmitted burst signals may be varied in time pattern (in addition to a modulation pattern for communications or telemetry). This greatly increases the security of the system and differentiates signals from nearly, if not all, ambient signals, that is, ambient signals which are not synchronous with transmitted burst signals. This also enables the employment of faster repetition rates with radar which would, absent such varying or dithering, create range ambiguities as between returns from successive transmission and therefore ranges. Burst signals are signals generated when a stepped, or near stepped, voltage change is applied to an impulse-responsive antenna as illustrated and discussed herein.

As still a further feature of this invention, the repetition rate of burst signals may be quite large, say, for example, up to 100 mHz, or higher, this enabling a very wide frequency dispersion; and thus for a given overall power level, the energy at any one frequency would be extremely small, thus effectively eliminating the problem of interference with existing radio frequency based services.

As still a further feature of this invention, moving targets are detected in terms of their velocity by means of the employment of a bandpass filter, following mixing and double integration of signals.

As a still further feature of the invention, when employed in this latter mode, two channels of reception are ideally employed wherein the incoming signal is multiplied by a selected range, or timed, locally generated signal in one channel, and mixing the same incoming signal by a slightly delayed, locally generated signal in another channel, delay being on the order of one-quarter to one-half the time of a monocycle. This accomplishes target differentiation without employing a separate series of transmissions.

As still another feature of this invention, multiple radiators or receptors would be employed in an array wherein their combined effect would be in terms of like or varied-in-time of sensed (or transmitted) output, to thereby accent either a path normal to the face of the antenna or to effect a steered path offset to a normal path accomplished by selected signal delay paths.

As still another feature of this invention, radio antenna elements would be positioned in front of a reflector wherein the distance between the elements and reflector is in terms of the time of transmission from an element or elements to reflector and back to element(s), typically up to about three inches, this being with tip-to-tip dimension of elements of somewhat below nine inches up to approximately nine inches.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a combination block-schematic diagram of an intelligence time domain transmission system.

FIG. **1**a is a schematic diagram of an alternate form of the output stage of the transmitter shown in FIG. **1**.

FIG. **2** is a block diagram of a time domain receiver as contemplated by this invention.

FIG. **3**A, FIG. **3**B, FIG. **3**C, FIG. **3**D, FIG. **3**E, FIG. **3**F, FIG. **3**G, FIG. **3**H, FIG. **3**I, FIG. **3**J, FIG. **3**K, and FIG. **3**L, depict electrical waveforms illustrative of aspects of the circuitry shown in FIGS. **1** and **1**a.

FIG. **4**T**1**, FIG. **4**T**2**, FIG. **4**Ta and FIG. **4**Ea is a set of electrical waveforms illustrating aspects of operation of the circuitry shown in FIG. **2**.

FIG. **5** is an electrical block diagram illustrative of a basic radar system constructed in accordance with this invention.

FIGS. **6**, **6**a and **7** illustrate the configuration of an antenna in accordance with the invention.

FIG. **8**a and FIG. **8**b show side and front views, respectively, of an alternate form of antenna constructed in accordance with this invention.

FIGS. **9**a and **9**b diagrammatically show side and front views, respectively, of another alternate embodiment of an antenna array.

FIGS. **10**–**15** illustrate different switching assemblies as employed in the charging and discharging of antennas to effect signal transmission.

FIG. **16** illustrates a radar system particularly for employment in facility surveillance, and FIG. **17** illustrates a modification of this radar system.

FIGS. **18**, **18**a and **19** illustrate the general arrangement of transmission and receiving antennas for three-dimensional location of targets.

FIG. **20** is a schematic illustration of a modified portion of FIG. **1** illustrating transmission and reception of time domain type sonic signals.

FIG. **21** is a schematic illustration of an alternate portion of FIG. **1** illustrating both the employment of like time domain signals and a like modulation system adapted to produce broadband modulated light signals from the output of a conventional narrow band laser.

FIG. **22** is an illustration of an optical frequency modulator.

FIG. **23** is an illustration of an optical frequency demodulator.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, and initially to transmitter **10**, a base frequency of 100 kHz is generated by oscillator **12**, typically being a crystal controlled oscillator. Its output, a pulse signal, is applied to +4 divider **14** to provide at its output a 25-kHz (0 to 5 volts) pulse signal shown in waveform A. of FIG. **3**. Further alphabetic references to waveform will simply identify them by their letter identity and will not further refer to the figure, which will be FIG. **3**. The 25-kHz output is employed as a general transmission signal.

The output of +4 divider **14** is employed as a signal base and as such is supplied through capacitor **20** to pulse position modulator **22**. Pulse position modulator **22** includes in its input an RC circuit consisting of resistor **24** and capacitor **26** which convert the square wave input to an approximately triangular wave as shown in waveform B, it being applied across resistor **25** to the non-inverting input of comparator **28**. A selected or reference positive voltage, filtered by capacitor **27**, is also applied to the non-inverting input of comparator **28**, it being supplied from +5-volt terminal **31** of DC bias supply **30** through resistor **32**. Accordingly, for example, there would actually appear at the non-inverting input a triangular wave biased upward positively as illustrated by waveform C.

The actual conduction level of comparator **28** is determined by an input signal supplied through capacitor **36**, across resistor **37**, to the inverting input of comparator **28**, as biased from supply **30** through resistor **38** and across resistor **32**. The combined signal input bias is illustrated in waveform D.

With switches **39**, **39**a, and **39**c open and switch **39**b in the alternate position to that shown, signal input would be simply the audio output of microphone **34**, amplitude, if needed, by amplifier **35**. Alternately, by closing switch **39**, the signal input to comparator **28** would be the sum of the audio output and a signal offset or dither voltage, for example, provided by the output of signal generator **33**, these signals being summed across resistor **41**. Signal generator **33** may, for example, provide a sine, binary, or other signal, and, as illustrated, it is labeled as providing a "binary sequence A." Thus, generator **33** would provide a binary signal voltage as a sequence of discrete voltage pulses varying between zero voltage and some discrete voltage, which may be representative of letters or numerical values or simply a random value. Thus, the input to comparator **28** would be the sum of these voltages, and by virtue of this combination, the output of comparator **28** would rise to a positive saturation level when triangular wave signal **40** (waveform E) is of a higher value than the effective modulation signal **42** and drop to a negative saturation level when modulation signal **42** is of a greater value than the triangular wave signal **40**. The output signal of comparator **28** is shown in waveform F, and the effect is to vary the turn-on and turn-off of the pulses shown in this waveform as a function of the combination of the intelligence and dither signals where one is employed. Thus, there is effected a pulse position modulation from an amplitude signal. The dither signal enables an added discrete pattern of time positions to be included with a transmitted signal, thus requiring that to receive and demodulator it, the dither signal must be accurately reproduced.

FIG. **1** also shows alternate arrangements for converting the analog voltage derived from microphone **34** to binary form or the employment of a general digital source, and as a computer, and whereby the output of comparator **28** would be governed by one of such sources. Accordingly, with switch **39** closed, and providing a dither voltage, it would be combined with one of the two other intelligence sources, either a digitally encoded voice signal or a digital signal from some independent digital source. Thus, in one instance, switch **39**a would be open and switches **39** and **39**c closed, with switch **39**b positioned to provide the signal from amplifier **35** to A/D converter **34**a. In such case, the microphone signal from amplifier **35** would be fed to A-D converter **34**a, and the resulting digitized output, being in parallel, would be fed to parallel-to-serial converter **34**b wherein its output would be a serial digital binary output which would be fed to comparator **28** as the sum of the dithered voltage and binary output of parallel-to-serial converter **34**b.

