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(71) Applicant: AT&E CORPORATION [US/US]; One Maritime Plaza, Suite 500, San Francisco, CA 94111 (US).

(72) Inventors: HOFF, Don, G. ; One Via Capistrano, Tiburon, CA 94920 (US). OWEN, Jeffrey, R. ; 11120 N.W. Lost Park Drive, Portland, OR 97229 (US).

(74) Agent: CUSHING, Keith, A.; AT&E Corporation, 10450 S.W. Nimbus Avenue, Portland, OR 97223 (US).

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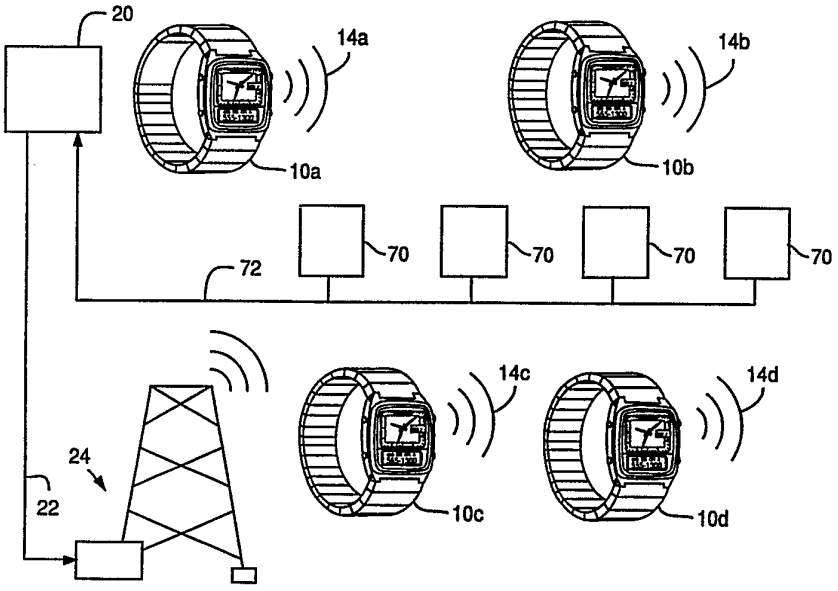

(57) Abstract

A paging system broadcasts a message to a selected remote pager at a known broadcast time. The selected remote pager transmits an acknowledge signal (84) following a predetermined delay relative to the broadcast time. The paging system verifies receipt of the message by offsetting the time of receiving the acknowledge signal with the predetermined delay (146), thereby deriving the broadcast time and associating the acknowledge signal with the selected remote pager (150). The remote pager broadcasts a low wattage acknowledge signal to conserve power and the paging system includes a network of acknowledge signal receivers distributed through the paging area for reporting times at which acknowledge signals occur within the paging area.

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ANSWER-BACK PAGER

Field of the Invention

The present invention relates to paging systems and, more particularly, to a paging system employing answer-back pagers for acknowledging receipt of message data.

Background of the Invention

Paging systems that employ one or more broadcast stations and a number of remote pager units located within a paging area are well know. Most remote pager units are small portable devices carried by individuals. Such pagers carry a battery power source requiring replacement or recharge. Accordingly, a major consideration with respect to pagers is power consumption.

Pagers that provide an acknowledgement signal when a message is received are known. Such systems can verify that a message has been received by the proper pager. In the known systems, such verification is achieved by transmission of a radio frequency acknowledge signal from the pager. Pagers that provide an acknowledgement are desirable because a pager may be outside the paging area, turned off, or unable to receive message data due to signal interference. The absence of an acknowledge signal from a pager may trigger retransmission of a message or other remedial action.

The prior art shows the use dedicated frequency subbands for transmitting acknowledge signals. In such systems a number of frequency subbands are required in order to provide answer-back capability, and unavoidable competition for these frequency subbands exists.

In U.S. Patent No. 4,713,808, issued December 15, 1987 to Gaskill, et al., pager power consumption is minimized by providing a transmission protocol wherein individual pagers activate during predetermined associated time slots and monitor a selected one of several broadcast stations, or frequencies, for message data. The one or several broadcast stations are programmed to broadcast message data for a pager only during time slots associated with that remote pager. In such a system the pagers, being active only during brief time periods, conserve power, yet reliably receive message data. To insure that each pager receives its message data, message data is rebroadcast a number of times with the expectation that eventually the remote pager will receive the message data. The Gaskill system would benefit by use of an acknowledge signal in that once a pager provides an acknowledge signal relative to a given message, there is no need to rebroadcast the message.

