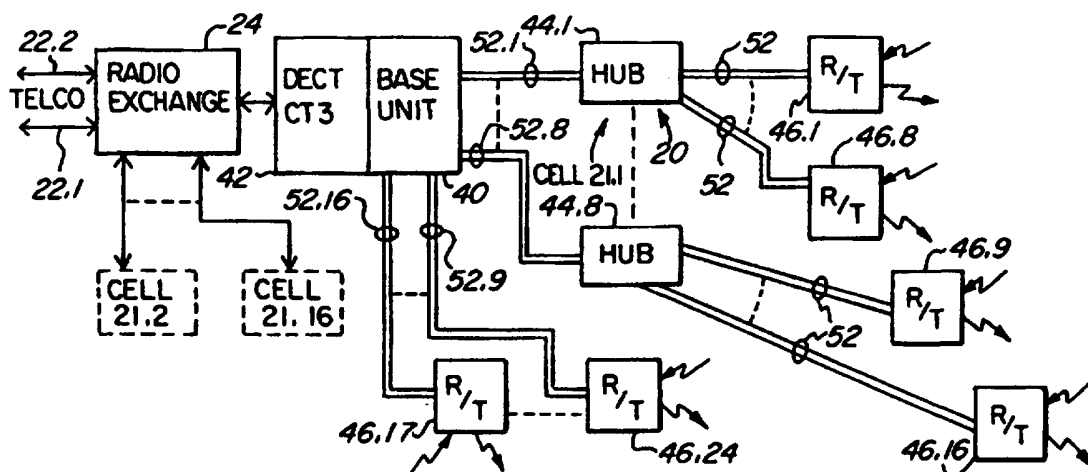




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(54) Title: METHOD AND APPARATUS FOR CORDLESS INFRARED COMMUNICATION



(57) Abstract

A method and apparatus for communicating from a base unit (40) to a plurality of portable infrared devices (48.1-48.8) are described using established communication protocols. The signals are sent along cables from the base unit via stationary infrared receiver/transmitter (RT, 46.1-46.16) modules at infrared carriers in standard transmission and receiving slots to and from the portable devices. The RT modules are distributed throughout a space in the building. Control circuits are used to assure that different infrared carrier signals, originating from nearby RT modules, arrive at any one portable device with a phase difference that does not exceed an acceptable amount. The system also includes circuitry in the base unit to select the best infrared signal detected by several RT modules from any one particular portable device. A hub is described to expand the number of RT modules with which a base unit can communicate.

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Method And Apparatus For Cordless Infrared Communication

Field Of The Invention

5 This invention generally relates to a method and apparatus for communicating from a base unit to a plurality of portable infrared units located randomly throughout a building while using established communication protocols. More specifically this invention relates to a digital communication method and system for enabling a central control connected to telephone lines to communicate with a plurality of portable infrared devices, such as handsets
10 and the like, located within an enclosed site.

Background Of The Invention

Several systems for digital communication with portable devices have been described. For example in an article entitled Cordless Personal Communications by a Dr W. Tuttlebee and published in the IEEE Communica-
15 tions Magazine of December 1992 at pages 42-53, various systems for digital cordless telephony are discussed. Much of such activity has taken place in Europe where several wireless data standards have emerged in recent years, such as the CT2, CT3 and DECT standards.

The principal function of such standards is to enable digital communica-
20 tion from a central control connected to telephone company lines to transfer calls to and from portable devices that may be at any location within a building. Standard cellular systems cannot adequately serve such function because of the long distance range of cellular RF signals and the need to accommodate a large number of simultaneous communications within a
25 relatively small volume such as a building.

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These wireless standards have been adopted so that both data and speech signals can be sent over RF frequencies between a central radio exchange and a large number of portable devices. These standards employ a time division multiple access/time division duplex/multiple carrier (TDMA/TDD/MC) approach. More simply put, digital signals to or from the radio exchange unit are sent in time slots. The communication thus occurs in frame signals of say twenty milliseconds long, with the time frame divided into say ten uplink or transmit slots followed by the same number of ten down link or receive slots. Each slot being one millisecond long. Each portable unit must respond to a signal addressed to it in one of the uplink slots in a corresponding downlink slot in the same frame signal.

In a radio frequency application of such a cordless digital communication system the number of simultaneous communications is limited by the number of available slots. If there are say ten slots, then for any one particular carrier frequency only ten telephone signals can be carried. In order to increase the capacity of the system additional carrier frequencies are employed typically about eight. Hence, for each cell, formed of a radio exchange unit, a total of eighty active telephone communications can be carried out.

These standard systems are designed to accommodate higher transmission requirements to and from any one portable unit by assigning additional slots, in which case the number of available slots for other portable devices is reduced. Furthermore, the RF communications are difficult to limit to specific areas within a particular building so that care must be taken that carrier frequencies in one cell do not interfere with those in another cell. For example, if such RF system is set up to operate communications on adjacent floors of a multistoried building, then a similar system on other floors must use sufficiently different carrier frequencies to avoid RF interference problems. Since the available RF carrier bandwidths tend to be limited, because of FCC

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or other governmental spectrum allocations, a need exists to enable practically unlimited digital cordless communications without interference problems.

Infrared communication systems are well known, see for example the
5 U.S. patents to Crimmins 4,553,267; 4,757,553; 4,977,619; 5,103,108;
5,319,191 and 5,351,149. In the '619 patent a communication system is
described wherein a base unit is hard wire connected to a plurality of
stationary infrared transmitter and receiver (R/T) units distributed in an
enclosure. An infrared portable unit can communicate with anyone of the R/T
10 units to establish a two way communication link with the base unit.

A need exists to accommodate standards for RF or cordless telephone
communications to infrared communications so that a large number of
telephone connections can be made at the same time within a cell without
interference problems in a reliable manner.

15 **Summary Of The Invention**

With an infrared cordless communication method and system in
accordance with the invention the channel limitations of radio frequency digital
cordless systems can be avoided and a high density of portable infrared
terminals can be accommodated without interference problems while using
20 standard communication protocols for RF cordless systems.

This is achieved in accordance with one form of the invention by
distributing stationary infrared RT (receiver/transmitter) modules throughout
a building area and connecting these to a base unit that in turn is connected
to a radio exchange unit for RF cordless systems. The RT modules are
25 located to cover a desired area so that portable IR units in the building area
can communicate through the RT modules with telephone lines connected to

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the radio exchange unit. The signal paths delays between the base unit and the RT modules are effectively made substantially the same for at least those RT modules that are in each other's vicinity. As a result infrared carrier frequencies incident upon any one portable unit from several nearby RT
5 modules will not be significantly out of phase.

The signal path delays can be equalized by employing similar cable lengths between the base unit and nearby RT modules. In another technique described in accordance with the invention signal path delays are equalized by introducing appropriate delays of signals sent to and from the base unit
10 and the RT modules. Signal path lengths are continually monitored and appropriate delays are automatically introduced for each signal path.

Since one or more RT modules may be sending signals to a base unit from the same portable unit another aspect of the invention is the selection of the best portable signal. For example, when a portable unit responds in a
15 time slot, several RT modules may receive the signal and forward it to the base unit. As a result the base unit, prior to actually receiving the signal from the RT's, makes a selection of the best signal based upon information sent to it by the RT modules. This selection is made for each slot transmission and enables the best signal to be used for the communication even while the
20 portable unit is moving between RT modules in the building area.

With an infrared communication system in accordance with the invention the number of infrared portable units that can be connected by a base unit can be made quite flexible and much higher than the number that is available using conventional RF techniques. This can be done by the use
25 of hubs each of which can be connected to a number of infrared RT modules. For example, if a base unit has sixteen ports, each of which could be connected to RT modules the number of RT modules can be increased by the use of hubs. Each hub having, for example, sixteen module connectable ports

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so that a total of 256 RT modules can communicate with a single base unit. As a result one base unit can serve a high density of portable users.

Each base unit can be considered as a separate cell designed to serve a particular area and yet be able to establish cordless digital telephone communication in a flexible manner. A number of different cells can be arranged, as the circumstances may require, with each cell enabling a separate telephone communication with a number of different infrared portable units. One could thus set up several cells on each floor of a large building so that a sufficient number of different simultaneous telephone communications can be established even though the cells adjoin each other, being only separated by an infrared opaque wall.

It is, therefore, an object of the invention to provide a cordless infrared communication system within a building with which a large and practically unlimited number of standard data and voice type telephone connections can be made.

It is a further object of the invention to provide a flexible cordless infrared communication system with which a high density of infrared portable units can be used.

These and other objects and advantages of a cordless infrared communication system in accordance with the invention can be understood from the following detailed description of several embodiments as shown in the drawings.

Brief Description Of The Drawings

Figure 1 is a schematic block diagram representation of one infrared communication system in accordance with the invention;

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Figure 1a is a partial representational view of a cable used in the IR system of Figure 1;

Figure 2 is a schematic representation of a building to illustrate the advantages of the infrared communication system in accordance with the invention;

Figure 3 is a schematic representation of a conventional cordless RF communication system;

Figure 4 is schematic representation of a typical signal frame used in the communication system shown in Figure 3;

Figure 4a is a timing diagram for illustrating the flow of signals in an IR communication system in accordance with the invention;

Figure 5 is a block diagram of a base unit employed in the infrared communication system shown in Figure 1;

Figure 6 is a partial block diagram view of the infrared communication system shown in Figure 1;

Figure 7 is a partial block diagram view of a portion of the infrared communication system used to select the optimum signal from the infrared RT modules;

Figure 8 is a block diagram for generating timing signals used in the system of Figure 1;

Figure 9A is a timing diagram of certain signals generated in the infrared communication system of Figure 1;

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Figure 9B is a timing diagram of certain signals generated during a receive slot when signals from a portable unit are sent by an RT module back to the base unit;

5 Figure 9C is a timing diagram on an expanded time scale of the leading portion of a receive slot;

Figure 10A is a block diagram view of an infrared RT module used in accordance with the invention;

Figure 10B is a more detailed block diagram view of an RT module used in accordance with the invention

10 Figure 11 is a state diagram of an RT module used in the IR communication system of Figure 1;

Figure 12 is a block diagram view of an infrared portable unit used with the infrared communication system of this invention;

15 Figure 13 is a system block diagram view of an alternate embodiment for an infrared communication system in accordance with the invention;

Figure 14 is a block diagram view of a hub used in an infrared communication system in accordance with the invention;

Figure 15 is a block diagram, view of a simplified base unit for use with a communication system as shown in Figure 13.

20 Figure 16 is a block diagram view of a simplified RT module for use with the communication system as shown in Figures 13 and 14; and

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Figure 17 is a schematic block diagram view of a network at the base unit shown in Figure 15 and is used to determine the best IR signal received at RT modules from portable devices.

Detailed Description Of The Drawings

5 With reference to Figures 1 through 4 an infrared (IR) communication system 20 in accordance with the invention is shown connected to telephone lines 22 through a radio exchange 24. The IR system 20 is made to operate with the protocols associated with a standard RF cordless communication system known as the CT3 system. However, other systems such as
10 compatible with the DECT protocol can be used.

 The use herein of cables crossed by a slash line and a number next to that line means the use of a number of paths in that cable equal to the number next to the slash. Some cables such as 54 have four twisted pairs indicating the use of four transmission paths though eight conductors may be
15 involved. In other lines sixteen paths are used with as many conductors.

 Also used herein is the practice of identifying items that are alike with the same number but with a decimal point and a number on the right of it to indicate particular ones of the items.

 The CT3 RF cordless standard employs a DECT type digital communication wherein a TDMA/TDD/MC system operates just below 2 GHz. The
20 CT3 system employs a 16 ms frame cycle 26 formed of a transmit segment 28 using 8 transmit slots 30 and a receive segment 32 using 8 receive slots 34. Each slot 30 or 34 is one millisecond in duration and a transmission within a slot includes 480 data bits formed of fields as illustrated at 36. The
25 system operates in such a way that when, for example, a transmission from radio exchange unit 24 arises by virtue of an incoming telephone call on an

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incoming line 22, a digital signal is placed in one of the outgoing or transmit slots 30 and is followed by a response in the same frame in a receive slot 34. Note that different frame lengths can be employed in different protocols as for example the ten slots used in the DECT system as described in the above mentioned IEEE article.

The infrared system 20 for a cell 21.1 is formed of a base unit 40 which communicates with a CT3 or DECT type controller or interface 42 to enable digital communication with system 20. System 20 further may be composed of a number of hubs 44, which in turn are connected to one or more stationary infrared receiver/transmit (RT) modules 46 distributed in a building. The RT modules 46 in turn communicate with portable or cordless infrared devices 48 such as telephones. The RT modules 46 may be directly connected to the base unit 40 such as is shown for modules 46.17- 46.24.

The use of hubs 44 and the distribution of RT modules 46 can be as varied as the circumstance require, it being understood that the distribution and connections of RT modules in Figure 1 is for illustration purposes and is not intended to be required.

The base unit 40 is connected to RT modules and to hubs 44 by way of twisted pair cables 52. Each cable 52, as shown in Figure 1a is formed of four twisted pairs of conductors 54.1-54.4 to respectively conduct distinct signals, namely, the transmit segment Tx, 28 of the frame signal 26 on pair 54.1, the receive segment Rx, 32, on pair 54.2, a signal to noise ratio signal on pair 54.3 and electrical power for the RT modules 46 on pair 54.4. The arrows are indicative of the direction of signal flow on the respective pairs 54. The use of a double headed arrow on signal pair 54.1 indicates that this pair is used to transfer signals in both directions, but at different times as will be further explained.

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With an infrared communication system in accordance with the invention a substantial advantage is achieved over a conventional RF type system as illustrated in Figure 3. There, the Telco lines 22 enter a radio exchange 24 and are passed on by it to RF base cells 60 connected to
5 antennas 62. The digital RF signals are sent to portable devices 64 which can roam over a large area within or outside a building while maintaining contact for communication with the radio exchange 24.

The effect of the large area coverage of any one RF cell is illustrated in Figure 2 wherein a building 66 of many floors 68 is shown. Any one base
10 cell 60, such as cell 60.1 tends to range over a volume of space that encompasses a number of floors as illustrated with the dashed line 70. As a result the number of portable devices that can be distributed or used within the cell is limited by the number of available slots in the DECT or CT3 type communication system. This then employs multiple carriers to increase the
15 available channels, but because of the spectrum allocation limitations still may be inadequate for accommodating the required number of portable devices 64.