As the other alternative, with switches **39** and **39**a closed and switch **39**c open, the input to comparator **28** would be the sum of the dithered and digital source voltage. The digital source voltage is provided by digital source **29**, and assuming that it is in parallel form, it would be converted to a serial form by parallel-to-serial converter **29**a, and then with switch **39**a closed, it would be provided along with the dithered output of generator **33** as an intelligence input to the inverting input of comparator **28**. Thus, the output of comparator **28** would be the algebraic sum of the voltages applied to comparator **28** as previously described.

With respect to the output signal of comparator **28**, we are interested in employing a negative going or trailing edge **44** of it, and it is to be noted that this trailing edge will vary in its time position as a function of the signal modulation. This trailing edge of the waveform, in waveform F, triggers "on" mono, or monostable multivibrator, **46** having an "on" time of approximately 50 nanoseconds, and its output is shown in waveform G. For purposes of illustration, while the pertinent leading or trailing edges of related waveforms are properly aligned, pulse widths and spacings (as indicated by break lines, spacings are 40 microseconds) are not related in scale. Thus, the leading edge of pulse waveform G corresponds in time to the trailing edge **44** (waveform F), and its time position within an average time between pulses of waveform G is varied as a function of the input modulation signal to comparator **28**.

The output of mono **46** is applied through diode **48** across resistor **50** to the base input of NPN transistor **52** operated as a triggering amplifier. It is conventionally biased through resistor **54**, e.g, 1.5 K ohms, from +5-volt terminal **31** of b **5**-volt power supply **30** to its collector. Capacitor **56**, having an approximate capacitance of 01 mf, is connected between the collector and ground of transistor **52** to enable full bias potential to appear across the transistor for its brief turn-on interval, 50 nanoseconds. The output of transistor **52** is coupled between its emitter and ground to the primary **58** of trigger transformer **60**. Additionally, transistor **52** may drive transformer **60** via an avalanche transistor connected in a common emitter configuration via a collector load resistor. In order to drive transformer **60** with a steep wave front, an avalanche mode operated transistor is ideal. Identical secondary windings **62** and **64** of trigger transformer **60** separately supply base-emitter inputs of NPN avalanche, or avalanche mode operated, transistors **66** and **68** of power output stage **18**. Although two are shown, one or more than two may be employed when appropriately coupled.

With avalanche mode operated transistors **66** and **68**, it has been found that such mode is possible from a number of types of transistors not otherwise labeled as providing it, such as a 2N2222, particularly those with a metal can. The avalanche mode referred to is sometimes referred to as a second breakdown mode, and when transistors are operated in this mode and are triggered "on," their resistance rapidly goes quite low (internally at near the speed of light), and they will stay at this state until collector current drops sufficiently to cut off conduction (at a few microamperes). Certain other transistors, such as a type 2N4401, also display reliable avalanche characteristics.

As illustrated, impulse antenna **200** is charged by a DC source **65** through resistors **67** and **69** to an overall voltage which is the sum of the avalanche voltage of transistors **66** and **68** as discussed above. Resistors **67** and **69** together have a resistance value which will enable transistors **66** and **68** to be biased as described above. Resistors **71** and **73** are of relatively low value and are adjusted to receive energy below the frequency of cut-off of the antenna. In operation, when a pulse is applied to the primary **58** of pulse transformer **60**, transistors **66** and **68** are turned "on," effectively shorting, through resistors **71** and **73**, antenna elements **204** and **206**. This action occurs extremely fast, with the result that a signal is generated generally as shown in pulse waveform G (but somewhat rounded). Antenna **200** differentiates the pulse G to transmit essentially a monocycle of the general shape shown in waveform H.

FIG. **1**a illustrates an alternate embodiment of a transmitter output stage. It varies significantly from the one shown in FIG. **1** in that it employs a light-responsive avalanche transistor **63**, e.g., a 2N3033. Similar components are designated with like numerical designations to that shown in FIG. **1**, but with the suffix "a" added. Transistor **63** is triggered by laser diode or fast turn-on LED (light emitting diode) **61**, in turn driven by avalanche transistor **52**a generally operated as shown in FIG. **1**. By employment of a light-activated avalanche or other avalanche mode operated semiconductor switches (now existing or soon appearing), or a series of them connected in series, it appears that the voltage for power source **65**a may be elevated into the multi-kilovolt range, thus enabling a power output essentially as high as desired. In this respect, and as a particular feature of this invention, a light-triggered, gallium arsenide, avalanche mode operated switch would be employed.

Referring back to FIG. **1**, the output of monocycle producing antenna **200**, with elements **204** and **206**, is typically transmitted over a discrete space and would typically be received by a like broadband antenna, e.g., antenna **200** of a receiver at a second location (FIG. **2**).

FIG. **2** illustrates a radio receiver which is particularly adapted to receive and detect a time domain transmitted signal. In addition, it particularly illustrates a system for detecting intelligence which has been mixed with a particular offset or dither signal, analog or digital, such as provided by binary sequence "A" generator **33** shown in FIG. **1**. It will thus be presumed for purposes of description that switch **39** of FIG. **1** is closed and that the signal transmitted by transmitter **10** is one wherein intelligence signals from microphone **34** are summed with the output of binary sequence "A" generator **33**, and thus that the pulse position output of transmitter **10** is one wherein pulse position is a function of both intelligence and offset or dither signals. Thus, the transmitted signal may be described as a pulse position modulated signal subjected to changes in pulse position as effected by a time offset pattern of the binary sequence "A."

The transmitted signal from transmitter **10** is received by antenna **200** (FIG. **2**), and this signal is fed to two basic circuits, demodulation circuit **222** and template generator **234**. In accordance with this system, a replica of the transmitted signal, waveform H (FIG. **3**), is employed to effect detection of the received signal, basic detection being accomplished in multiplier or multiplying mixer **226**. For maximum response, the template signal, reproduced as waveform FIG. **4** T_1 in FIG. **4**, must be applied to mixer **226** closely in phase with the input, as will be further described. As in the waveforms of FIG. **3**, further references to the waveforms of FIG. **4** will not refer to the figure designation but will instead refer to the alphabetic designation of the waveforms. It will differ by a magnitude not perceptible in the waveforms of FIG. **4** as a function of modulation, effecting swings of approximately ±200 picoseconds, typically for a 1-nanosecond pulse. To accomplish such near synchronization, template generator **234** employs a crystal. controlled but voltage controlled oscillator **227** which is operated by a control voltage which synchronizates its operation in terms of the received signal.

Oscillator **227** operates at a frequency which is substantially higher than the repetition rate of transmitter **10**, and its output is divided down to the operation frequency of 25 kHz by frequency divider **230**, thus equal to the output of divider **14** of transmitter **10**.