Unfortunately, known methods of broadcasting acknowledge signals from pagers are unsatisfactory due to the number

of dedicated frequency subbands or the amount of power required.

Objects and Advantages of the Invention

It is an object of the present invention to provide a low power consumption pager with message acknowledge capability. Such a pager would have a long battery life while providing message verification.

It is a further object of the present invention to avoid use of multiple dedicated frequency subbands for acknowledge signals. By avoiding multiple dedicated frequency subbands for acknowledge signals, only a single acknowledge signal frequency subband is required, yet no competition for the acknowledge signal frequency subband exists.

It is yet a further object of the present invention to avoid redundant message transmission after a pager has received a message. By providing an acknowledge signal, redundant message transmission is avoided and subsequent time slots, otherwise used for redundant message data, are available for new message data.

Summary of the Invention

The foregoing objects and advantages are achieved by a paging system broadcasting a message to a selected remote

pager at a known broadcast time. The selected pager transmits an acknowledge signal following a known delay relative to the broadcast time. The paging system verifies receipt of the message by offsetting the time of receiving the acknowledge signal with the known delay, thereby deriving the known broadcast time and associating the acknowledge signal with the selected pager.

In a principle embodiment of the present invention, message data is broadcast to a selected pager during a predetermined time slot associated with the selected pager. Each pager activates during its associated time slot to receive message data. In the event that message data is received during a given time slot, the pager transmits an acknowledge signal following a predetermined delay relative to the given time slot. The paging system thereby associates the acknowledge signal with a given pager by offsetting the time of receiving the acknowledge signal by the predetermined delay to derive the time slot associated with the given pager.

In a first aspect of the present invention, the paging system broadcasts identical message data for the selected pager on several stations or frequencies, but offset in time. The predetermined delay between receipt of message data and broadcast of an acknowledge signal is a fixed delay period plus a station dependent delay period. The station dependent delay period staggers acknowledge

signals from pagers receiving message data concurrently on different stations and enables the paging system to uniquely associate each acknowledge signal with one pager.

In a second aspect of the present invention, the pager broadcasts a low wattage acknowledge signal to conserve power and the paging system includes a network of acknowledge signal receivers distributed through the paging area for reporting times at which acknowledge signals occur within the paging area.

Brief Description of the Drawings

A complete understanding of the present invention may be obtained by reference to the accompanying drawings, when taken in conjunction with the detailed description thereof and in which:

FIG. 1 illustrates a paging system including remote pagers and corresponding pager address values uniquely identifying each pager and determining associated message data time slots;

FIG. 2 illustrates a set of time frames each including sub-frames comprising message data time slots, wherein identical message data is transmitted on different broadcast stations each referencing a different time

frame, and each time frame is offset in time relative to the other time frames;

FIG. 3 illustrates concurrence of time slots between the time frames of FIG. 2 and time intervals in which acknowledge signals occur;

FIG. 4 illustrates the paging system of FIG. 1 and an acknowledge signal receiver network with the remote pagers of FIG. 1 located within the network;

FIG. 5 is a flow chart for broadcasting an acknowledge signal from one of the remote pagers;

FIG. 6 illustrates a dedicated frequency subband containing an acknowledge signal;

FIG. 7 is a flow chart for processing acknowledge signals at the acknowledge signal receivers of FIG. 3;

FIG. 8 is a block diagram of one of the acknowledge signal receivers of FIG. 3; and

FIG. 9 is a flow chart for processing reports from the acknowledge signal receivers.

Description of the Preferred Embodiment

For expository convenience, the present invention will be illustrated with reference to a paging system (the "Gaskill system") described in U.S. Patent 4,713,808 and in allowed application Serial No. 07/121,139. However, it will be understood that the invention is not so limited. The disclosures of U.S. Patent 4,713,808 and allowed application Serial No. 07/121,139 are incorporated herein by reference.

The Gaskill system includes a number of wrist-watch remote pagers 10, individually numbered 10a-10d in FIG. 1, each having an associated pager address value 12, individually numbered 12a-12d in FIG. 1, for identifying each remote pager 10 and determining when each remote pager 10 activates to receive message data. As fully explained in U.S. Patent No. 4,713,808, and discussed hereafter, address values 12 specify sub-frames of repeating time frames and further specify time slots within the sub-frames in which the corresponding remote pagers 10 activate to receive message data.