In contrast, when an infrared communication system 20 in accordance with the invention is used, each floor can be provided with one or more hubs 44 and as a result many RT modules 46 can be made available to accommo-
20 date as many infrared portable devices 48 as are needed. Signals between a hub 44 and a portable device 48 do not spill over onto unwanted areas, such as separate floors and thus security and interference problems are avoided.

In IR communication system 20 signals are transferred between the
25 radio exchange and the portable units 48 in compliance with the established protocol by inserting special signals and using signal lines for particular purposes as depicted in the view of Figure 4a. A signal pattern as shown in Figure 4 has for illustrative purposes transmissions occurring during slots

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30.1, 30.5 (indicated by check marks) and as a result response signals in receive slots 34.1 and 34.5 also evidenced by the check marks in these slots.

Just prior to the sending of a transmission in a slot 30, system 20 inserts a delay 71 to assure that the transmissions destined for nearby RT modules 46 arrive at the same time. The reasons for this can be explained with reference to Figure 6 in which a base unit 40 is shown connected by cable 52.1 and 52.2 of different lengths to RT modules 46.1 and 46.2 respectively. As a result the IR carrier energy arriving at a portable unit 48.1 may include portions from both nearby RT modules and differ in phase, depending upon the different signal path lengths from the base unit 40. If the signals are about 180 degrees out of phase as shown at 67, the net effect at a portable unit 48 is a cancellation of IR carrier signals, in effect a null, and thus adversely impacts communication with that portable unit.

Hence, it is desired that the signal path lengths from the base unit to RT modules 46 which are near each other be made about the same. This means, in accordance with one embodiment of the invention, inserting a delay for the signal placed on the cable 52.1 and of sufficient duration to reduce the phase difference, $\Delta\phi$, attributable to cable lengths variations to a maximum of about ninety degrees ($1/4$ wavelength) as illustrated at 69.

For simplicity, the inserted delays are selected so that transmissions from a base unit during any one slot arrive at all the RT modules 46 at the same time. The delays are first automatically determined as shown in Figure 4a during those intervals such as 72.2 and 72.6 when slots, such as 30.2 and 30.6, do not require a transmission. Delays are measured by sending a pulse signal 73 from the base unit 40 to each of the RT modules 46 and measuring the time for a return signal 74 to arrive from that module.

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Measuring of delays need not be done every time there is no transmission. Hence, a counter is employed to allow measuring of delays at some increased time interval.

Another feature of IR system 20 arises from the possibility that more
5 than one RT module 46 responds to the return transmission from a portable device 48. IR system 20 selects the best RT module signal just prior to the occurrence of the return transmission. As shown in Figure 7 an RT module 46 includes a photo detector 75 responsive to IR signals from portable devices 48. The output of the detector 75, after amplification, is passed onto an
10 analog to digital converter 76 to produce a digital Rx receive signal for return to the base unit 40.

A signal strength indication is generated at the output of a comparator 77 after it has compared the output from the photo detector 75 with a squelch level signal from a squelch generator 78. The signal strength indication is also
15 converted to digital form with a fast A/D converter 79. This A/D converter generates a three bit signal strength signal with each bit placed on a separate line 54 for return to the base unit 40.

As shown in Figure 4a the fast analog to digital conversion of the signal strength is sent at 79a to the base unit 40 before it receives the Rx receive
20 slot signal 34. A selection of the strongest signal is then made at 81a. This is done at 81 shown in Figure 7, and used at 83 to pass the best Rx signal on to the radio exchange unit 24. This selection of the strongest signal is also used to choose a best RSSI signal. An RSSI signal for each receive slot 34 may be required by the CT3 or DECT protocols and represents the strength
25 of the received portable IR signal at an RT module 46.

With reference to Figure 5 one form of a base unit 40 in accordance with the invention is shown in further detail. Signals to and from a conven-

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tional CT3 radio exchange interface 42 occur on lines 90.1-90.5. These signals are respectively a serial digital transmission signal T_x , on line 90.1; a logic control signal T/R on line 90.2; a frame logic signal on line 90.3; a received signal R_x on line 90.4; and a signal strength indication RSSI signal on
5 line 90.5.

The transmission signal T_x , destined for all RT modules in a cell 21, is applied to an FM modulator 91 wherein a digital voltage controlled oscillator, in response to an input from an oscillator 92 at 55 MHz, produces zeroes represented by a frequency at 3.429 MHz and ones at a frequency of 4.571
10 MHz. Different frequencies can of course be employed. The output 93 from the modulator 91 is applied to an electronically controlled switch 94 and then through a multiplexer 95 to a delay network 96. The delay network 96 delays the transmission signal T_x by an amount that is sufficient to assure that transmissions, from at least those RT modules 46 which are near each other,
15 occur at essentially the same time. For simplicity the delays are selected so that transmissions from RT modules 46 during any one slot occur essentially at the same time.

Hence, the transmission signal T_x , destined for each individual RT module 46, is delayed a particular amount, depending upon the length of the
20 cable connecting that module to the base unit 40. The delays are selected so that they are equivalent to the delay caused by the longest cable length involved.

The delayed T_x signals are then passed through a multiplexer 97 onto the transmitter lines 54.1 of the various cables 52 leading to the hubs 44 and
25 RT modules 46. This process is continued for each of the T_x signals in the respective transmission slots 30 of a frame signal 26.

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The lines 54 are twisted pairs and are driven by amplifiers 98a and terminated with receivers 98b. These amplifiers and receivers enable a tristate condition on the lines 54 so as to preserve power when no transmissions are to occur and permit two way signal flow when this is needed as for the transmission lines 54.1. The tristate condition is regulated by signals
5 generated from a controller 114 as hereafter described.

During the receive cycle each of the RT modules 46 which had passed on a T_x signal to the portable devices 48 returns a receive signal R_x to the base unit 40 in the slot which corresponds to the transmission slot in which
10 the T_x signal being responded to was located. In addition, a signal indicative of the signal strength of the infrared signal received at the RT modules, from the portable devices 48 sending a response, is transmitted to the base unit as an S/N signal.

Since the receive signals arrive at the base unit 40 at different times,
15 because of the delays imparted by connecting cables 52, the receive signals R_x from the respective RT modules and hubs are passed through the delay network 96 to undergo delays of the same duration as the delays imparted to the corresponding transmission signals T_x . The sixteen receive signals R_x on cable lines 54.2 are, therefore, coupled to the input side of the multiplexer 95
20 and then passed through the delay network 96 to essentially arrive simultaneously at the output lines 98 of multiplexer 97.

During the receive segment 32 of a transmission, several receive signals R_x from different RT modules 46 are presented and the base unit 40 includes a network 100 to select that signal representative of the best
25 available R_x signal. The R_x signals are applied to a multiplexer 101 where the best receive R_x signal is selected and placed on line 90.4 leading to the interface 42. The best R_x signal is selected with control signals on lines 98 derived from a digital magnitude comparator 102.

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The latter comparator 102 compares signals on input lines representative of the signal to noise ratios of the infrared inputs to the RT modules as previously described with reference to signals 79a and 81a in Figure 4a. As explained, this comparison is done at a time preferably just prior to the applicable receive slot. The selection of the best receive signal R_x , therefore, occurs during a very brief interval between slots 30 as will be further explained.

The control signals on lines 99 are also applied to a multiplexer 104 whose inputs are connected to the respective signal strength lines 54.3 from the various hubs 44 and RT modules 46. The best signal strength signal is selected for each slot 30 and stored in a register 106 with a clock signal presented on the T_{x1-16} lines 54.1 from the RT modules 46. The clock signal is presented on the output line 103 of a multiplexer 105 whose input lines connected to lines 54.1. The value of the signal in the register 106 is converted by a digital to analog converter 108 to an analog signal and presented on line 90.5 as the RSSI signal associated with the slot 34 to which the receive signal R_x relates.

The identification of the best R_x signal with control lines 99 can be used as an indication of the location of the portable which was the source of the receive signal. The control signals on lines 99 identify the port where the receive signals arrived and are stored in a register 107. The port identification signals are clocked out onto the RSSI line 90.5 with the clock signals on line 103 from multiplexer 105.

Control over the operation of the base unit 40 and the functions of the above described networks is obtained with a sequencer 110. This may be in the form of a micro processor with appropriate programming. However, the speed with which the required signals have to occur makes it desirable to employ discrete circuits. The sequencer 110 produces appropriate control

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signals with which the various functions of the base unit 40 accomplishes its tasks.

Hence, in response to the T/R and frame signals, on lines 90.2 and 90.3 respectively, the sequencer 110 produces timing signals such as a sync
5 signal on line 112.1, a transmit enable signal on line 112.6, a transmit or receive selection signal on lines 112.2 and 112.7 to set up the appropriate mode in the multiplexers 95 and 97 respectively and a calibration enable signal on lines 112.3. In addition the sequencer generates tap register enable signals on lines 112.4 and a best receive selection signal on line 112.5. The
10 sequencer includes a calibration controller 114 and a 12 MHz clock 115 with which the electrical delays produced by the cable lengths may be repetitively measured and then used to set the appropriate delays. Selected ones of these signals also control the tristate conditions of several amplifiers 98a and receivers 98b employed at the base unit 40 to drive the lines 54.

15 Before describing the hubs 44 and RT modules 46 in greater detail, the operation of the infrared system 20 in accordance with the invention can be best understood with reference to Figures 4, 5, 8 and 9A-9C. A frame sync signal as appears on line 90.3 in Figure 5 is a square wave 130.1, see Figure 9A, having equal transmission and receive segments 132 and 134 corresponding to the transmission and receive segments 28 and 32 shown in
20 Figure 4. The transition 136 from a transmit segment 132 to a receive segment 134 is a timing reference used to initiate certain timing signals as shown in Figure 8.

The frame sync signal 130 is, therefore, connected in the sequencer
25 110 to a frame pulse generator 137 which causes a resetting of a fourteen bit counter 140 driven by 12 MHz clock 115. Certain counts achieved inside counter 140 are decoded with a comparator 141 as indicated on lines 142 with the count number placed adjacent the lines 142. When the register is full

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a pulse is applied to drive a slot clock 146 and its output pulses counted in a slot counter 148. This circuitry thus produces timing signals on lines 142 to cause certain events to occur during a slot and to enable the slots 30 and 32 in a frame 26 to be counted. The numbers placed along the lines 142 signify the count in the register 140 that yields an output on that line with reference to the frame transition 136 in the frame sync signal.

The T/R logic signal 160 on line 90.2 in Figure 5 from the radio exchange unit 24 signifies when a transmission occurs during a slot 30. In Figure 9A an illustrative example of a T/R signal 160 is shown wherein a transmission is to occur in the first slot 30.1 and none in the subsequent slots 30.2, 30.3. and 30.4. The occurrence of the various timing signals on output lines 142 and obtained from the register 140 are depicted on the T/R signal line 160 as shown, with the larger counts being abbreviated as illustrated with apostrophes.

As shown in Figure 5 data for transmission is sent on line 90.1 commencing with the count of 144, see Figures 8 and 9A. The transmission begins at a time identified also by numeral 162. Transmission ends at the end of sending a fixed number of 480 bits, as explained with reference to Figure 4, at a time identified at 164 shown in Figure 9A. The end of transmission occurs just prior to the timing signal on line 142.5 bearing the count 11904. The time period following the transmission of the last bit until the next count of 144 is an interval 166 associated with time between sequential transmission slots 30.

During intervals 166 any signals occurring on the data line 90.1 from the radio exchange 24 can be construed as noise and transmissions can and are inserted by the base unit 40 to the hubs 44 and RT modules 46 as well as received from these devices for the operation of the communication system.

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One calibration mode of operation that is preparatory for the functioning of the IR communication system involves an automatic determination of the length of delay needed to assure that adjacent or nearby RT modules 46 are activated for transmissions at substantially the same time. This employs a
5 transmission of a special sync signal 170, see Figure 9, commencing on a line 172, see Figure 5. The sync signal is passed through the multiplexer 95, and delay measuring and applying network 96 and sent out on an output line 54.1 of a cable 52 to a particular RT module 46. The sync signal is recognized by virtue of its unique duration by the RT module 46 to which it is sent.

10 Upon recognition of the sync signal 170 the RT module returns a response 176, see Figure 9A, to the base unit 40 on the same transmission line 54.1 on which the sync signal is sent. The response 176 is initiated upon detection of the sync signal at the RT module 46. The arrival of the response 176 at the base unit 40 is detected by the delay measuring network 96. The
15 time of the arrival of the response 176 is indicative of the roundtrip travel interval 178 of signals along the cable 52.

The base unit 40 measures the delay imparted by the length of the cable 54 connecting the base unit 40 to the RT module 46 by counting the pulses from oscillator 92, see Figure 5, in a shift register 180 associated with
20 the particular RT module 46. These pulses are counted starting from the time that the sync signal 170 is first sent until the arrival of the response 176. The count accumulated in the register 180 is then representative of twice the length of the cable 52 between the base unit 40 and an RT module 46. Since the count represents the roundtrip distance, the count is divided by two,
25 obtained with a simple shift of the count in the register 180, and then stored in a tap register 182 as equivalent to the required one way trip delay.

The delay count in a tap register 182 is so coupled to an associated shift register 180 that the delay count determines where along the shift

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register 180 a transmission of data to is to begin entering the shift register 180. In this manner a small delay count, representative of a relatively long cable 52, causes data to be entered towards the input end of a shift register 180. A large count on the other hand causes data to be entered towards the
5 output end of a shift register 180.

Hence, data destined for a nearby RT module 46 will be delayed longer and data for a farther RT module 46 will be delayed less by the shift registers 180. In the aggregate, however, taking into account the additional delays imparted by the cables 52, data will arrive at RT modules 46 at the same
10 time.

The process for determining the cable delays is initially carried out for each of the RT modules 46 as the system is started up. Once the system is operational the delay calibration is continued on a repetitive basis depending upon the traffic of data along the cables 52, i.e. the availability of a transmiss-
15 ion slot 30.

The sequencer 110 provides the appropriate timing signals for the system with the calibration controller 114. This regulates, with the T/R line 90.2 and the frame sync line 90.3 from the radio exchange interface 42, and produces signals for enabling transmissions in a slot. It also generates the
20 control signals on lines 112 needed to establish a delay calibration for a slot if this has not been done within a predetermined time or after a certain number of transmissions. This circuitry needed to generate signals can be produced with an array logic or such other suitable programmed microprocessor.