In order to introduce a pattern of dither corresponding to that provided by binary sequences "A" generator **33**, a like generator **228** provides a binary changing voltage to programmable delay circuit **232** which applies to the signal output of divider **230**, a delay pattern corresponding to the one effected by binary sequence "A" generator **33** of FIG. **1** when added to intelligence modulation. Thus, for example, this might be four 8-bit binary words standing for the numerals 4, 2, 6, and 8, the same pattern having been generated by binary sequence "A" generator **33** and transmitted by transmitter **10**. It is further assumed that this is a repeating binary pattern. Thus, programmable delay **232** will first delay a pulse it receives from divider **230** by four units. Next, the same thing would be done for the numeral **2**, and so on, until the four-numeral sequence has been completed. Then, the sequence would start over. In order for the two binary sequence generators to be operated in synchronization, either the start-up time of the sequence must be communicated to the receiver, or else signal sampling would be for a sufficient number of signal input pulses to establish synchronization by operation of the synchronization system, as will be described. While a repeatable sequence is suggested, it need not be such so long as there is synchronization between the two generators, as by transmission of a sequence start signal and the provision in the receiver of means for detecting and employing it.

Either programmable delay **232** or a second delay device connected to its output would additionally provide a general circuit delay to take care of circuit delays which are inherent in the related circuitry with which it is operated, as will be described. In any event, the delayed output of delay **232**, which is a composite of these, will be provided to the input of template generator **234**, and it is adapted to generate a replica of the transmitted signal, illustrated in FIG. **4** T_1. Differential amplifier **246** basically functions to provide a DC voltage as needed to apply a correction or error signal to oscillator **227** as will enable there to be provided to mixer **226** replica signal T_1 exactly in phase with the average time of input signal E_a.

In order to generate the nearest signal, the input signal E_a is multiplied by two spaced, in time, replicas of the template signal output of template generator **234**. The first of these, indicated as T_1, is multiplied in mixer **236** by input signal E_a in mixer **238**. As will be noted in FIG. **4**, T_2 is delayed from signal T_1 by delay **240** by a period of essentially one-half of the duration of the major lobe P of template signal T_1.

The output of mixer **236** is integrated in integrator **242**, and its output is sampled and held by sample and hold unit **244** as triggered by delay **232**. The output of sample and hold unit **244**, the integral of the product of the input signal E_a and T_1, is applied to the non-inverting input of differential amplifier **246**. Similarly, the output of mixer **238** is integrated by integrator **249** and sampled and held by sample and hold **259** as triggered by delay **232**, and the integrated product of the input signal E_a and template signal T_2 is applied to the inverting input of differential amplifier **246**.

To examine the operation of differential amplifier **246**, it will be noted that if the phase of the output of oscillator **227** should advance, signals T_1 and E_a applied to mixer **236** would become closer in phase, and their product would increase, resulting in an increase in input signal to the non-inverting input of differential amplifier **246**, whereas the advance effect. on template signal T_2 relative to the input signal E_a would be such that their coincidence would decrease, causing a decrease in the product output of mixer **238** and therefore a decreased. voltage input to the inverting input of differential amplifier **246**. As a result, the output of differential amplifier **246** would be driven in a positive direction, and this polarity signal would be such as to cause oscillator **227** to retard. If the change were in the opposite direction, the result would be such that higher voltages would be applied to the inverting input than to the non-inverting input of differential amplifier **246**, causing the output signal to decrease and to drive oscillator **227** in an opposite direction. In this manner, the near average phase lock is effected between the input signal E_a and template signal T_a which is directly employed in the modulation of the input signal. The term "near" is used in that the output of differential amplifier **246** is passed through low pass filter **253** before being applied to the control input of oscillator **227**. The cut-off frequency of low pass filter **253** is set such that it will take a fairly large number of pulses to effect phase shift (e.g., 10 Hz to perhaps down to 0.001 Hz). As a result, the response of oscillator **227** is such that it provides an output which causes waveform T_1 and thus waveform T_a to be non-variable in position with respect to modulation effect. With this limitation in mind, and in order to obtain a synchronous detection of the input signal, the output T_1 of template generator **234** is delayed by a period equal to essentially one-fourth the period P of the major lobe of the template and input signal, and this is applied as signal T_a with the input signal E_a, to multiplying mixer **226**. As will be noted, the resulting delayed signal, T_a, is now near synchronization with the input signal E_a, and thus the output of multiplier **226** provides essentially a maximum signal output. In instances where there is simply no signal, or a noise signal, at the signal input of mixer **226**, there would be between input signals E_a an elapsed time of exactly 40 milliseconds shown in FIG. **4**, and a quite minimum deviation in output would appear from mixer **226**.

The signal output of mixer **226** is integrated in integrator **251**, and the output signal is multiplied by a factor of 0.5 by amplifier **252**. Then this one-half voltage output of amplifier **252** is applied to the inverting input of comparator **254**, and this voltage represents one-half of the peak output of integrator **250**. At the same time, a second output of integrator **251** is fed through delay **256** to the non-inverting input of comparator **254**, delay being such as required for stabilization of the operation of amplifier **252** and comparator **254** in order to obtain an effective comparison signal level that will be essentially free of the variable operation of these two units. The output of comparator **254** represents an essentially precise time marker which varies with the position of input signal E_a. It is then fed to the reset input of flip-flop **258**, a set input being provided from the output of delay **232** which represents, because of low pass filter **253**, an averaged spacing between input signals, thus providing a reference against which the modulation controlled time variable output signal of comparator **254** may be related. It is related by virtue of the output delay **232** being provided as the set input of flip-flop **258**. Thus, for example, the output of flip-flop **258** would rise at a consistent time related to the average repetition rate a essentially dictated by low pass filter **253**. Thus, the output of flip-flop **258** would be brought back to zero at a time which reflected the intelligence modulation on the input signal. Thus, we would have a pulse height of a constant amplitude, but with a pulse width which varied directly with modulation. The output of flip-flop **258** is then fed through low pass filter **260**, which translates the signal from pulse width demodulation to amplitude signal modulation, which is then reproduced by loudspeaker **262** with switch A in the upper position.

Where the intelligence transmission is in digital form, switch A is moved to the lower position wherein the output of comparator **261**a and the thus parallel in form digital signal is fed to the non-inverting input of comparator **261**a, a, potential being applied to the inverting input sufficient to block the transition of comparator **261**a from an off state to an on state absent a significant "1" binary signal. Assuming that the digital signal is a converted analog signal and the signal is representative of an analog voice input as shown in FIG. **1**, switch B will be positioned in the indicated position wherein the output of comparator **261**a is fed to D-A converter **261**b, and the thus derived analog signal is fed via switch C in the lower position to loudspeaker **262**.

In the event that the digital transmission is derived from another digital source, such as illustrated by digital source **29** in FIG. **1**, which might be a computer, switch B is switched from its shown position to its lower position, wherein the output of comparator **261**a is fed in a serial-to-parallel converter **261**d to digital register **261**c, such as another digital computer or a digital computer terminated by a monitor. Thus, in this configuration, purely transmitted digital signals would be processed in purely digital form. In this case, switch C would be moved to its upper position as no signal is being transmitted to it.

While the generation and detection of digital signals have been described in terms of binary encoding, it is to be appreciated that multi-level encoding might be employed and detected wherein discretely positioned bits would be represented by different effected delays and encoded in this manner.

Assuming that binary sequence "A" generator **33** of transmitter **10** and binary sequence "A" generator **228** for the receiver are operated essentially in synchronization, the effect of the time position dither effected by generator **33** of transmitter **10** will have no dislocating effect on the signal.