25 During operation of IR communication system 20 signals representative of data or voice information is sent in slots 30 to all of the RT modules 46 either directly from the base unit 40 or through a hub 42. The slot signal

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assigned to a particular portable unit 48 is so loaded into a shift register 180 associated with a particular RT module 46 as to be delayed in time in proportion to the delay previously measured for the associated cable 52 and stored in the associated tap register 182.

5 Since during transmission each slot signal is sent to all of the RT modules 46 in a cell, the sequencer 110 enables the loading of each transmission slot signal into all of the shift registers 180. Signals are shifted out of the registers 180 onto the output lines 54.1 in each cable 52 to arrive substantially at the same time at the RT modules 46.

10 At the end of the transmission cycle 28, see Figure 4, those portable units 48 which had been addressed with a particular slot signal must, if a response is to be produced, do so during a receive slot 34 assigned to be associated with a particular transmission slot 30. If no response occurs then the radio exchange 24 assumes that the portable device is not active.

15 The response is generated at a time dependent on the slot of the transmission signal that caused the response. This is done in a manner as is well known in CT3 or DECT type communication systems. Suffice it to note that the return signals, known and described herein as receive signals, are preferably placed in the receive slot 34, see Figure 4, which corresponds to
20 the position of the transmission slot 30 in the transmission cycle 28.

 In the RF version of a CT3 system there is one receiver for a cell 21. In the IR communication system 20 a single cell contains a large number of possible IR receivers in the form of RT modules 46. Since several RT modules 46 near a portable unit 48 are likely to generate receive signals it is
25 desired to provide the radio exchange unit 24 with the best signal at one of these RT modules. The best signal is to be selected for each receive signal slot 34. The best signal can then also be made available as an RSSI (receiver

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signal strength) signal for transfer to the radio exchange unit 24 as representative of the signal strength at the receiver from the respective portable unit from where the signal originates.

In system 20 a best signal selection is done just prior to the start of each active receive slot 34. As illustrated with reference to Figure 9A the receive segment 134 of a frame signal 130.2 is shown in synchronized relationship with the frame signal 130.1 shown above it for the transmission cycle. Several receive slots 34 are illustrated and in response to the occurrence of a transmission in transmission slot 30.1 a response is to be sent back in slot 34.1.

Recognition of the beginning of a receive slot commences at the base unit 40 and with its recognition of the transition 136.2 in the frame sync signal 130. When the frame sync signal transition 136.2 occurs, see Figure 9A, the control signal generator 114 produces on line 112.1 a sync square wave pulse 184 composed of two microsecond segments. This start-receive slot sync pulse 184 is sent out to the RT modules at the beginning of each receive slot 34 in response to the slot clock signals on line 147, see Figure 8.

Hence, when an RT module 46 detects the receive slot sync signal 184 the RT module 46 samples the received IR signal strength. The sampled value is then immediately transmitted to the base unit 40 before beginning a transmission of a signal in a receive slot 34. This can be understood with reference to the timing diagrams of Figures 9B and 9C.

Detection of the receive slot start sync signal 184 is promptly followed by a fast A/D conversion of the IR signal detected by the photo detector 75, see Figure 7, during an interval 166, see Figure 9A, between slots. The fast A/D conversion occurs after the start at 186 of the portable IR carrier for a

- 22 -

receive slot transmission and allowing at 187 for settling of the output 188 from an amplitude detection circuit, not shown, for the IR signal.

Since the interval 166 during which the fast A/D conversion is done is quite short the three bit output from the A/D converter 79, see Figure 7, is
5 applied in parallel as shown at 188 in Figures 9B and 9C, to the lines 54.1, 54.2 and 54.3 in the connected cable 52. Figure 10B shows the circuitry used to provide the described functions for an RT module 46. An IR transmitter 200 for sending IR signals to portable units 48 and an IR detector 75 for detecting responses from portable units are used.

10 The RT modules 46 include a programmable array logic (PAL) and other appropriate circuits 204 (enclosed by the dashed line in Figure 10B) for processing inputs and outputs. The transmission inputs on line 54.1 from the base unit 40 or a hub 44 are passed on to a modulator 206 and amplifier 208 for activating the IR transmitter 200. The transmitter 200 may use a suitable
15 number of IR generating diodes 200 in a manner as is well known in the art to produce the desired IR signal output to the portable units 48.

An amplifier 210 and a demodulator 212 are used to respond to IR signals from the portable units 48 to produce electrical signals for transmission to the base unit 40, either directly or through a hub 44.

20 P.A.L circuit 204 employs an external clock 214 which drives a counter 216 to produce clock pulses at three microsecond intervals. A carrier detection circuit 218 is used to detect the arrival of a transmission on the transmit line 54.1 and apply a signal to that effect on line 220. The transmit line 54.1 is also directly applied to circuit 204 to enable it to detect appropriate
25 data and logic conditions. A logic network 222 detect the presence of a calibration sync pulse 176, see Figure 9A. The logic circuit 222 generates a

- 23 -

response signal on output line 224 which is returned to the base unit 40 via a multiplexer 226.2 for the previously described cable delay calibration.

5 The fast three bit A/D converter 79, which is controlled by a signal on line 227 from the P.A.L. circuit 204 has outputs 228.1-228.3 respectively applied to multiplexers 226.1-226.3. The operations of the multiplexers 226 are controlled with signals on lines 230.1-3 from circuit 204. The various tristate conditions of amplifiers 232.1-4 driving the lines 54.1-3 in cable 52 are also controlled with signals on lines 234.1-3 from circuit 204.

10 The programming and operation of the P.A.L. circuit 204 can be best understood from the self-explanatory state diagram 250 in Figure 11 in conjunction with the counts as illustrated on top of the figure. At 252 and commencing at start up step 252 the presence of a transmitter carrier on a transmission input line 54.1 from the base unit 40 is awaited at 256. When a carrier is detected an idle mode is entered at 258. If a sync pulse is present as detected at 260 either the occurrence of a calibration mode sync occurred or a receiver mode sync pulse has been detected. In the case of a calibration sync pulse a return sync pulse is generated at 266 and returned to the base unit 40 and the state is returned to step 258.

20 In the event a receiver slot sync pulse was detected then control is shifted to step 270. A fast abbreviated (three bit) A/D conversion is carried out as previously described at 272 followed by a full slower A/D conversion at 274 and sending of signals for a receive slot at 276 as received from a portable device 48.

25 The portable unit 48 shown in Figure 12 also includes an IR transmitter 320 and an IR detector 322 respectively connected to a modulator 324 and demodulator 326. A logic circuit 328 is used to handle the digital traffic and convert the signals to appropriate format for use by the conventional handset

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330. A key board 332 such as used with conventional handsets is available to initiate calls. The logic network 328 provides the functions and operations like those in an RF portable unit and need, therefore, not be further described.

Figure 14 shows a hub 44, which is very similar to a base unit 40. For that reason circuits and lines having similar functions have the same numbers as described with reference to the base unit 40. A variation from the base unit occurs at the input of a hub where the incoming connections are made with a cable 52 having the T_x , 54.1, R_x , 54.2, and S/N, 54.3 lines as previously described. The resulting inputs correspond to the lines described with reference to Figure 5 and have been correspondingly numbered 90.1', 90.4' and 90.5'.

The slot sync 90.2' and frame sync 90.3' are derived from the input line 90.1' with a sync detector 370. This detector recognizes when a calibration sync pulse is being sent and responds with a return signal on line 372.

Figure 13 shows an alternative IR system 20' in accordance with the invention. Instead of an automatic delay generating system, the cables 52 connecting a base unit 40 to nearby RT modules 46 are made all essentially the same in length. This requires that the shorter cables 52 include extra lengths that are wound into coils 350. The cable lengths need not be the same for those RT modules 46 not sufficiently close or separated by a wall and thus not likely to communicate with the same portable device 48 at the same time.

The system 20' may use a simplified base unit 360 as shown in Figure 15 wherein like numbers designate similar circuits or networks as previously described. Base unit 360 employs a logic network 362 which responds to the incoming frame sync signal on line 90.3 to enable an AND gate 364 during

- 25 -

the transmission segment 28 of the operation. The transmission from the base unit 20' is passed directly on to the cables 52 through appropriate drivers 98a.

During the receive segment 32 the R_x signals from the various RT modules 46', see Figure 16, are passed through a best signal selection network 366. The circuits and networks described with reference to base unit 360 can be implemented by a microprocessor instead of with discrete circuitry as shown. The operation of these networks can be best explained with reference to the modified RT module 46' as shown in Figure 16 and wherein like numerals designate like components as previously described.

10 In Figure 16 the demodulated IR signal from a portable device is applied as an R_x signal to an AND gate 380. A signal representative of the received signal strength is applied on line 75a to squelch type networks 78 and 382. If the IR signal level is very high, thus representing a high quality signal, a comparator 384 detects that the signal exceeds an adjustable
15 threshold value as set at 386. The output is a high quality signal on line 388 which is applied to the signal to noise ratio line 54.3 from this RT module 46' to the base unit 360.

As long as the signal level on line 75a is sufficient for passing on to the base unit 360, because the signal exceeds an adequate threshold level as set
20 at 390, the AND gate 380 is enabled and the digital R_x signal is passed on to the R_x data output line 54.2 to the base unit 360.

Returning to the base unit 360 shown in Figure 15 and with reference also to Figure 17 the best signal selection process can be explained keeping the signals from the RT modules 46' in mind. The signal lines 54 identified in
25 Figure 17 represent the same signals as on lines 54 except that they lines are single conductors from the outputs of receivers, not shown, connected to lines 54 from the RT modules 46'. A priority network 394 is used to first assure that

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the R_x signal having a high quality level associated with it is detected with network 400 and thus first passed on to the radio exchange 24 via line 90.4. A second priority network 402 is used to pass an R_x signal onto line 90.2 as long as one of the signals from the RT modules 46' exceeds the adequate signal threshold level set by networks 390 (Figure 16).

A final decision network 404 is used to combine the outputs from the networks 400 and 402 to present on line 90.4 the R_x signal for the radio exchange 24. The best signal selection works by coupling the high quality signals on lines 54.3', the S/N signals, from sixteen RT modules 46' to AND gates 406.1-16. The RT module 46', which could be the one connected to port 1 of the base unit 360, has its S/N line 54.3' coupled to the input of AND gate 406.1 together with a reference signal on line 408 representing an inactive signal level. If there is a high quality signal level present on line 54.3' leading to AND gate 406.1 then its output 412.1 is enabled and in turn enables the AND gate 410.1. This allows data from the RT module 46' on line 54.2' to be passed on to the OR gate 414 in network 404.

The occurrence of an active signal level on line 412.1 is coupled through an OR gate 416.1 and an inverter 418.1 to disable AND gate 406.2. All subsequent portions of circuit 400 are disabled in this manner so that only one high quality data signal is passed on to network 404. In a similar manner if the only high quality signal occurs on any other line 54.3' it is passed on to network 404. The occurrence of a high quality signal level on any line 54.3' results in the disablement of the outputs from the selection network 402 with a signal on line 418 from the last OR gate 416.16 in the chain. This disabling signal is applied to an AND gate 420 in network 404.

In the event there is no high quality signal level, then a data signal having the next acceptable signal level is passed on to network 404 by the selection network 402. This process involves the generation of an adequate

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level signal Q on lines 420.1-16. These Q signals are derived from the combination of a lack of signals on lines 54.3' and the presence of data (R_x) signals on any one of the lines 54.2'. The selection of the best R_x signal by circuit 402 employs a similar technique as described for circuit 400.

5 The first Q signal on line 430 is applied through an inverter to an AND gate 432.1 together with the data signals on line 54.2'. If there is an adequate signal level then this is passed onto network 404 via OR gate 434 and thus through AND gate 420 to the output line 90.4 through OR gate 436. If the adequate signal level occurs from any other RT module 46', the next highest
10 data signal in the chain of priority is passed on.

Having thus described several embodiments in accordance with the invention its advantages can be understood. Variations from the drawings can be made without departing from the scope of the invention as defined by the following claims.

15 What is claimed is:

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1. An infrared digital and analog communication system using a time division multiple access communication protocol for enabling a central control connected to telephone lines to communicate with a plurality of portable infrared devices located within a building through a signal processing unit
5 which produces a repetitive frame signal having time spaced transmission and receiving segments each of which includes a plurality of time spaced respective transmission and receiving slots, comprising:
 - a base unit operatively located between the signal processing unit and the portable devices for enabling communication therebetween;
 - 10 a plurality of spaced apart stationary infrared receiver and transmitter (RT) modules transmitting and receiving infrared signals at a desired carrier frequency;
 - a plurality of cables connecting the base unit to the RT modules, each of said cables carrying transmission signals in said transmission slots from the
15 base unit to the RT modules and carrying received signals in said receiving slots from the RT modules to the base unit, and carrying, to said base unit, signal strength signals representative of the strength of infrared signals from infrared portable devices and incident on the RT modules; and
 - means for controlling the transmission of signals between the base unit
20 and RT modules so that signals from the base unit arrive at substantially the same time at RT modules which are near each other and with phase differences between infrared carrier signals received by a portable device from nearby RT modules not exceeding a preselected amount.
2. The infrared communication system as claimed in claim 1, wherein said controlling means comprises a plurality of said cables connected between the base unit and said nearby RT modules with cables connected to nearby RT modules having lengths selected to be substantially the same.
3. The infrared communication system as claimed in claim 2, wherein said controlling means comprises cables connected to nearby RT modules with

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3. The infrared communication system as claimed in claim 2, wherein said controlling means comprises cables connected to nearby RT modules with lengths which do not differ more than an equivalent electrical delay of about a quarter wavelength of the highest infrared carrier frequency employed between the nearby RT modules and portable devices.

4. The infrared communication system as claimed in claim 1 wherein said controlling means comprises:

means for generating control signals representative of electrical signal travel times along cables connecting the base unit to the RT modules; and

means responsive to said control signals for delaying communications between the base unit and selected RT modules so as to cause infrared carrier transmissions from nearby RT modules and related to the same transmission slot to be transmitted at effectively the same time and cause processing at the base unit of received signals from different RT modules and related to the same receiving slot to be at effectively the same time.

5. The infrared communication system as claimed in claim 1 and further comprising:

means in said base unit and responsive to received signals from different RT modules and related to the same slot for selecting those received signals representative of the best infrared signal strength at the RT modules and coupling said selected received signals for each respective slot to said signal processing unit.