As suggested above, in order to ensure synchronization, some form of signaling between the transmitter and receiver as to the starting of the binary sequence generator, generator **33**, is required. This may be done by an auxiliary transmitter or by a decoding arrangement wherein there would be provided at the conclusion of, say, one sequence of binary sequence generator **33**, a start signal for binary sequence generator **228** of the receiver. Absent this, in the free running mode, there would be effected synchronization by the operation of template generator **234** which, for short codes, and with relatively low noise levels, would be relatively short; and for longer codes, or instances where noise was a significant problem, longer codes would be required for synchronization. Where needed, a receiving station might transmit back to the original transmitting station an acknowledgement that synchronization has been achieved.

From the foregoing, it should be appreciated that applicant has provided both an inexpensive and practical time domain system for communications. While a system has been described wherein a single short pulse, for example, a nanosecond, is transmitted at a repetition rate such that 40 microseconds is between pulses, the invention contemplates that a group of pulses might be sent which would be separated by the longer period. Thus, for example, an 8-bit set might be transmitted as a group wherein there was simply room between the pulses to detect their multiposition shifts with modulation. By this arrangement, it is to be appreciated that intelligence information transmitted would be increased by up to 256 times, or the immunity from noise could be substantially improved by this technique and related ones.

FIG. **5** particularly illustrates a radar system of the present invention for determining range. Impulse-responsive, or impulse, antenna **200**, or antenna **201** as shown in FIG. **6**a, of transmitter **329** comprises triangular elements A and B with closely spaced bases. A dimension of a base and a dimension normal to the base of each element is approximately 4½ inches and is further discussed and illustrated with respect to FIGS. **6** and **7**. Typically, a reflector would be used as illustrated in FIGS. **8**a and **8**b. Alternately, as shown in FIG. **6**a, a base is reduced to 2¼ inches wherein the elements are halved as shown in FIG. **6**a. Significantly, however, the length of path from a feed point to an edge is the same in both cases.

The transmitter is basically controlled by control **310**. It includes a transmit sequence, or rate, control portion **312** which determines the timing of transmitted signal bursts, at, for example, 10,000 bursts per second, in which case transmit sequence control **312** generates an output at 10,000 Hz on lead **314**. Oscillator **316** is operated at a higher rate, for example, 20 mHz.

The signal output of transmit sequence control **312** is employed to select particular pulse outputs of oscillator **316** to be the actual pulse which is used as a master pulse for controlling both the output of transmitter **329** and the timing of receiver functions, as will be further described. In order to unambiguously and repetitively select an operative pulse with low timing uncertainty from oscillator **316**, the selection is one and some fraction of an oscillator pulse interval after an initial signal from control **312**. The selection is made via a control sequence employing D-type flip-flops **318**, **320**, and **322**. Thus, the transmit sequence control pulse on lead **314** is applied to the clock input of flip-flop **318**. This causes the Q output of flip-flop **318** to transition to a high state, and this is applied to a D input of flip-flop **320**. Subsequently, the output of oscillator **316** imposes a rising edge on the clock input of flip-flop **320**. At that time, the high level of the D input of this flip-flop is transferred to the Q output. Similarly, the Q output of flip-flop **320** is provided to the D input of flip-flop **322**, and the next rising edge of the pulse from oscillator **316** will cause the not Q output of flip-flop **322** to go low and thus initiate the beginning of the transmit-receive cycle.

For the transmit mode, the not Q output of flip-flop **322** is fed as an input to analog programmable delay **313** and to counter **315**. Counter **315**, for example, would respond to the not Q outputs of flip-flop **322** and count up to a selected number, for example, **356**, and recycle to count again. Its binary output would be fed as an address to memory unit **317**, ROM or RAM, which would have stored, either in numerical address order, or randomly selected order, a number. As a result, upon being addressed, a discrete output number would be fed to D/A converter unit **321**. D/A converter unit **321** would then provide an analog signal output proportional to the input number. This output is employed to sequentially operate programmable delay unit **313** for delays of pulses from flip-flop **322** by an amount proportional to the signal from D/A converter **321**. The range of delays would typically be up to the nominals timing between pulses, in this case, up to 300 nanoseconds, and practically up to 99 nanoseconds. The delayed output of programmable delay unit **313** is then fed to fixed delay unit **324**, which provides a fixed delay of 200 nanoseconds to each pulse that it receives. The thus delayed pulses are then fed to trigger generator **323**. Trigger generator **323**, e.g., an avalanche mode operated transistor, would provide a sharply rising electrical output at the 10,000 Hz rate or a like response of light output, e.g., by laser, depending upon the transmitter to be driven. In accordance with one feature of this invention, trigger generator **323** would be an ultraviolet laser. In any event, a pulse of trigger generator **323** is fed to and rapidly turns "on" a switch, for example, diamond **335**, which, for example, may again be an electrically operated or light operated switch, such as a diamond switch in response to the ultraviolet laser triggering device via fiber optic **327**. Importantly, it must be capable of switching in a period of a nanosecond or less. It is then switched "on" to discharge antenna **200**, having earlier been charged from power source B through resistors R_1 and R_2, source B being, for example, 100 to 5,000 volts.

Conformal impulse antenna **200** or **200**a (FIG. **6**a) is turned "on" or turned "off," or successively both, by switch assembly **319** which applies stepped voltage changes to the antenna. It responds by transmitting essentially short burst signals each time that it is triggered. These burst signals are then transmitted into space via a directional version of antenna **200** as illustrated in FIGS. **8**a, **8**b and **9**a, **9**b or simply by an omnidirectional. antenna as shown by antenna **200** in FIG. **1** or **200**a in FIG. **6**a.

Signal returns from a target would be received by receiver **326**, typically located near or together with transmitter **329**, via receiving antenna **200**, which would, for example, be like a transmitting antenna. The received signals are amplified in amplifier **328** and fed to mixer **330**, together with a signal from template generator **332**, driven by delay line **336**, which is timed to produce signals, typically half cycles in configuration, and corresponding in time to the anticipated time of arrival of a signal from a target at a selected range.

Mixer **330** functions to multiply the two input signals, and where there are coincidence signals, timewise and with like or unlike polarity coincident signals, there is a significant and integratable output, indicating a target at the range. A mixer and the following circuitry may be reused for later arriving signals representative of different range, this range or time spacing being sufficient to complete processing time for reception and integration at a range as will be described.

Additional like mixtures and following circuitry sets may be employed to fill in the range slots between that capable for one set.

Since the goal here is to determine the presence or absence of a target based on a number of signal samplings as effected by integration, where a true target does not exist, the appearance of signals received by mixer **330** corresponding to the time of receipt of signals from template generator **332** will typically produce signals which vary not only in amplitude, but also in polarity. It is to be borne in mind that the present system determines intelligence, not instantaneously, but after a period of time, responsive to a preponderance of coherent signals over time, a facet of time domain transmission. Next, it is significant that the template generator produce a template signal burst which is no longer than the effecting signal to be received and bear a consistent like or opposite polarity relationship in time with it. As suggested above, received signals which do not bear this relation to the template signal will be substantially attenuated. As one signal, the template signal is simply a one polarity burst signal. Assuming that it maintains the time relationship described, effective detection can be effected.