6. The infrared communication system as claimed in claim 5 and further including:

means within said RT modules for detecting the infrared signal strength incident on an RT module for each respective receiving slot prior to reception of received signals related to the receiving slot and producing amplitude signals indicative thereof;

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means for activating said selecting means to cause a said selection of received signals prior to their arrival at the base unit.

7. The infrared communication system as claimed in claim 5 and further including:

means within said RT modules for detecting the infrared signal strength incident on an RT module and producing amplitude signals indicative thereof; and

a priority network responsive to the amplitude signals and received signals for selecting those received signals at the base unit representative of the best infrared signal strength at the RT modules.

8. An infrared digital and analog communication system using a time division multiple access communication protocol for enabling a central control connected to telephone lines to communicate with a plurality of portable infrared devices located within a building through a signal processing unit which produces a repetitive frame signal having time spaced transmission and receiving segments each of which includes a plurality of time spaced respective transmission and receiving slots, comprising:

a base unit operatively coupled to the radio exchange for sending transmission and receiving signals in respective transmission and receiving slots to and from portable infrared devices;

a plurality of spaced apart stationary infrared receiver and transmitter (RT) modules, said RT modules including means for sending signals received from the base unit within transmission slots at infrared carrier frequencies to portable infrared devices and means for sending signals received from portable devices within receiving slots to the base unit;

a plurality of cables connecting the base unit to the RT modules, each of said cables carrying transmission signals in said transmission slots from the base unit to the RT modules and carrying receiving signals in said receiving slots from the RT modules to the base unit; the lengths of cables connecting

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20 at least nearby RT modules being selected so that transmission signals from the base unit arrive at said nearby RT modules at a time selected to limit phase differences between infrared carrier frequency signals received by a portable device from said nearby RT modules below a preselected amount.

9. The infrared communication system as claimed in claim 8 and further including:

5 a hub interposed between the base unit and a plurality of RT modules; said hub having a first port for connection to the base unit and a plurality of second ports for connection to a plurality of RT modules, said hub having an interconnection network between said first port and said second ports to enable communication between said portable devices and said base unit within said transmission and receiving slots;

10 a first cable interconnecting said base unit to the first port of the hub and a plurality of second cables connecting the second ports of the hub to said RT modules; the combined length of the first cable and each of at least selected ones of said second cables being selected so that transmission signals from the base unit and passing through the hub arrive at nearby RT modules at a time selected to limit phase differences between infrared carrier frequency signals received by a portable device from nearby RT modules below a preselected amount.

10. The infrared communication system as claimed in claim 8 and further including:

5 means within the RT modules for generating signal strength signals indicative of the amplitude of infrared carrier signals incident on RT modules from portable devices and coupling the signal strength signals to said base unit along cables connected therebetween;

said base unit including selection means controlled by said signal strength signals for selecting, for respective receiving slots, received signals

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from an RT module representative of the best signal strength and coupling said selected received signals to said signal processing unit.

11. The infrared communication system as claimed in claim 10:
wherein said signal strength generating means in said RT modules comprises:

means for generating amplitude signals representative of the amplitude of the infrared signals incident on the respective RT modules;

means responsive to said amplitude signals for determining the presence of high quality infrared signals incident on the RT module and producing high quality signals indicative thereof;

means for transmitting said high quality signals to said base unit along a said cable;

wherein said system includes means for generating satisfactory quality signals representative of satisfactory infrared signal levels incident on respective RT modules during receiving slots; and

wherein said selection means in said base unit further comprises a priority network responsive to high quality and satisfactory quality signals and said received signals to produce the best received signals from the RT modules during said receiving slots.

12. The infrared communication system as claimed in claim 11 wherein said signal strength generating means in said RT modules further comprises:

means for generating a threshold signal indicative of a satisfactory infrared signal level incident on respective RT modules; and

means responsive to said threshold signal and signals indicative of received infrared signals at the associated RT module for producing said received signals for re-transmission to said base unit.

13. An infrared receiver/transmitter (RT) module for use in a communication system using a time division multiple access communication protocol for

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enabling a central control connected to telephone lines to communicate with a plurality of portable infrared devices located within a building through a signal processing unit which produces a repetitive frame signal having time spaced transmission and receiving segments each of which includes a plurality of time spaced respective transmission and receiving slots, comprising:

an infrared, receiver and transmitter (RT) module, said RT module including means for sending electrical signals received from a base unit within transmission slots at an infrared carrier frequency to portable infrared devices and means for sending electrical signals received in the form of infrared signals from portable devices within receiving slots to the base unit;

said RT module including a signal strength detector to produce amplitude signals indicative of the strength of infrared signals occurring during respective receiving slots and incident at the RT module from infrared portable devices communicating during said respective receiving slots with the base unit.

14. The RT module as claimed in claim 13 wherein said signal strength detector further comprises:

means for producing a reference signal indicative of a high quality infrared signal level incident on the RT module; and means responsive to the reference signal and a signal representative of the infrared signal incident on the RT module for producing said amplitude signals when said infrared signals incident on the RT module exceed the reference signal level.

15. The RT module as claimed in claim 13 wherein said signal strength detector further comprises:

means for producing a reference signal indicative of an acceptable quality infrared signal level incident on the RT module;

means responsive to the reference signal and a signal representative of the infrared signal incident on the RT module for producing an enabling

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signal when said infrared signals incident on the RT module exceed the reference signal level; and

10 means responsive to the enabling signal and an electrical form of the infrared signals incident upon the RT module for activating the electrical sending means.

16. The RT module as claimed in claim 13 wherein said signal strength detector further comprises:

means for producing a control signal representative of the end of a preceding slot; and

5 means activated by the control signal for generating an amplitude signal indicative of the strength of the infrared signal incident on the RT module during a receiving slot which follows the preceding slot.

17. The RT module as claimed in claim 17 wherein said receiving signals sent in different slots during receiving segments are separated by short intervals of time; and

5 wherein said amplitude signal generating means comprises a fast analog to digital converter coupled to produce a predetermined number of data bits representative of the signal strength of the infrared signals incident on the RT module during the short intervals.

18. The RT module as claimed in claim 18 and further including means for sending the individual data bits from the analog to digital converter on separate lines to said base unit.

19. The RT module as claimed in claim 13 wherein said RT module further includes means for sensing a calibration mode and means responsive to the sensed calibration mode for returning signals to a base unit for a measurement of the length of a cable coupling the RT module to the base unit.

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20. A base unit for use in a communication system using a time division multiple access communication protocol for enabling a central control connected to telephone lines to communicate with a plurality of portable infrared devices located within a building through a signal processing unit which produces a repetitive frame signal having time spaced transmission and receiving segments each of which includes a plurality of time spaced respective transmission and receiving slots, with a plurality of distributed infrared transmitter and receiver (RT) modules electrically coupled by cables to the base unit and interposed to enable the base unit to communicate with portable infrared devices, comprising:

a best signal selection network responsive to signals in receiving slots and originating from infrared portable devices for selecting the best infrared signal from infrared portable devices during a common receiving slot.

21. The base unit as claimed in claim 21 wherein the base unit has a plurality of ports for connection by cables to remote receiving and transmission (RT) modules, said ports having receiving lines connected to said best signal selection network, which further comprises a priority network connected to the receiving lines to enable the best signal received at the RT modules to be selected during respective receiving slots for coupling to the signal processing unit.

22. The base unit as claimed in claim 21 wherein said receiving signals sent in different slots during receiving segments are separated by short intervals of time and wherein the base unit has a plurality of ports for connection by said cables to remote receiving and transmission (RT) modules, the best signal selection network further comprising:

means for monitoring respective ports for deriving a control signal during said intervals as indicative of which of said ports represents the best signal during a subsequent slot; and

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means responsive to said control signal for selecting the best received signal during said subsequent slot.

23. The base unit as claimed in claim 23 and further including: means responsive to said control signal for selecting a best signal strength indication from said RT modules.

24. The base unit as claimed in claim 23 and further comprising: means for providing said signal processing unit with an indication of a location for the portable device yielding the best signal received signal.

25. The base unit as claimed in claim 21 wherein said signal processing unit generates frame sync pulses representative of said transmission and receive segments and generates slot sync signals representative of the occurrence of transmissions during transmission slots; and further comprising:

a timing signal generator for producing a plurality of timing signals synchronized to said frame sync signal;

means responsive to a first of said timing signals for determining the beginnings of said intervals;

means synchronized to said first timing signals for generating mode sync signals indicative of desired operating modes of said base unit during transmission slots and coupling said mode sync signals to said RT modules.

26. The base unit as claimed in claim 26 wherein said mode signal generating means generates a calibration mode signal representative of a calibration mode for cables coupling said base unit to said RT modules.

27. The base unit as claimed in claim 27 and further including:
means for storing signals;

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means for generating cable length signals indicative of the difference in lengths of cables coupling said base unit to said RT modules and storing said cable length signals in said storing means.

28. The base unit as claimed in claim 28 and further including means for retaining received signals, arriving at said base unit during any one slot from said RT modules, in association with stored cable signals respectively associated with the RT modules from which the received signals originated; and

means for applying said retained received signals to said best signal selection network substantially at the same time.

29. The base unit as claimed in claim 29 and further including:

means for comparing signal strength signals respectively associated with RT modules and a common receiving slot prior to arrival of received signals from the RT modules at said base unit; and

means responsive to the comparison for generating a selection signal indicative of the best received signal from said RT modules during the associated receiving slot.

30. A method for communicating with a plurality of infrared portable devices via an analog communication system using a time division multiple access communication protocol for enabling a central control connected to telephone lines to communicate through a signal processing unit which produces a repetitive frame signal having time spaced transmission and receiving segments each of which includes a plurality of time spaced respective transmission and receiving slots, comprising the steps of:

generating transmission signals destined for the infrared portable devices via spatially distributed stationary RT modules during transmission slots and delaying selected transmission signals so that the transmission signals arrive at RT modules essentially at the same time;

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sending the transmission signals over an infrared carrier to said infrared portable devices; and

15 passing selected received signals representative of infrared signals from infrared portable devices to a base unit and delaying selected received signals so as to enable them to be processed at said base unit at essentially the same time.

31. The method as claimed in claim 31 wherein said delaying steps comprise the steps of inserting cables between the base unit and said RT modules of essentially the same length.

32. The method as claimed in claim 31 and further including the step of:
 comparing received signals at said base unit and selecting the best received signal for transmission to said signal processing unit.

33. The method as claimed in claim 33 wherein said comparing step comprises the steps of:

5 generating amplitude signals at said RT modules and representative of the signal strength of infrared signals incident on RT modules from infrared portable devices and sending the amplitude signals to the base unit;
 comparing the amplitude signals at the base unit and, in response to said latter comparing step, selecting the best received signal.

34. The method as claimed in claim 34 wherein said amplitude signals generating step and said step of comparing the amplitude signals occurs prior to the step of passing said received signals to said base unit during a receiving slot.

35. The method as claimed in claim 32 wherein said delaying steps comprises the steps of:

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5 calibrating the length of cables coupling the base unit to RT modules
and generating delay signals representative of the difference in the lengths of
said cables; and
 delaying the transmission signals destined to RT modules along cables
in accordance with said delay signals so as to cause said transmission signals
to arrive at said RT modules at essentially the same time.

36. The method as claimed in claim 36 wherein said delaying step further
comprises the steps of:

5 delaying received signals at said base unit in accordance with said
delay signals so as to enable the comparing of said received signals to be
done essentially at the same time.