For purposes of illustration, we are concerned with looking at a single time slot for anticipated signal returns following signal bursts from transmitting and receiving antennas **200**. Accordingly, template generator **332** is driven as a function of the timing of the transmitter. To accomplish this, coarse delay counter **335** and fine delay programmable delay line **336** are employed. Down counter **335** counts down the number of pulse outputs from oscillator **316** which occur subsequent to a control input of lead **338**, the output of programmable delay unit **313**. A discrete number of pulses thereafter received from oscillator **316** is programmable in down counter **335** by an output X from load counter **341** on lead **340** of control **310**, a conventional device wherein a binary count is generated in control **310** which is loaded into down counter **335**. As an example, we will assume that it is desired to look at a return which occurs **175** nanoseconds after the transmission of a signal from antenna **200**. To accomplish this, we load into down counter **335** the number "7," which means it will count seven of the pulse outputs of oscillator **316**, each being spaced at 50 nanoseconds. So there is achieved a 350-nanosecond delay in down converter **335**, but subtracting 200 nanoseconds as injected by delay unit **324**, we will have really an output of down counter **335** occurring 150 nanoseconds after the transmission of a burst by transmitting antenna **200** or **200**a. In order to obtain the precise timing of 175 nanoseconds, an additional delay is effected by programmable delay line **336**, which is triggered by the output of down counter **335** when its seven count is concluded. It is programmed in a conventional manner by load delay **342** of control **310** of lead Y and, thus in the example described, would have programmed programmable delay line **336** to delay an input pulse provided to it by 25 nanoseconds. In this manner, programmable delay line **336** provides a pulse output to template generator **332**, 175 nanoseconds after it is transmitted by transmitting antenna **200**. Template generator **332** is thus timed to provide, for example, a positive half cycle or square wave pulse to mixer **330** or a discrete sequence or pattern of positive and negative excursions.

The output of mixer **330** is fed to analog integrator **350**. Assuming that there is a discrete net polarity likeness or unlikeness between the template signal and received signal during the timed presence of the template signal, analog integrator **350**, which effectively integrates over the period of template signal, will provide a discrete voltage output. If the signal received is not biased with a target signal imposed on it, it will generally comprise as much positive content as negative content on a time basis; and thus when multiplied with the template signal, the product will follow this; characteristic, and likewise, at the output of integrator **350**, there will be as many discrete products which are positive as negative. On the other hand, with target signal content, there will be a bias in one direction or the other, that is, there will be more signal outputs of analog integrators **350** that are of one polarity than another. The signal output of analog integrator **350** is amplified in amplifier **352**, and then, synchronously with the multiplication process, discrete signals emanating from analog integrator **350** are discretely sampled and held by sample and hold **354**. These samples are then fed to A/D converter **356** which digitizes each sample, effecting this after a fixed delay of 40 nanoseconds provided by delay unit **358**, which takes into account the processing time required by sample and hold unit **354**. The now discrete, digitally calibrated positive and negative signal values are fed from A/D converter **356** to digital integrator **362**, which then digitally sums them to determine whether or not there is a significant net voltage of one polarity or another, indicating, if such is the case, that a target is present at a selected range. Typically, a number of transmissions would be effected in sequence, for example, 10, 100, or even 1,000 transmissions, wherein the same signal transmit time of reception would be observed, and any signals occurring during like transmissions would then be integrated in digital integrator **362**, and in this way enable recovery of signals from ambient, non-synchronized signals which, because of random polarities, do not effectively integrate.

The output of digital integrator **362** would be displayed on display **364**, synchronized in time by an appropriate signal from delay line **336** (and delay **358**) which would thus enable the time or distance position of a signal return to be displayed in terms of distance from the radar unit.

FIGS. **6** and **7** illustrate side and front views of an antenna **200**. As is to be noted, antenna elements A and B are triangular with closely adjacent bases, and switch **335** connects close to the bases of the elements as shown. As an example, and as described above, it has been found that good quality burst signals can be radiated from impulses having a stepped voltage change occurring in one nanosecond or less wherein the base of each element is approximately 4½ inches, and the height of each element is approximately the same. Alternately, the antenna may be, as in all cases, like that shown in FIG. **6**a where antenna. **200**a is sliced in half to have a base dimension of 2¼ inches. Either of the antennas illustrated in FIGS. **6**, **8**, or **6**a may be employed as antennas in any of the figures.

FIGS. **8**a and **8**b diagrammatically illustrate an antenna assembly wherein a multiple, in this case, **12**, separate antenna element sets, for example, as antenna **200**, are employed, each being spaced forward of a metal reflector **200**R by a distance of approximately 3 inches, for a nine-inch tip-to-tip antenna element dimension. The antennas are supported by insulating standoffs **200**b, and switches **335** (transmitting mode) are shown to be fed by triggering sources **323** which conveniently can be on the back side of reflector **200**R, and thus any stray radiation which might tend to flow back beyond this location to a transmission line is effectively shielded. The multiple antennas may be operated in unison, that is, all of them being triggered (in the case of a transmitter) and combined (in the case of a receiver) with like timing, in which case the antenna would have a view or path normal to the antenna array or surface of reflector as a whole. Alternately, where it is desired to effect beam steering, the timing by combination, or triggering devices (receiving or transmitting), would be varied. Thus, for example, with respect to reception, while the outputs of all of the antennas in a column might be combined at a like time point, outputs from other columns might be delayed before a final combination of all signals. Delays can simply be determined by lead lengths, and, in general, multiple effects are achievable in almost limitless combinations.

Alternately, antenna elements may be arranged in an end-fire format wherein each element is driven with or without a reflector. They may be arrayed as illustrated in FIGS. **9**a and **9**b wherein four end-fire unit Y_1, Y_2, Y_3, and Y_4 are employed and positioned in front of a common reflector. Alternately, the reflector may be omitted, and further alternately, an absorber may be positioned behind the array.

FIG. **10** diagrammatically illustrates a transmitting switch wherein the basic switching element is an avalanche mode operated transistor **400**, the emitter and collector of which are connected through like resistors **403** to antenna elements A and B of antenna **200**, the resistors being, for example, 25 ohms each (for an antenna as shown in FIG. **6**a, it would be doubled). In the time between the triggering "on" of avalanche transistor **400**, it is charged to a DC voltage, e.g., 150 volts, which is coordinate with the avalanche operating point of transistor **400**. Charging is effected from (+) and (−) supply terminals through like resistors **404** to antenna elements A and B. The primary of pulse transformer **408** is supplied a triggering pulse, as from trigger circuit **323** of FIG. **5**, and its secondary is connected between the base and emitter of transistor **400**. Typically, the transmission line for the triggering pulse would be in the form of a coaxial cable **410**. When triggered "on," transistor **400** shorts antenna elements A and B and produces a signal transmission from antenna **200** (or antenna **200**a).