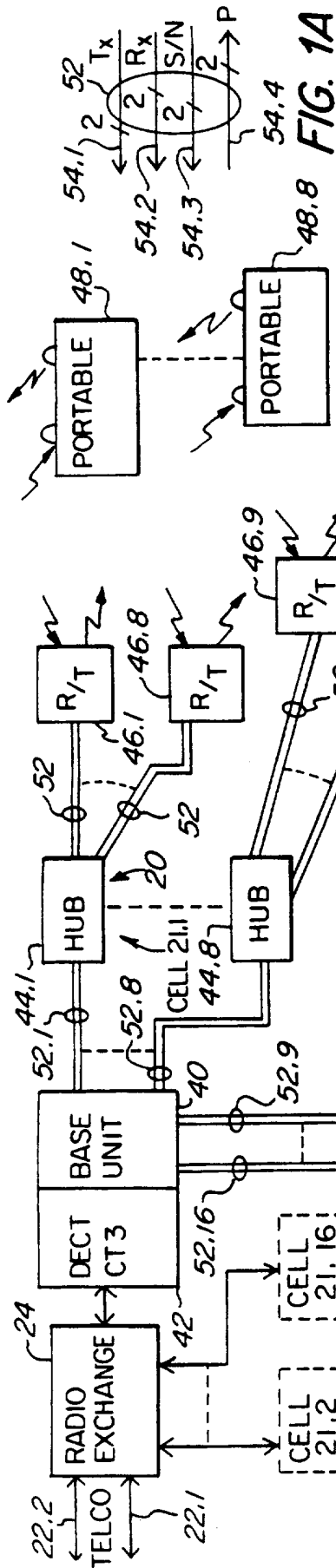


FIG. 1

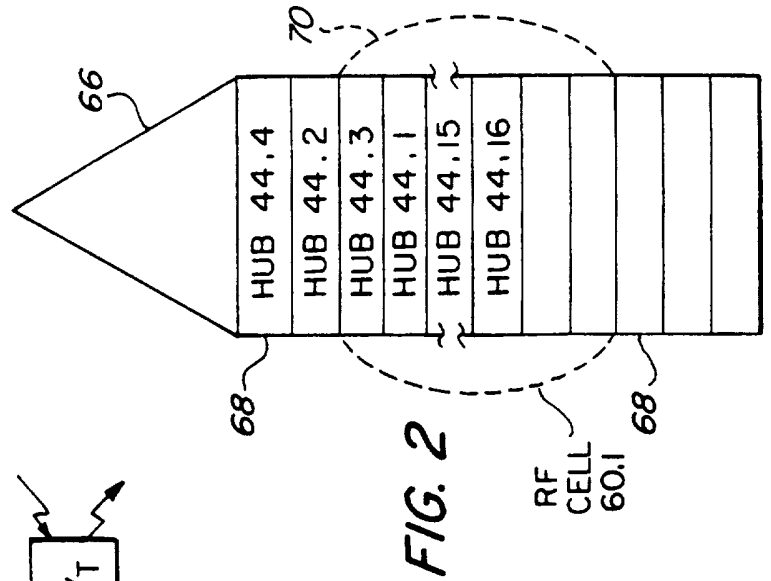


FIG. 2

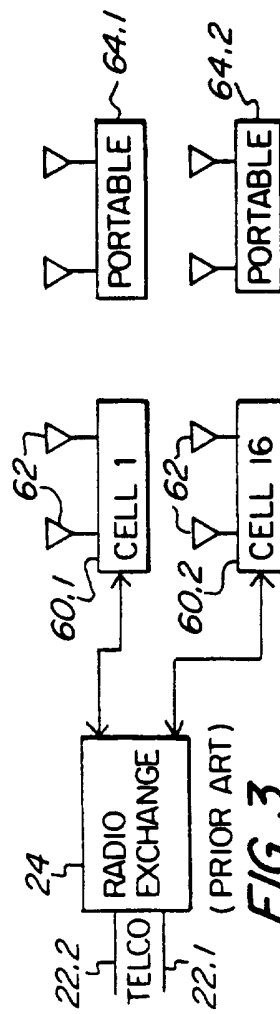


FIG. 3

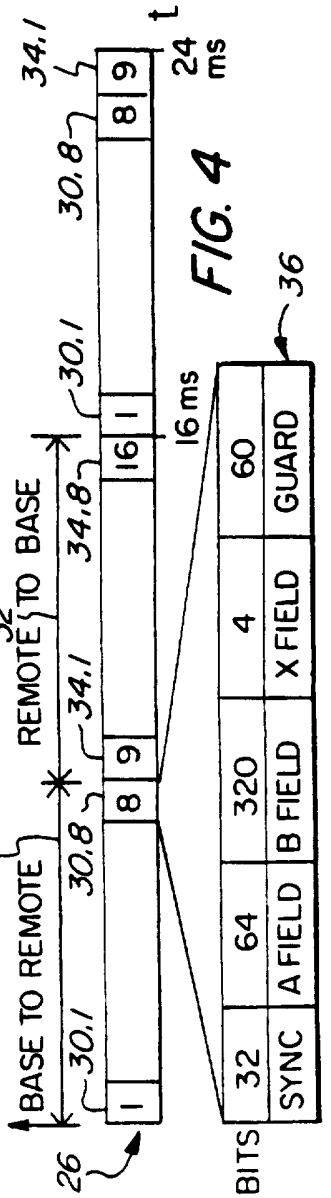


FIG. 4

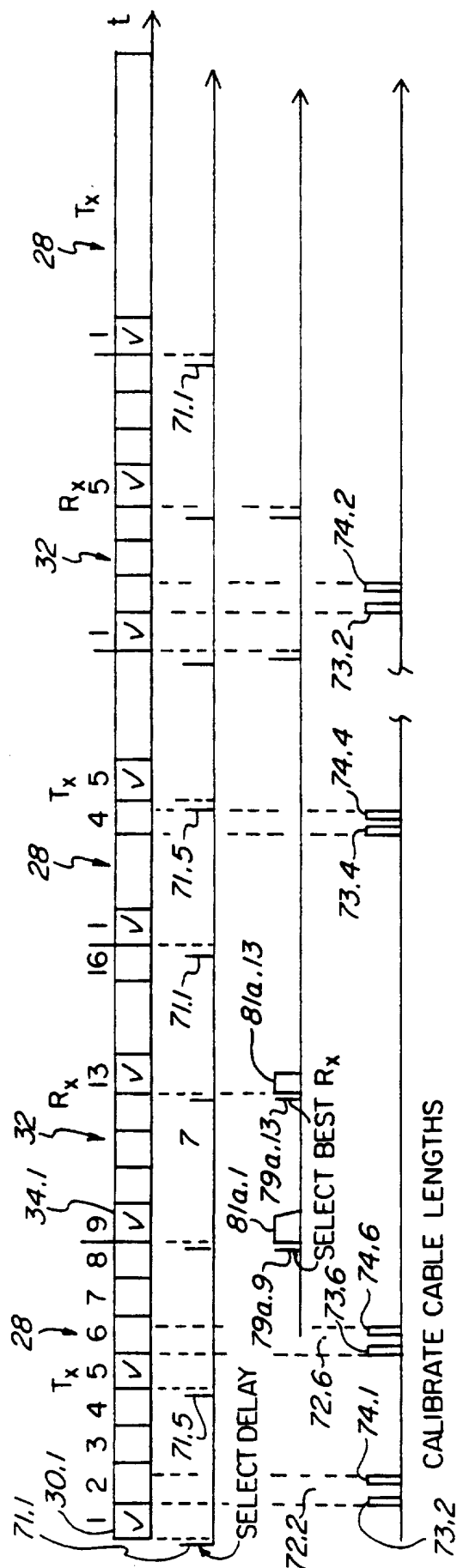


FIG. 4A

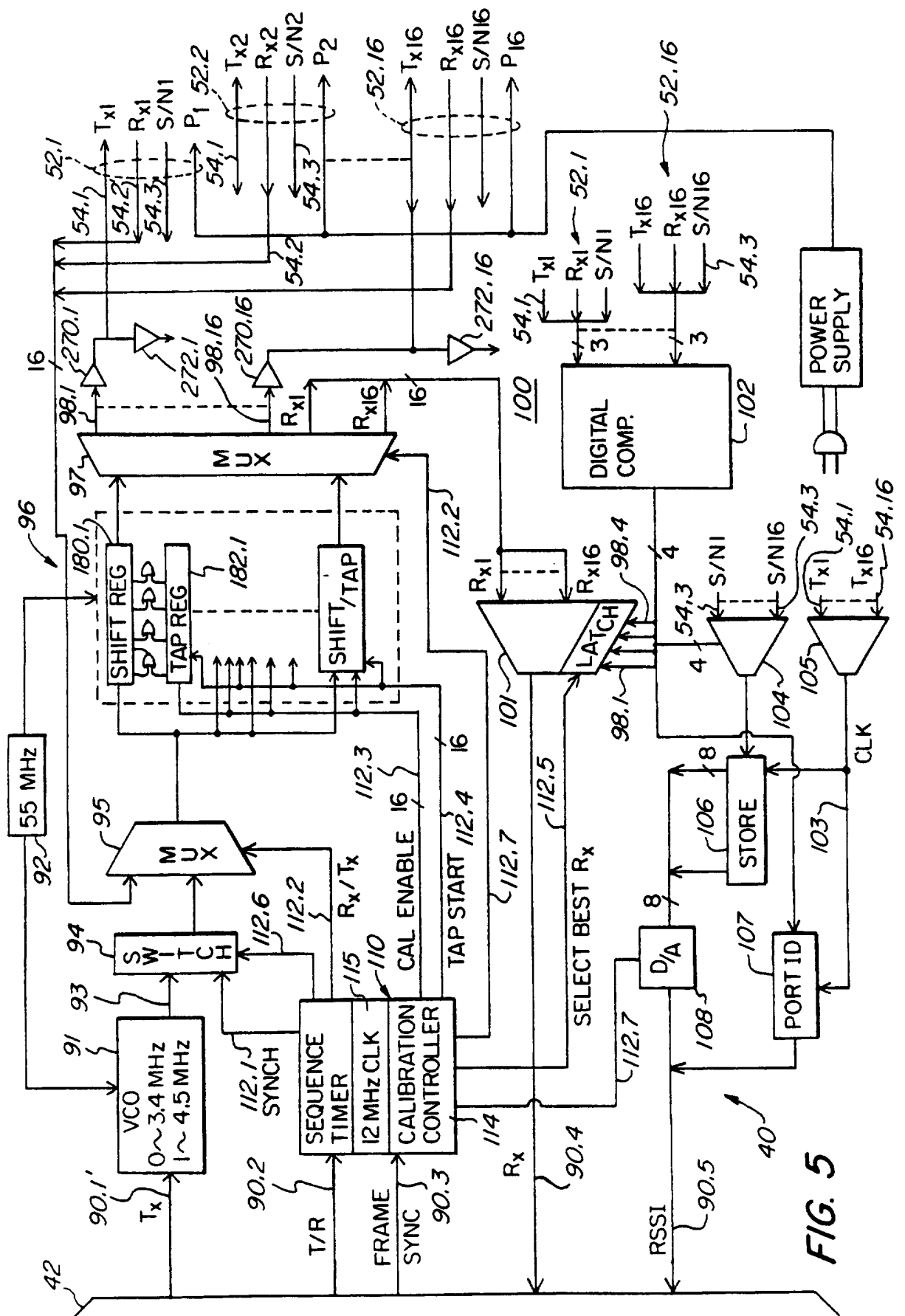


FIG. 5

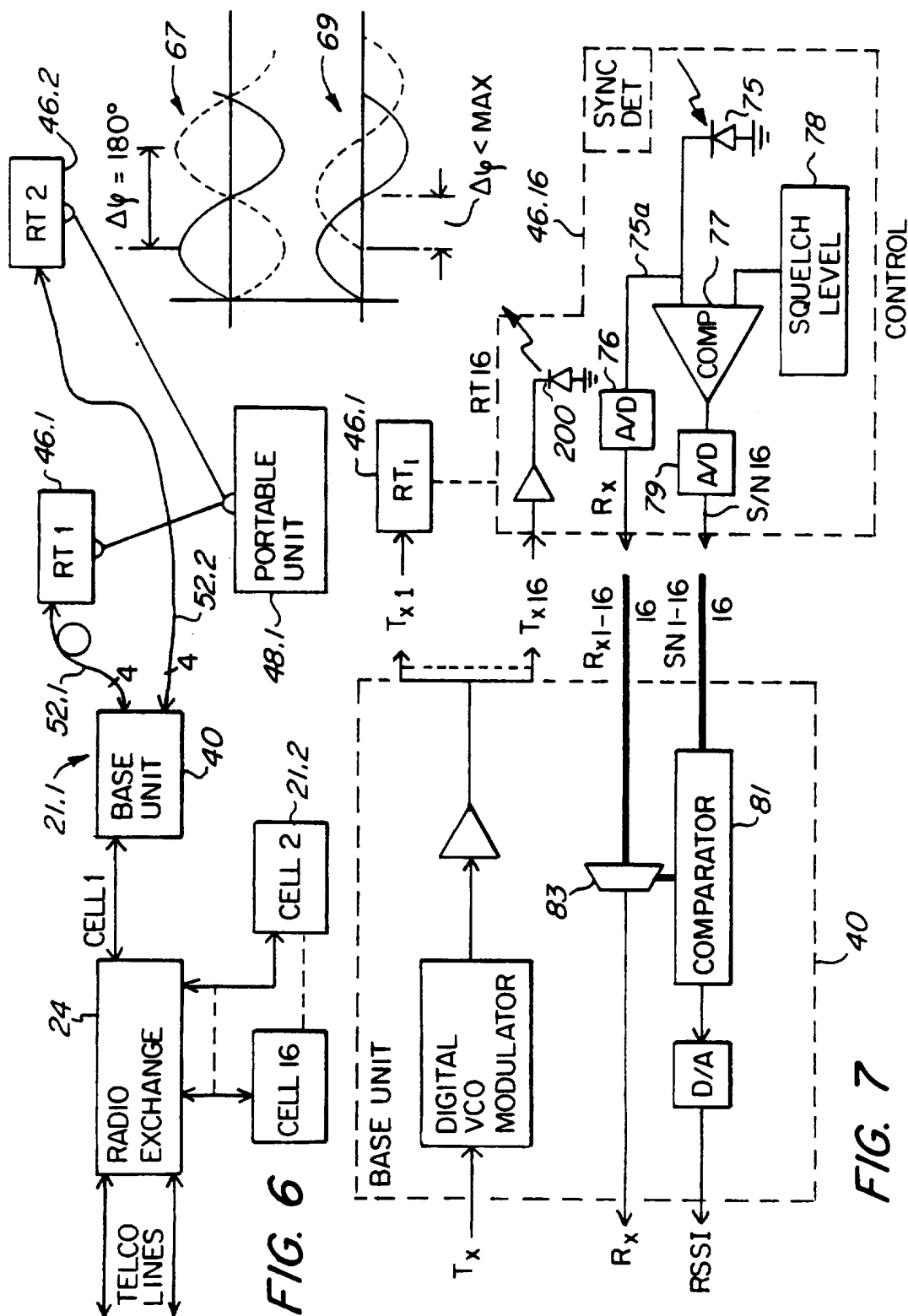


FIG. 7

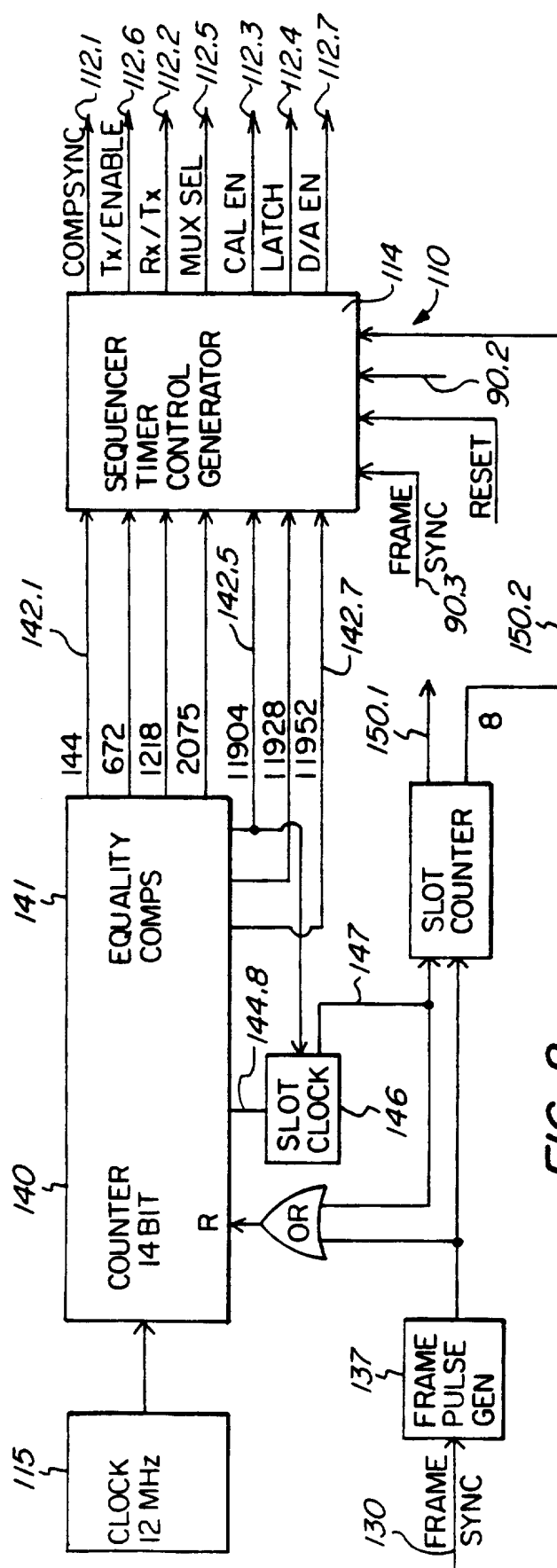


FIG. 8

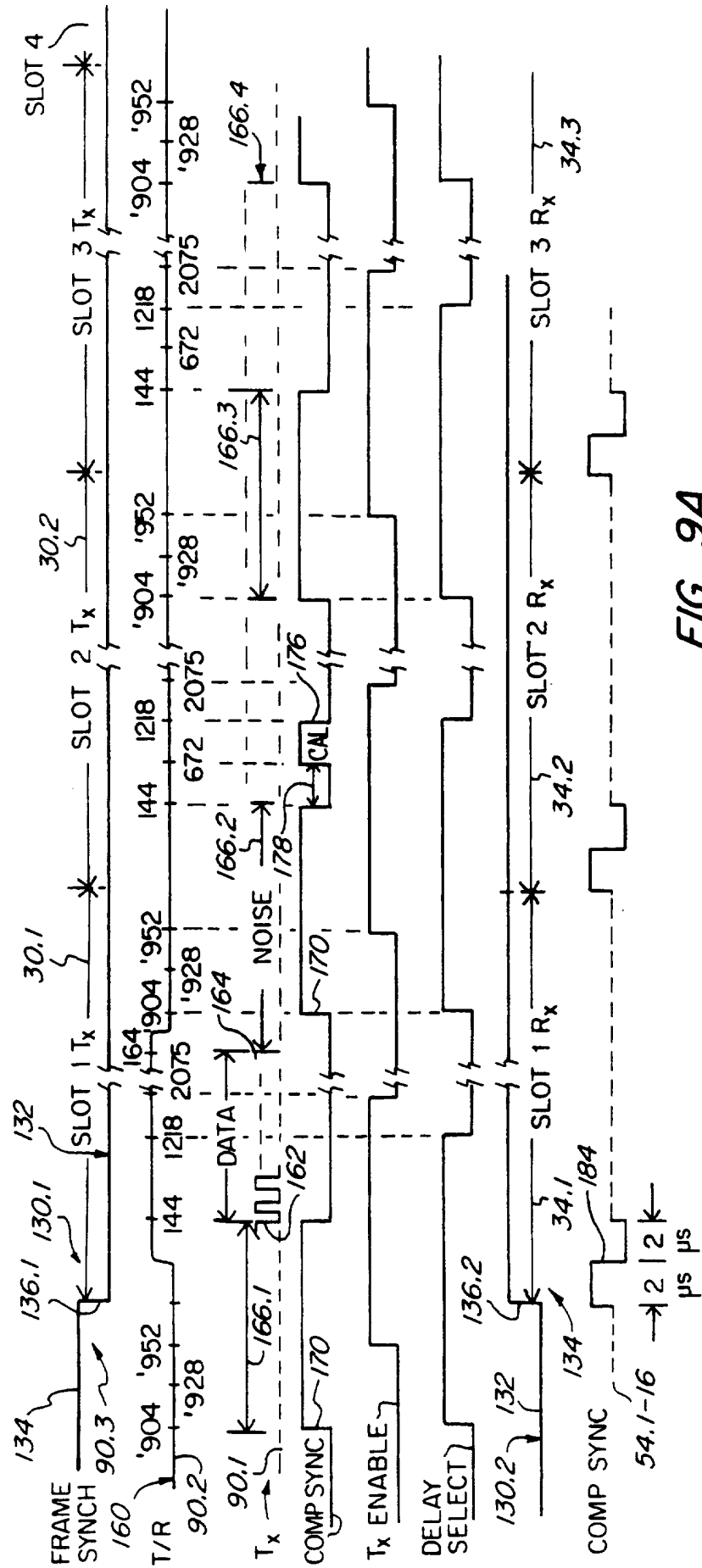
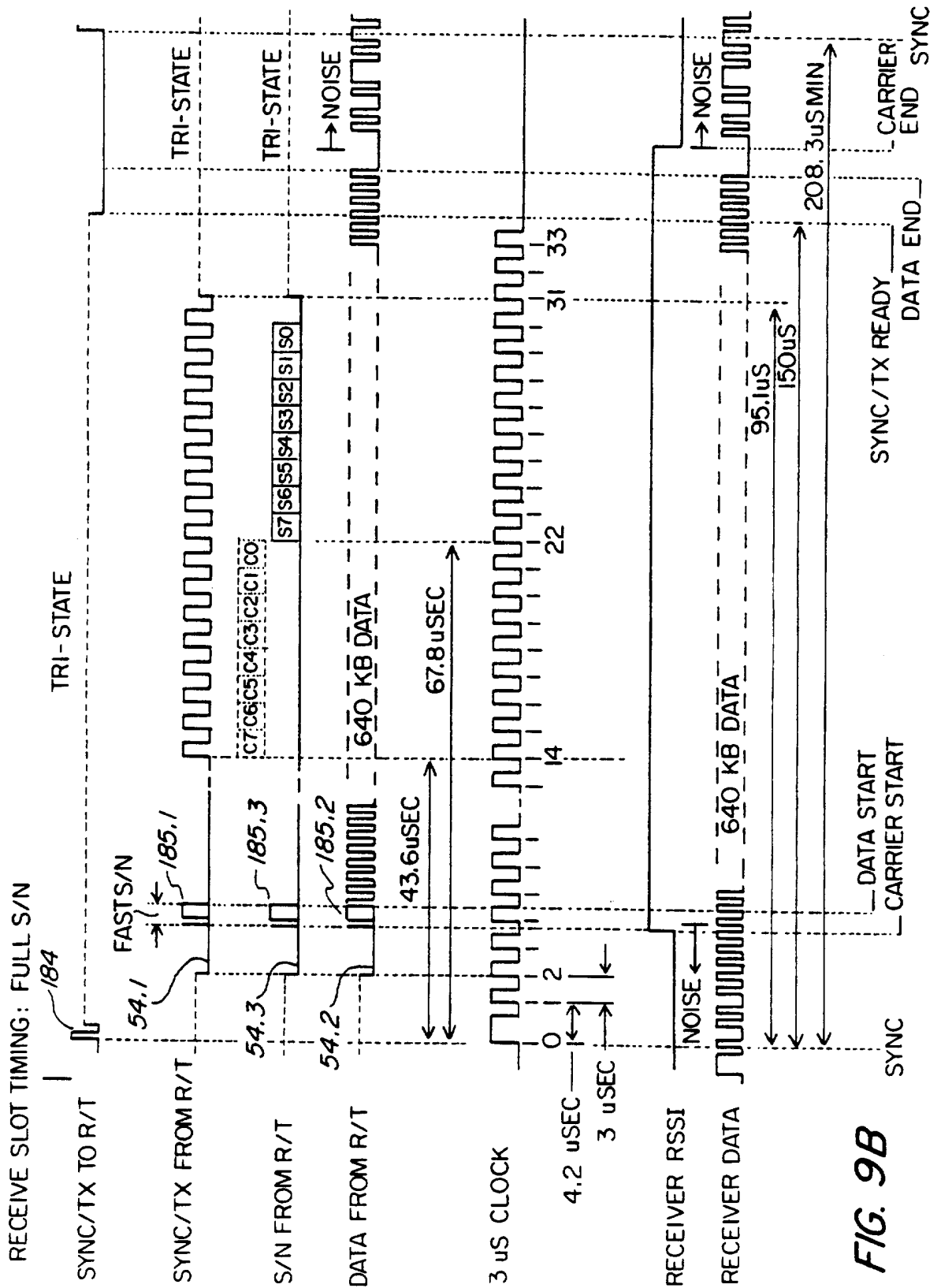
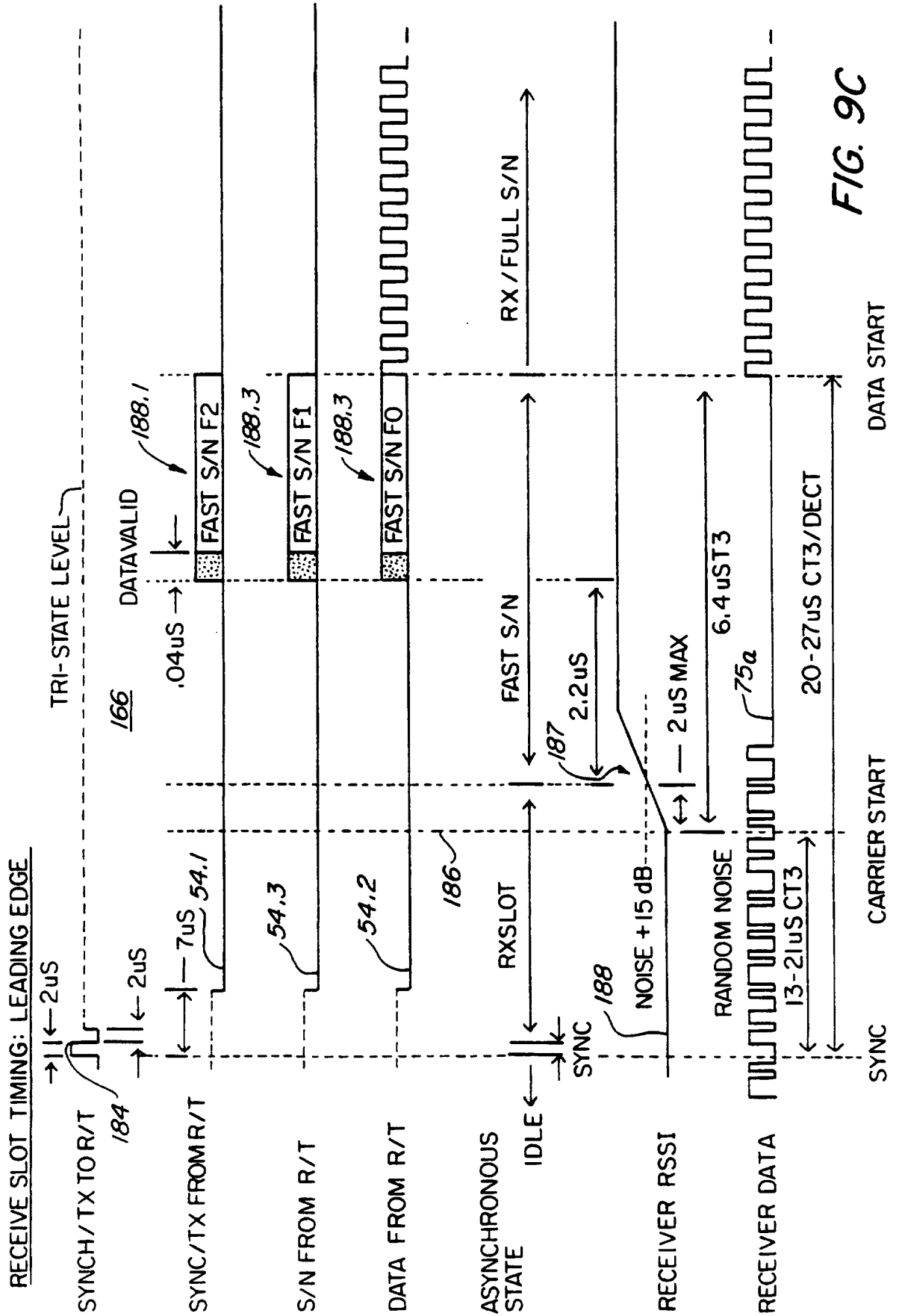