FIG. **11** illustrates a modified form of applying a charging voltage to antenna elements A and B, in this case, via constant. current source, and wherein the charging voltage is supplied. across capacitor **507** through coaxial cable **412**, which also supplies a triggering voltage to transformer **408**, connected as described above. For example, the (+) voltage is supplied to the inner conductor of coaxial cable **412**, typically from a remote location (not shown). This voltage is then coupled from the inner conductor of the coaxial cable through the secondary of pulse transformer **408** and resistor **414**, e.g., having a value of 1 K ohms, to the collector of a transistor **416** having the capability of standing the bias voltage being applied to switching transistor **400** (e.g., 150 volts). The (+) voltage is also applied through resistor **418**, for example, having a value of 220 K ohms, to the base of transistor **416**. A control circuit to effect constant current control is formed by a Zener diode **420**, across which is capacitor **422**, this Zener diode setting a selected voltage across it, for example, 7½ volts. This voltage is then applied through a variable resistor **424** to the emitter of transistor **416** to set a constant voltage between the base and emitter and thereby a constant current rate of flow through the emitter-collector circuit of transistor **416**, and thus such to the antenna. Typically, it is set to effect a full voltage charge on antenna **200** in approximately 90% of the time between switch discharges by transistor **400**. The thus regulated charging current is fed through resistors **406** to antenna elements A and B. In this case, discharge matching load resistors **402** are directly connected between transistor **400** and antenna elements A and B as shown.

FIG. **12** illustrates the employment of a light responsive element as a switch, such as a light responsive avalanche transistor **423**, alternately, a bulk semiconductor device, or a bulk crystalline material such as diamond, would be employed as a switch, there being switching terminals across, on opposite sides of, the bulk material. The drive circuit would be similar to that shown in FIG. **10** except that instead of an electrical triggering system, a fiber optic **426** would provide a light input to the light responsive material, which would provide a fast change from high to low resistance between terminals to effect switching.

FIG. **13** bears similarity to both FIGS. **11** and **12** in that it employs a constant current power source with light responsive switching element **423**, such as a light responsive transistor, as shown. Since there is no coaxial cable for bringing in triggering signals, other means must be provided for bias voltage. In some applications, this may simply be a battery with a DC-to-DC converter to provide the desired high voltage source at (+) and (−) terminals.

FIGS. **14** and **15** illustrate the employment of multiple switching elements, actually there being shown in each figure two avalanche mode operated transistors **450** and **452** connected collector-emitter in series with resistors **402** and antenna elements A and B. As will be noted, separate transformer secondary windings of trigger transformer **454** are employed to separately trigger the avalanche mode transistors. The primary winding of a transformer would typically be fed via a coaxial cable as particularly illustrated in FIG. **10**. Antenna elements A and B (either **200** or **200**a) are charged between occurrences of discharge from (+) or (−) supply terminals, as shown.

FIG. **15** additionally illustrates the employment of a constant current source as described for the embodiment shown in FIGS. **11** and **13**. Actually, the system of feeding the constant current source through coaxial cable as shown in FIG. **11** can likewise be employed with the circuitry shown in FIG. **14**.

Referring to FIG. **16**, there is illustrated a radar system particularly intended for facility surveillance, and particularly for the detection of moving targets, typically people. Transmitter **500** includes a 16-mHz clock signal which is generated by signal generator **501**. This signal is then fed to +16 divider **502** to provide output signals of 1 mHz. One of these 1-mHz outputs is fed to 8-bit counter **504** which counts up to 256 and repeats. The other 1-mHz output of +16 divider **502** is fed through a programmable analog delay unit **506** wherein each pulse is delayed by an amount proportional to an applied analog control signal. Analog delay unit **506** is controlled by a magnitude of count from counter **504**, which is converted to an analog voltage proportional to this count by D/A converter **509** and applied to a control input of analog delay unit **506**.

By this arrangement, each of the 1-mHz pulses from +16 divider **502** is delayed a discrete amount. The pulse is then fed to fixed delay unit **508** which, for example, delays each pulse by 60 nanoseconds in order to enable sufficient processing time of signal returns by receiver **510**. The output of fixed delay unit **508** is fed to trigger generator **512**, for example, an avalanche mode operated transistor, which provides a fast rise time pulse. Its output is applied to switch **514**, typically an avalanche mode operated transistor as illustrated in FIG. **10** or **11**. Antenna **200** (or **200**a) is directly charged through resistors **503** from a capacitor **507** (FIG. **11**) which generally holds a supply voltage provided at the (+) and (−) terminals.

Considering now receiver **512**, antenna **513**, identical with antenna **200** or **200**a, receives signal returns and supplies them to mixer **514**. Mixer **514** multiplies the received signals from antenna **513** with locally generated ones from template generator **516**. Template generator **516** is triggered via a delay chain circuitry of analog delay unit **506** and adjustable delay unit **518**, which is set to achieve generation of a template signal at a time corresponding to the sum of the delays achieved by fixed delay **508** and elapsed time to and from a target at a selected distance. The output of mixer **514** is fed to short-term analog integrator **520** which discretely integrates for the period of each template signal. Its output is then fed to long-term integrator **522** which, for example, may be an active low pass filter and integrates over on the order of 50 milliseconds, or, in terms of signal transmissions, up to, for example, approximately 50,000 such transmissions. The output of integrator **522** is amplified in amplifier **524** and passed through adjustable high pass filter **526** to alarm **530**. By this arrangement, only AC signals corresponding to moving targets are passed through the filters and with high pass filter **526** establishing the lower velocity limit for a target and low pass filter **522** determining the higher velocity of a target. For example, high pass filter **526** might be set to pass signals from targets at a greater velocity than 0.1 feet per second and integrator-low pass filter **522** adapted to pass signals representing targets moving less than 50 miles per hour. Assuming that the return signals pass both such filters, the visual alarm would be operated.

FIG. **17** illustrates a modification of FIG. **16** for the front-end portion of receiver **510**. As will be noted, there are two outputs of antenna **200**, one to each of separate mixers **650** and **652**, mixer **650** being fed directly an output from template generator **618**, and mixer **652** being fed an output from template generator **618** which is delayed 0.5 nanosecond by 0.5 nanosecond delay unit **654**. The outputs of mixers **650** and **652** are then separately integrated in short-term integrators **656** and **658**, respectively. Thereafter, the output of each of these short-term integrators is fed to separate long-term integrators **660** and **662**, after which their outputs are combined in differential amplifier **664**. The output of differential amplifier **664** is then fed to high pass filter **526** and then to alarm **530**, as discussed above with respect to FIG. **16**. Alternately, a single long-term integrator may replace the two, being placed after differential amplifier **664**.

By this technique, there is achieved real time differentiation between broad boundary objects, such as trees, and sharp boundary objects, such as a person. Thus, assuming that in one instance the composite return provides a discrete signal and later, for example, half a nanosecond later, there was no charge in the scene, then there would be a constant difference in the outputs of mixers **650** and **652**. However, in the event that a change occurred, as by movement of a person, there would be changes in difference between the signals occurring at the two different times, and thus there wold be a difference in the output of differential amplifier **664**. This output would then be fed to high pass filter **526** (FIG. **16**) and would present a discrete change in the signal which would, assuming that it met the requirements of high pass and filter **526** and integrate-low pass filters **660** and **662** (FIG. **17**), be signalled by alarm **530**.