FIG. 9A





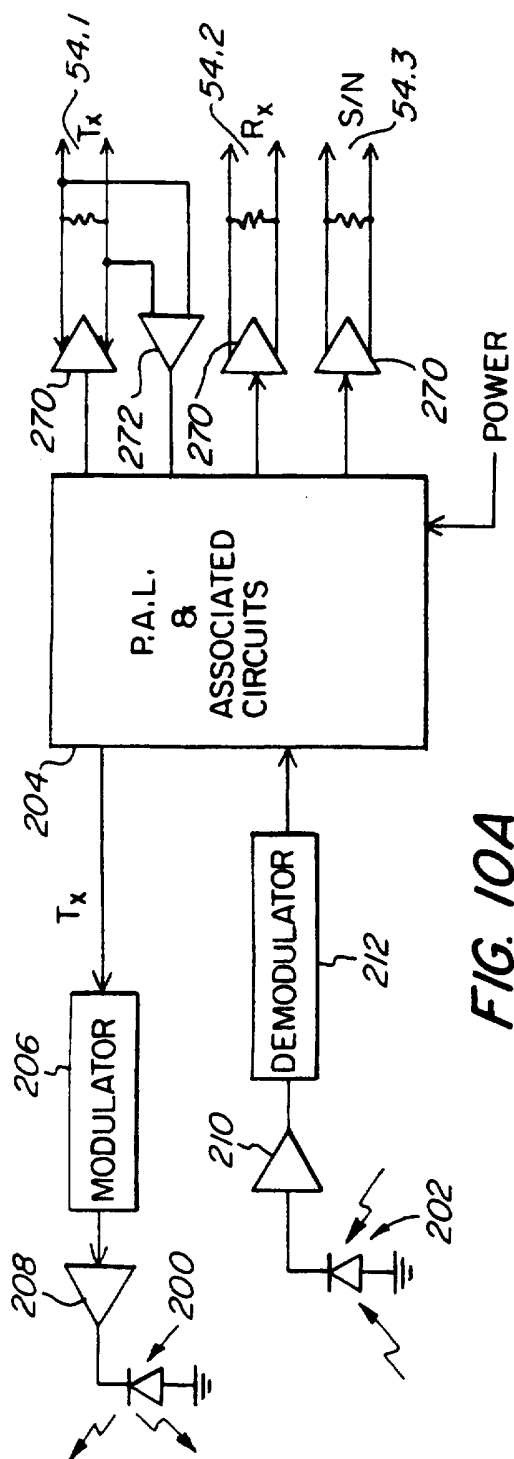


FIG. 10A

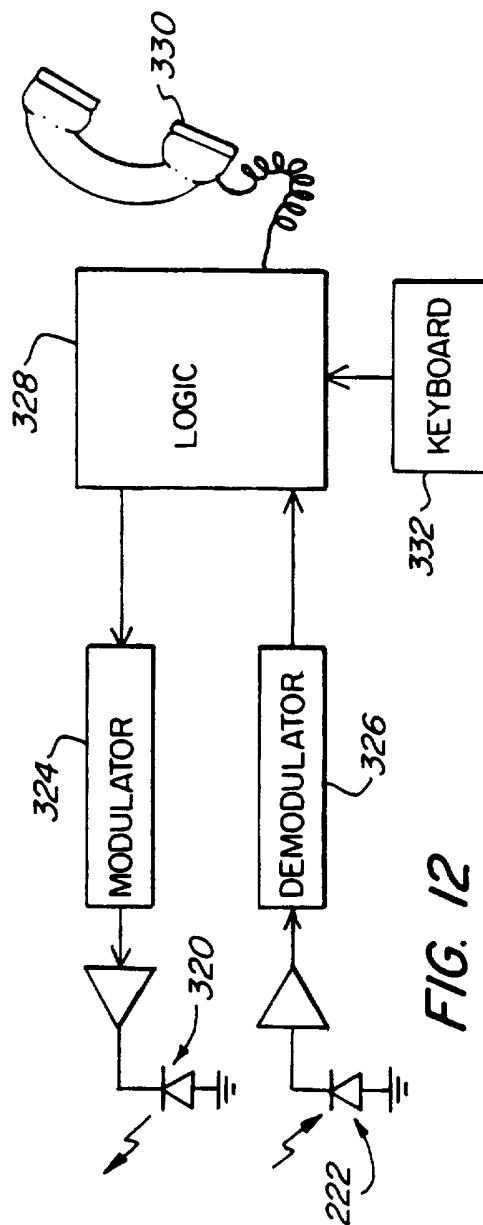


FIG. 12

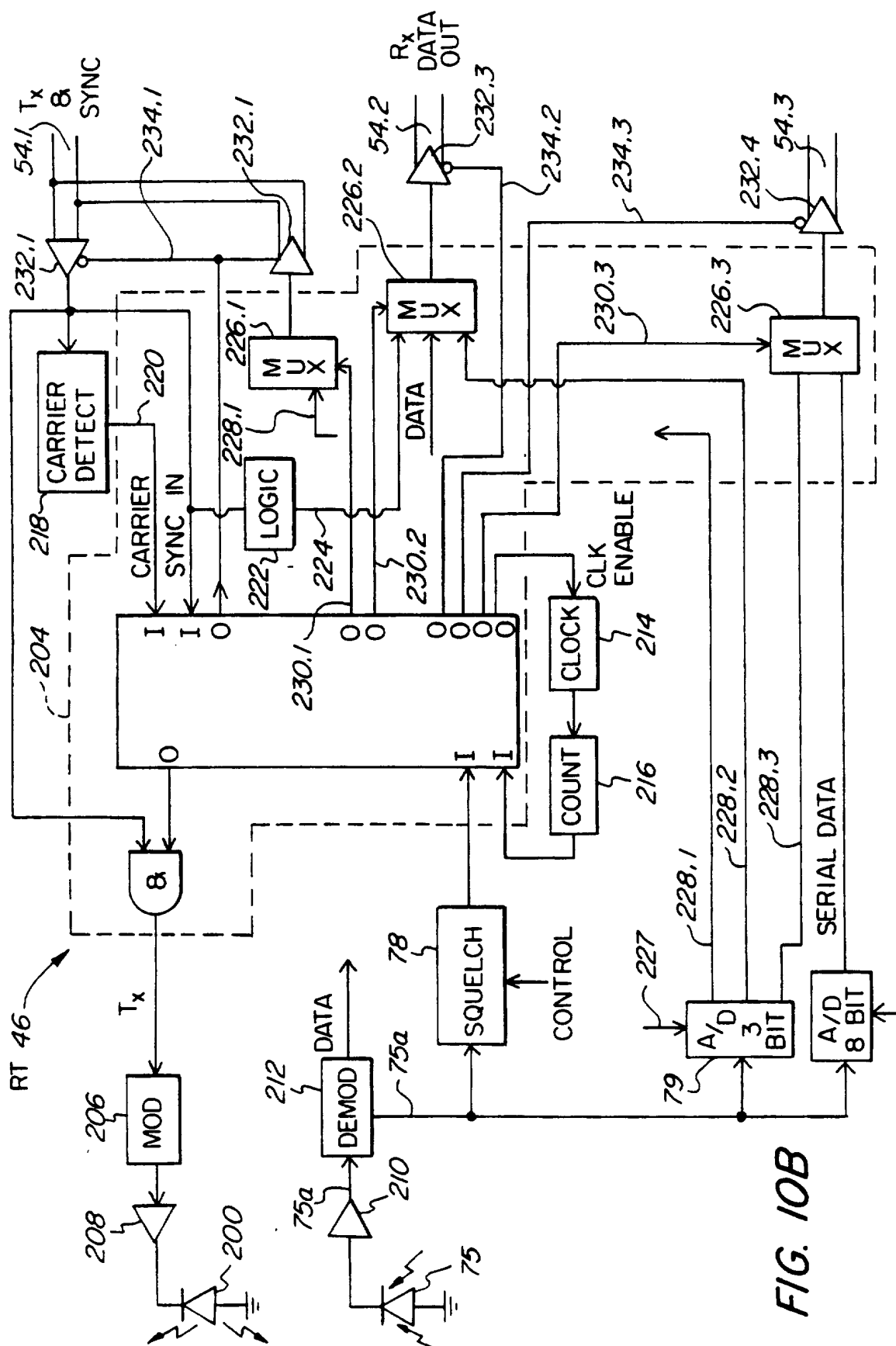
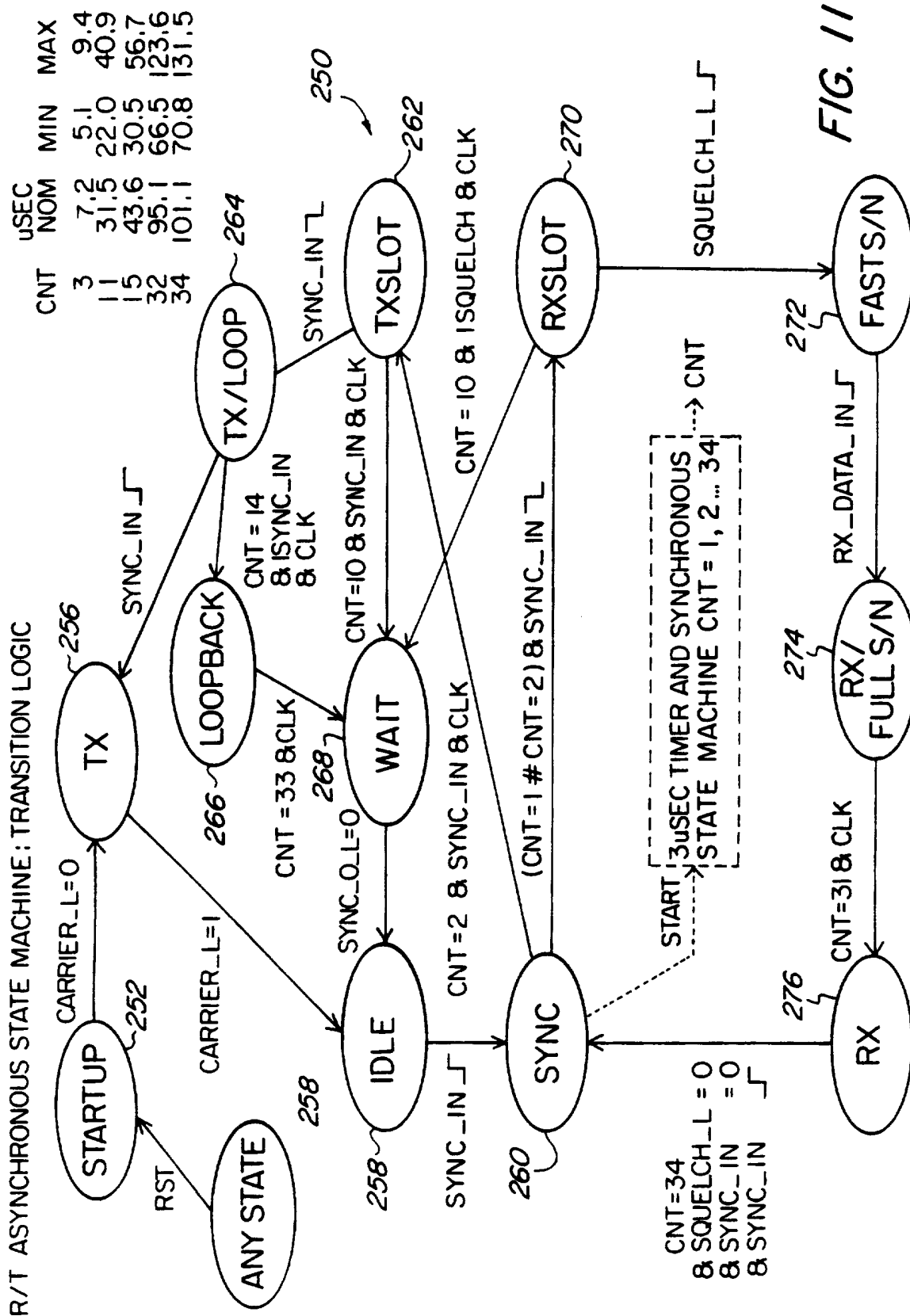


FIG. 10B



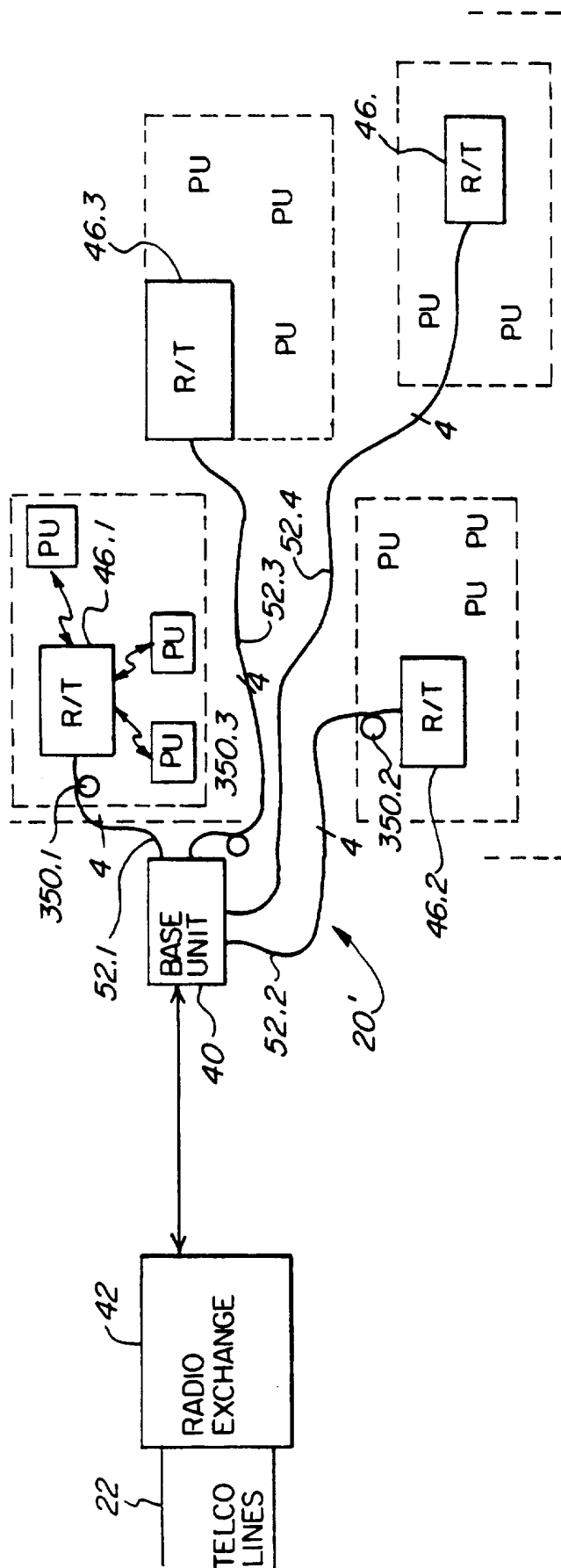


FIG. 13

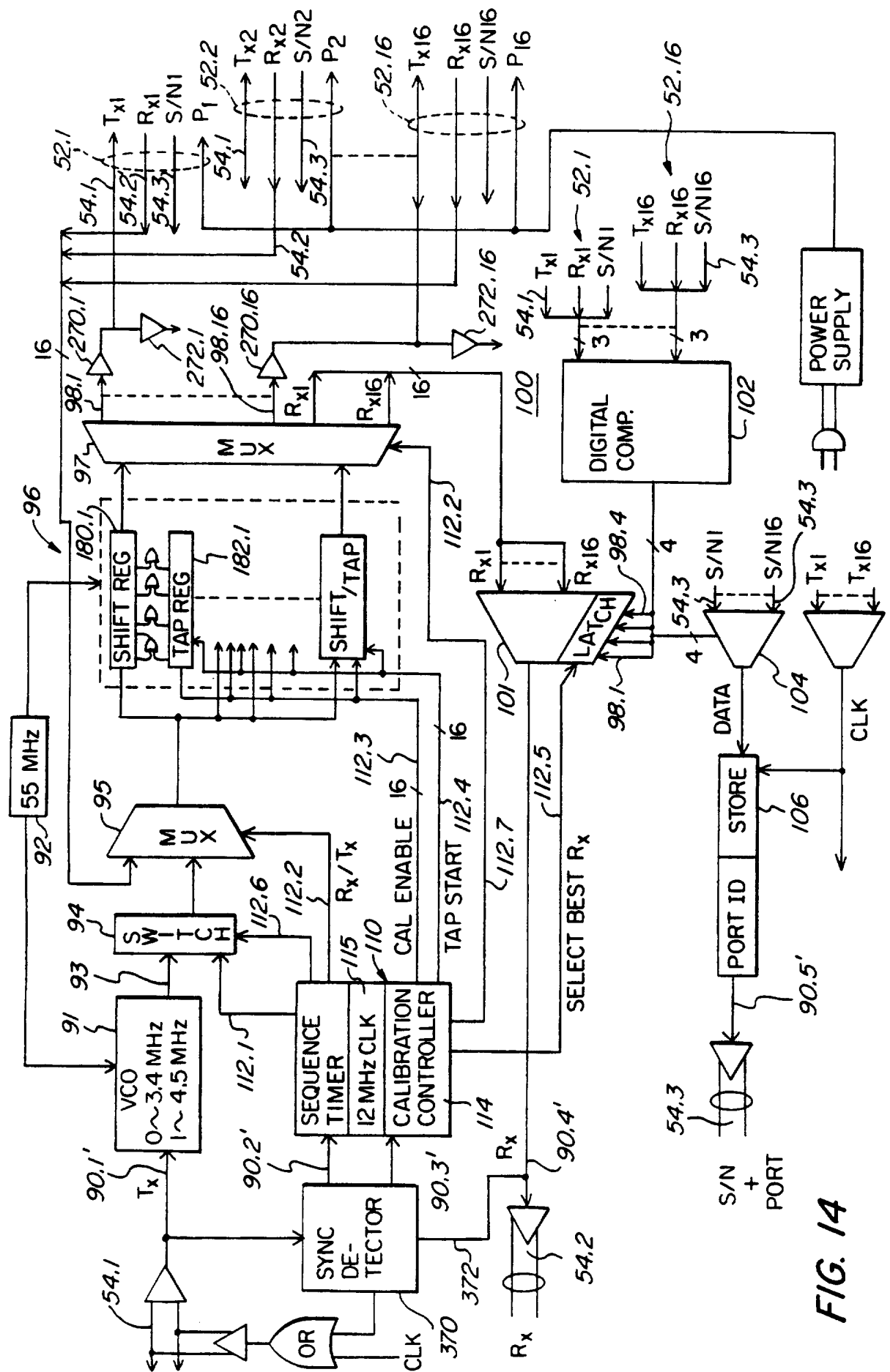


FIG. 14

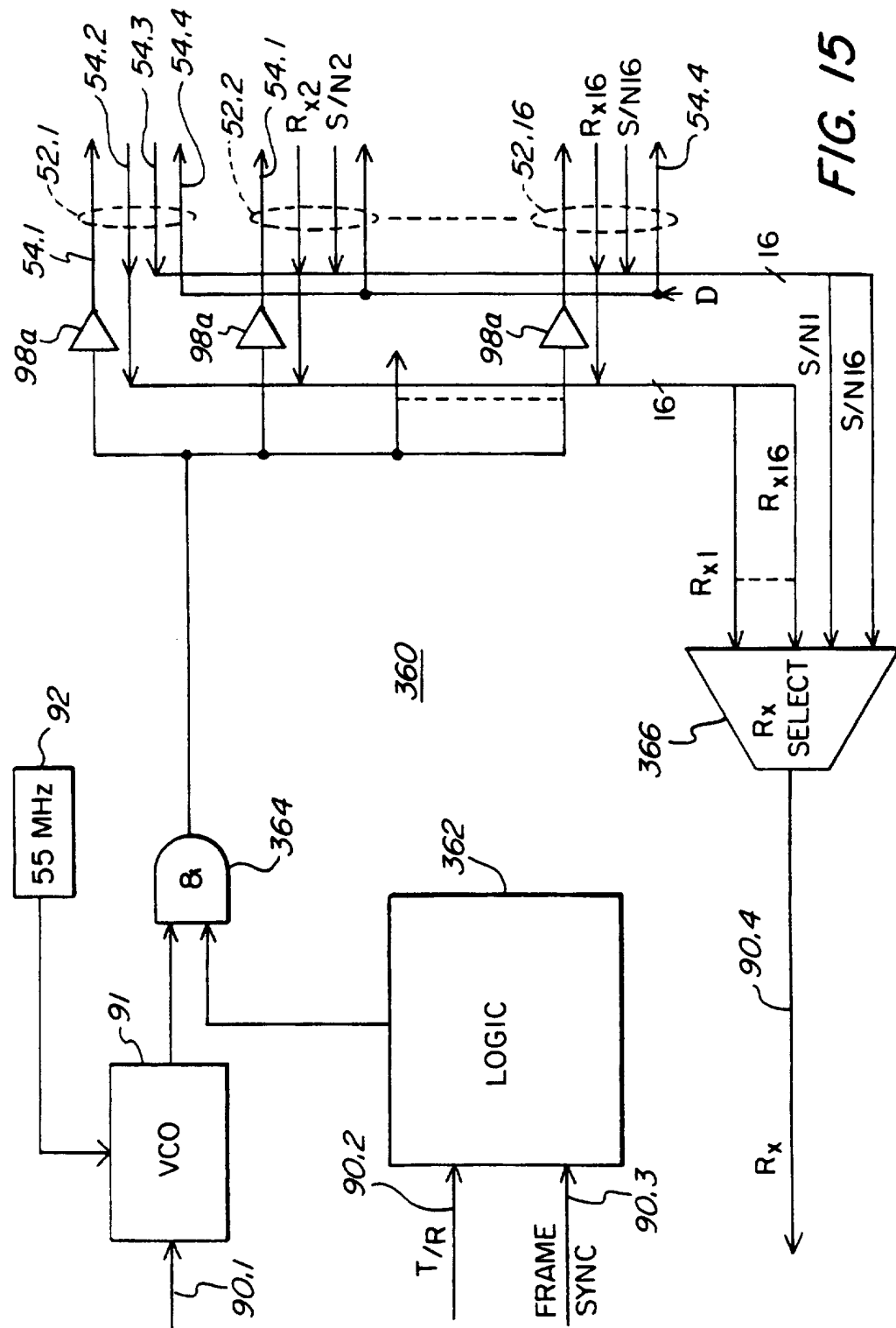


FIG. 15

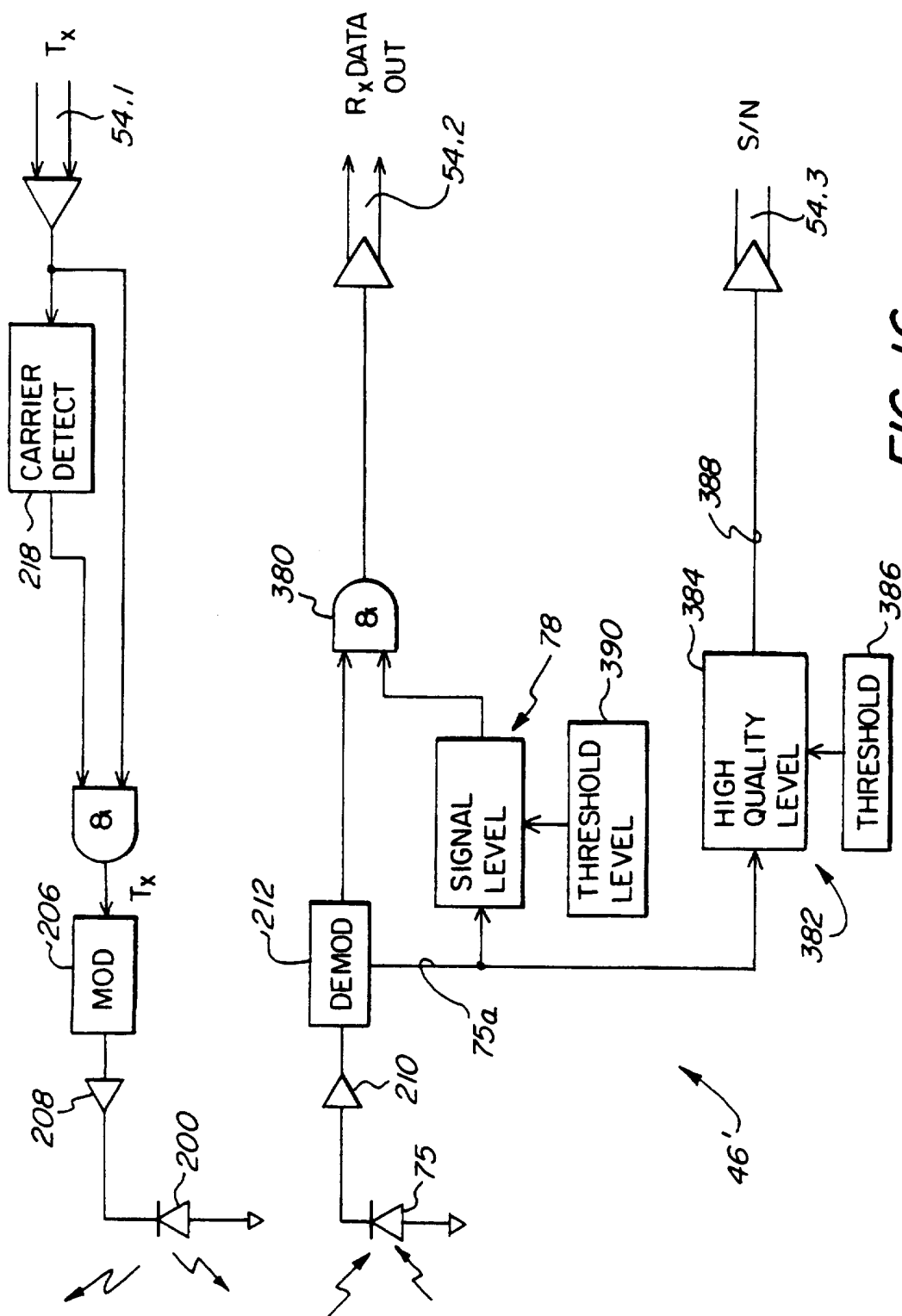


FIG. 16

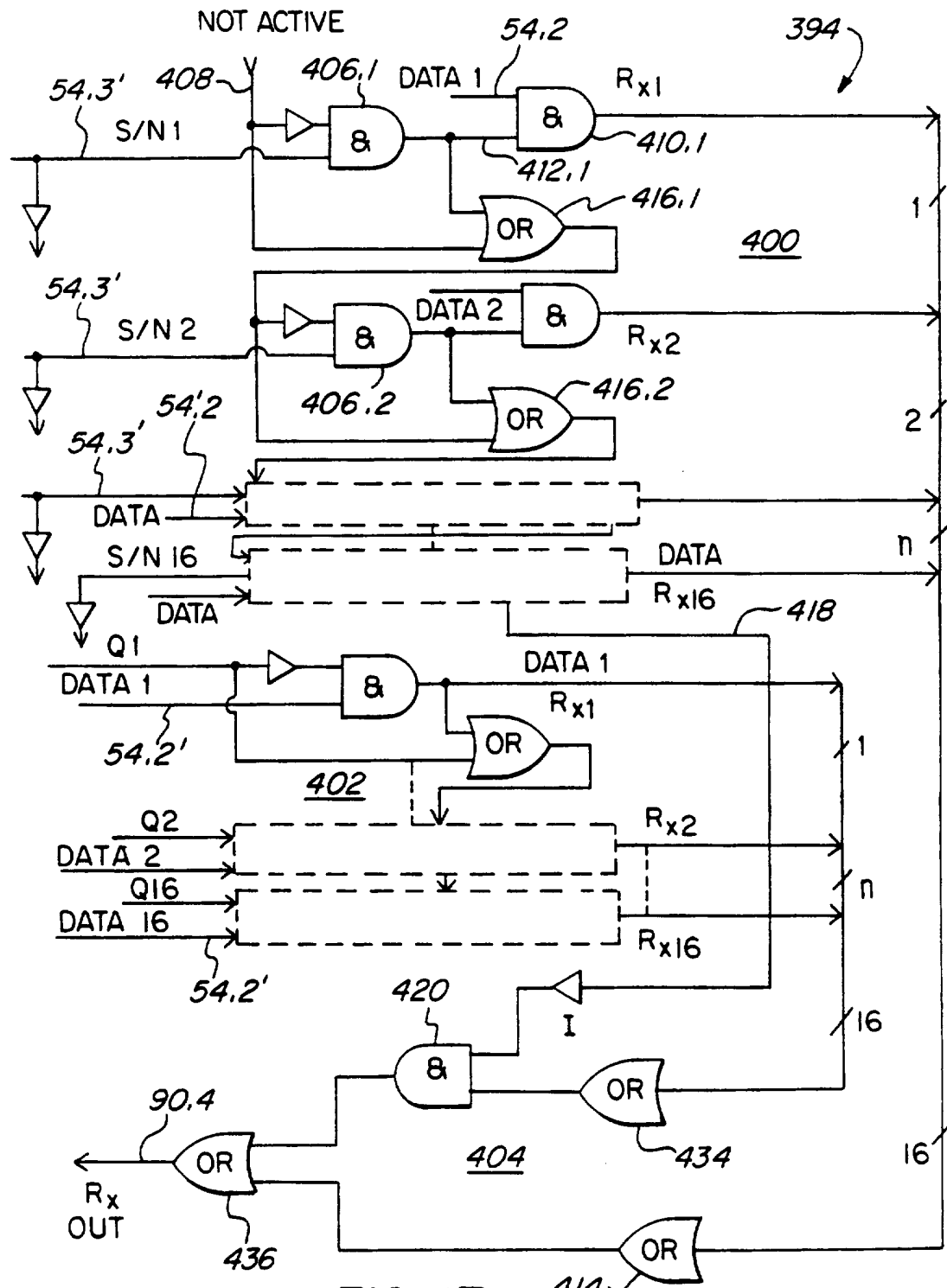


FIG. 17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/04318

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : HO4B 10/00

US CL : 359/142, 172, 152, 158, 137, 140; 455/51.1, 51.2

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 359/142, 172, 152, 158, 137, 140; 455/51.1, 51.2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,456,793, (BAKER ET AL) 26 JUNE 1984, COL. 9. LINES 49-63.	1,2,5-36
Y	US, A, 5,201,061 (GOLDBERG ET AL) 06 APRIL 1993, COL. 2, LINES 25-50.	1,2,5-36
Y,P	US, A, 5,566,022 (SEGEV) 15 OCTOBER 1996, COL. LINES 26-55.	1,2,5-36
Y	US, A, 5,361,398 (CHRISTIAN ET AL) 01 NOVEMBER 1994, COL. 2, LINES 29-48.	1,2,5-36



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*G* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

20 MAY 1997

Date of mailing of the international search report

10 JUN 1997

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

B. Hander
RAFAEL BACARES

Telephone No. (703) 305-4928