In terms of a system as illustrated in FIG. **16**, it has been able to detect and discriminate very sensitively, sensing when there was a moving object within the bounds of velocities described and within the range of operation, several hundred feet or more. For example, movement of an object within approximately a ±1-foot range of a selected perimeter of measurement is examinable, leaving out sensitivity at other distances which are neither critical nor desirable in operation. In fact, this feature basically separates the option of this system from prior systems in general as it alleviates their basic problem: committing false alarms. Thus, for example, the present system may be positioned within a building and set to detect movement within a circular perimeter within the building through which an intruder must pass. The system would be insensitive to passersby just outside the building. On the other hand, if it is desirable to detect people approaching the building, or, for that matter, approaching objects inside or outside the building, then it is only necessary to set the range setting for the perimeter of interest. In general, walls present no barrier. In fact, in one test, an approximately 4-foot thickness of stacked paper was within the perimeter. In this test, movement of a person just on the other side of this barrier at the perimeter was detected.

While the operation thus described involves a single perimeter, by a simple manual or automatic adjustment, observations at different ranges can be accomplished. Ranges can be in terms of a circular perimeter, or, as by the employment of directional antenna (antenna **200** with a reflector) or yagi-type array, effect observations at a discrete arc.

FIG. **18** illustrates an application of applicant's radar to a directional operation which might cover a circular area, for example, from 20 to 30 feet to several thousand feet in radius. In this illustration, it is assumed that there is positioned at a selected central location a transmit antenna, in this case, oriented vertically as a non-directional, or omnidirectional, antenna **700**. There are then positioned at 120° points around it like received antennas **702**, **704**, and **706**. An antenna, e.g., as previously described, is powered by a trigger switch transmitter **707**. Assuming that a single signal burst is transmitted from transmit antenna **700**, it would be radiated around 360° and into space. At some selected time as discussed above, receivers **708**, **710**, and **711** would be supplied at template signal as described above to thus, in effect, cause the receivers to sample a signal echo being received at that precise instant. This process would be repeated for incrementally increasing or decreasing times, and thus there would be stored in the memory's units **712**, **714**, and **716** signals representative of a range of transit times. Then, by selection of a combination of transit times for each of the receivers, in terms of triangularizations, it is possible to select stored signals form the memory units representative of a particular location in space. For surveillance purposes, the result of signals derived from one scan and a later occurring scan would be digitally subtracted, and thus there an object at some point within the range of the unit has moved to a new location, there will then be a difference in the scan information. This thus would signal that something may have entered the area. This process in general would be controlled by a read-write control **718** which would control the memory's units **712**, **714**, and **716** and would control a comparator **720** which would receive selected values X, Y, and Z from memory units **712**, **714**, and **716** to make the subtraction. Display **722**, such as an oscilloscope, may be employed to display the relative position of an object change with respect to a radar location.

FIG. **19** illustrates an application of applicant's invention to a radar system wherein there is one transmitting antenna, e.g., antenna **200**, located in a discrete plane position with respect to the direction of observation, three receiving antennas spaced in a plane parallel to the first plane, and a fourth receiving antenna positioned in a third plane. Thus, radiation from transmitting antenna **200**, responsive to transmitter or transmitter switch **802**, which is reflected by a target, is received by the four receiving antennas as varying times by virtue of the difference in path length. Because of the unique characteristic of applicant's system in that it can be employed to resolve literally inches, extreme detail can be resolved from the returns. Control **800** directs a transmission by a transmitter **802**, which supplies a signal burst to transmitting antenna **200**. Signal returns are received by antennas **806**, **808**, and **810** and are located, for example, in a plane generally normal to the direction of view and separate from the plane in which transmit antenna **200** is located. A fourth receiving antenna **812** is located in still a third plane which is normal to the direction of view and thus in a plane separate from the plane in which the other receiving antennas are located. By virtue of this, there is provided means for locating, via triangularization, a target in space, and thus there is derived sufficient signal information to enable three-dimensional information displays. The received signals from receivers **811**, **814**, **816**, and **818** are separately supplied to signal processor and comparator **820**, which includes a memory for storing all samples received and in terms of their time of receipt. From this data, one can compute position information by an appropriate comparison as well as target characteristics, such as size and reflectivity, and can be displayed on display **822**.

FIG. **20** illustrates a portion of a radar system generally shown in FIG. **5** except that the pulse output of switch **335** is applied through an impedance matching device, i.e., resistor **900**, to wideband sonic transducer **902**. Sonic transducer **902** is a known structure, it being, for example, constructed of a thin piezoelectric film **904** on opposite sides of which are coated metallic films **906** and **908** as electrodes. The energizing pulse is applied across these plates. Impedance matching is typically required as switch **335** would typically supply a voltage from a relatively low impedance source wherein sonic transducer **902** typically would have a significantly higher impedance. The sonic output of sonic transducer **902**, a wide frequency band, on the order of at least three ocaves, would typically be attached to an impedance transformer for the type of medium into which the sonic signal is to be radiated; for example, transducer **902** would attach to a low impedance material **903**, such as glass, in turn mounted on a support **905** (for example, the hull of a ship).

An echo or reflection from a target of the signal transmitted by sonic transducer **902** would be received by a similarly configured sonic transducer **910**, and its output would then be coupled via plates **912** and **914** to amplifier **328** and thence onto mixer **330** as illustrated in FIG. **5** wherein operation would be as previously described.

FIG. **21** illustrates a broadband light transmitter. With respect to a first version, with switches **929** and **929**a in the indicated positions, a pulse as from switch **335** (FIG. **5**) triggers a conventional laser **922** operating, for example, in a conventional narrow frequency mode at approximately 700 nanometers to provide such an output to a narrow band to wideband light converter assembly consisting of light modulator **924** and a dispersive medium **926**. The output of laser **922** is applied to one end **928** of a fiber optic **923** having a variable refractive index as a function of an applied voltage and, in this case, for example, having a thickness dimension on the order of 2 millimeters and a length dimension of approximately 1 meter. The fiber optic is positioned between two elongated metallic or otherwise conductive plates **930** and **932**. A modulating voltage from signal generator **934**, for example, a ramp voltage, is applied across the plates adjacent to the exiting end of fiber optic **923** and terminated by resistor **939** as a load and ground. Plate **932** is grounded at both ends to prevent destructive reflections. Generator **934** typically would be triggered also by switch **335** to create, in this example, a ramp voltage which would effect a traveling wave from right to left along the plates and thus along the enclosed fiber optic, opposing the traveling light pulse from left to right. As a result, there is effected a light output at end **936** which varies, changing from the initial wavelength of the input light pulse to a higher or lower frequency, and this, in effect, creates a chirp-type pulse. It is then supplied to a dispersive material **926** such as lead glass, with the result that at its output, the resultant light pulse is converted to a quite short duration pulse having a wide broadband spectrum of frequencies, or white or near white light output. Emitted beam **938** then travels outward, and upon striking a target, a reflection is reflected back to optical mixer **940** which is also supplied a laser output pulse from laser **942** (e.g., by a beam splitter), in turn triggered by a selectably variable delay line **942**, being delayed in terms of selected range. As a result, optical mixer **940** multiplies the two input signals, a template signal and a received signal, and provides a multiplied output to integrator **950**, and the signals are then processed as generally described with respect to FIG. **5**.

It is believed of perhaps greater significance that light modulator **924**, a light frequency modulator, has many other applications, particularly as an intelligence modulator of a laser beam.

FIG. **22** illustrates a modification of the transmitter shown in FIG. **20**, illustrating the technique of frequency modulation multiplexing of a plurality of intelligence signals. In this case, the same optical assembly **924** is illustrated as in FIG. **20**, leaving out signal generator **934** and switch **335**. Further, the dispersive material **926** would not be needed. Thus, there is provided to plate **930** a plurality of frequency modulated multiplexed signals in place of a radar type signal. Two frequency modulation signals are illustrated, and with respect to one of them, it would take this form. An IF source **941** would generate a first intermediate frequency signal, typically being small with respect to the frequency of the laser beam itself. Its output wold be fed to frequency modulator **942** which would then frequency modulate the applied IF frequency over a desired frequency deviation, typically depending upon the bandwidth of the intelligence signal applied to it, and it would be supplied as a first intelligence signal as shown. Thus, the output of frequency modulator **942** would be provided as one input to plate **930** of the light modulator **924**, being applied across summing resistor **944**. As an illustration of multiplexing, a second IF frequency would be generated by IF source **946** at a different frequency than that generated by IF source **941**, and it would be applied to frequency modulator **948**, which in turn would receive a second intelligence signal. As a result, frequency modulator **948** would provide a selected frequency deviation of the IF frequency applied to it, and its output would also be provided to light modulator **924** across summing resistor **944**. The combined outputs of modulators **942** and **948** would then be transmitted by optical modulator **924**.

Referring now to FIG. **23**, which shows a receiver for the transmitter shown in FIG. **22**, the signal output **938** of optical modulator **924** would be received in the receiver by optical detector **982** which would provide an electrical output to mixer **984** to which is also applied the two IF frequencies generated in FIG. **22**, one by a local oscillator **986** and the other by oscillator **988**. As a result, mixer **984** provides an output, being the first IF frequency modulation and a second frequency modulation, these being applied separately to signal discriminators **990** and **992** to thus provide typical analog outputs of the two modulations effected by the system shown in FIG. **22**. Of course, where digital signals are involved, accordingly, the output of signal discrimination **990** and **992** would provide discrete outputs representative of the modulated levels for digital signals, either being of the multi-level type or binary type.

Of course, in a typical installation, there could be many, many separate signal discriminators, each providing a frequency modulated output of one set of intelligence. Thus in the system just described, there is provided a frequency modulated multiplex system which not only can carry many, many different signals, but also is quite cheap to construct, certainly much cheaper than the present system of high-speed digital communications.

Having thus described my invention, I claim:

1. A wideband transmission system comprising:

generating means for generating a plurality of time spaced signals, said signals varying in time spacing at least as a function of a selected signal source, and each signal of said plurality of signals having a stepped-in-amplitude portion;

transmitting means including a broad frequency band radiator responsive to said generating means for transmitting wideband, time-spaced, burst signals into a selected medium; and

receiving means responsive to wideband burst signals present in said medium, as received signals, for processing, said received signals comprising:

a template circuit providing template pulse signals occurring in like time spacing to that of said signal source,

a coincidence, coherent, detector responsive to said received signals and said template signals for providing as an output a signal pulse when a received signal and template signal are simultaneously present,

integration means responsive to outputs from said coincidence detector for providing an integral output, and

intelligence output means responsive to said integration means for providing an intelligence output when said integration means has an integrated output resulting from having integrated a plurality of signal outputs from said coincidence detector.

2. A system as set forth in claim **1** wherein a said template signal is of a curved amplitude character wherein the output of said coincidence detector has a varying gain across a cycle of detection, and said coincidence detector thereby provide gain for an enhanced signal output.

3. A system as set forth in claim **1** wherein said coincidence detector is a multiplier.

4. A system as set forth in claim **1** wherein:

said integration means comprises a short-term integrator for integrating, separately, a plurality of coincidently detected signals; and

said intelligence output means includes a long-term integrator responsive to said short-term integrator for discretely sensing short-term signals and being insensitive to signal energy appearing between said short-term integrated signals.

5. A system as set forth in claim **1** wherein said system further includes modulation means coupled to said signals varying in time spacing as a function of a selected signal source, for additionally varying said last-named signals as a function of intelligence.

6. A system as set forth in claim **5** wherein said modulation means includes means for effecting a plurality of discrete values in time spacing which represent discrete coded levels of intelligence.

7. A system as set forth in claim **6** wherein said plurality comprises two time spacings, one representative of a "1" and the other representative of a "0."

8. A system as set forth in claim **1**, wherein said template pulse signals each have a lobe with a first phase polarity and said received signals each have a lobe with a second phase polarity, and said coincidence detector provides an output when said received signal lobe and said template pulse signal lobe are coherent as to their phase polarity.

9. A system as set forth in claim **8** wherein said template pulses are of no longer duration than a said half cycle.

10. A system as set forth in claim **8**, wherein

said integration means comprises a first integrator means and a second integrator means,

said first integrator means integrates said output of said coincidence detector for a integration time approximately equivalent to a period of one of said template pulse signals, and

said second integrator means integrates an output of the first integrator means for an integration time greater that the period of one of said template pulse signals,

whereby electrical energy reaching said first integrator means between occurrences of said template pulse signals is ignored, thus the presence of a signal output from said second integrator means indicates intelligence, whereby the signal-to-noise of said system is enhanced.

11. A wide spectrum transmission system comprising:

a pulse position modulator responsive to an intelligence signal and a dither signal, wherein said pulse position modulator produces a plurality of timing signals, wherein said timing signals vary in time as a function of said intelligence signal and said dither signal; and

an output stage, including a broadband radiator, responsive to said timing signals, wherein said output stage outputs wide spectrum signals.

12. The wide spectrum transmission system of claim **11**, further comprising a receiver configured to receive and detect said wide spectrum signals.

13. A wide spectrum transmission system comprising:

a pulse position modulator responsive to a dither signal, wherein said pulse position modulator produces a plurality of timing signals, wherein said timing signals vary in time as a function of said dither signal; and

an output stage, including a broadband radiator, responsive to said timing signals, wherein said output stage outputs wide spectrum signals.

14. The wide spectrum transmission system of claim **13** further comprising a receiver configured to receive and detect said wide spectrum signals.

15. A method for the transmission of wide spectrum signals comprising the steps of:

(a) pulse position modulating responsive to an intelligence signal and a dither signal and outputting a plurality of timing signals, wherein said timing signals vary in time as a function of said intelligence signal and said dither signal;

(b) outputting wide spectrum signals responsive to said timing signals; and

(c) radiating said wide spectrum signals.

16. The method of claim **15** further comprising a step of (d) receiving and detecting said wide spectrum signals.

17. A method for the transmission of wide spectrum signals comprising the steps of:

(a) pulse position modulating responsive to a dither signal and outputting a plurality of timing signals, wherein said timing signals vary in time as a function of said dither signal;

(b) outputting wide spectrum signals responsive to said timing signals; and

(c) radiating said wide spectrum signals.

18. The method of claim **17** further comprising a step of (d) receiving and detecting said wide spectrum signals.

19. A system as set forth in claim 8 wherein said integration means comprises a first integrator, an amplifier, and a second integrator, connected in the named order, said first integrator integrating, separately, discrete outputs of said coincidence detector for the period of a said template pulse signal, said amplifier amplifying the output of said first integrator, and said second integrator being responsive to a plurality of amplified outputs of said amplifier for integrating said plurality of amplified outputs, whereby electrical energy reaching said first integrator between the times of said template pulse signals is ignored, thus the presence of a signal output from said second integrator indicates intelligence, whereby the signal-to-noise of said system is enhanced.

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