FIG. 1 also illustrates a central clearinghouse 20 for processing and broadcasting message data to remote pagers 10. Clearinghouse 20 communicates by way of communication link 22 to antenna tower 24 for broadcasting an FM radio signal to remote pagers 10. Clearinghouse 20 is a fully automated, centralized facility which accepts messages, validates customer

identification, determines message destinations, and routes messages to the appropriate broadcast stations facility, e.g., tower 24, for transmission.

In accordance with the protocol of the Gaskill system, each remote pager 10 is programmed to activate during predetermined time slots and monitor one of several broadcast stations or frequencies for message data. In accordance with the present invention, each of remote pagers 10 then provides an acknowledge signal 14 to clearinghouse 20 following a predetermined delay relative to message receipt, more particularly, relative to the predetermined time slot. A particular acknowledge signal 14 is then associated with one of remote pagers 10 based on the time at which the acknowledge signal 14 is broadcast. Such association is accomplished by offsetting the time at which the acknowledge signal 14 is broadcast by the predetermined delay to derive a time slot uniquely associated with one of remote pagers 10.

FIG. 2 illustrates the message protocol of the Gaskill system. A time frame 30 of predetermined length, such as 7 and one-half minutes, repeats cyclically. Within time frame 30 are a predetermined number of sub-frames, represented as rows in FIG. 2. As shown, time frame 30 is divided into 32 such sub-frames, numbered 0 to 31, of about 14 seconds each. Each of sub-frames 0-31 is, in turn, divided into a predetermined number of time slots

40. The first three time slots 40 of each sub-frame are reserved for control data and the remaining time slots 40 in each sub-frame are reserved for message data. Each time slot 40 is then approximately fourteen milliseconds in duration. Each message data time slot 40 of each sub-frame is uniquely numbered, i.e., 0 to 1,023.

Address values 12 for each remote pager 10 determine which time slots 40 in time frame 30 are associated with a given remote pager 10. For example, remote pager 10a of FIG. 1 is programmed to activate 8 times during each time frame 30, beginning in message data time slot number 38 of sub-frame 2 and repeating every fourth sub-frame, i.e., in subsequent sub-frames 6, 10, 14, 18, 22, 26 and 30. In FIG. 2, remote pager 10a activates during time slots 40a. Similarly, remote pager 10b activates during time slots 40b, remote pager 10c activates during time slots 40c and remote pager 10d activates during time slots 40d. In each case, only the first three time slots 40 associated with each remote pager 10 are shown in FIG. 2.

The Gaskill system also employs multiple stations for broadcasting identical message data. Each station broadcasts the same message data, but offset in time such that an individual remote pager 10 may switch stations and receive a message at a later time in the event that

message data is lost, errors are detected or re-synchronization is necessary.

Thus, identical message data is broadcast during time frame 32 as is broadcast during time frame 30, but offset in time relative to time frame 30 by a fixed amount. The time offset F0 between time frame 30 and time frame 32 is equal to one sub-frame plus sixteen time slots 40. Similarly, identical message data is broadcast during time frame 34, but offset relative to time frame 32 by the time offset F0. Accordingly, if time frame 30 begins at a time T0, time frame 32 begins at a time T0 + F0 and time frame 34 begins at a time T0 + (2*F0).

In the following discussion, it will be assumed that message data is broadcast on three separate active broadcast stations each referencing one of time frames 30, 32, and 34. However, it will be understood that additional broadcast stations referencing additional time frames 36 may be potentially active. Accordingly, it will be further assumed that the system is capable of broadcasting on up to seven different active stations, each referencing a separate one of time frames 30, 32, 34 and 36. Because the time offset F0 is a multiple of time slots, a concurrence of time slots on different stations exists. For three active broadcast stations, three time slots 40 coincide, each coincident time slot 40 being associated with a respective one of the time frames 30,

32 and 34. For each additional active broadcast station, additional time slots 40 coincide.

FIG. 3 better illustrates the concurrence of time slots among time frames 30, 32, 34 and 36. In FIG. 3, each time frame may be viewed as a repeating sequence of time slots 40. Time frames 30, 32, 34 and 36 are shown as individual rows of time slots 40. Time line 50 begins at time T0 and is divided into major time intervals 52, each major time interval 52 being equal in duration to one time slot 40 and corresponding to a set of concurrent time slots 40. Each major interval 52 is divided into seven minor intervals 54, each minor interval 54 corresponding to one of the seven possible broadcast stations. Time slots 40 aligned in columns, as shown in FIG. 3, are coincident time slots. For example, the column 56 contains seven time slots 40, each members of respective ones of times frames 30, 32, 34 and 36 and concurrent in time during a major time interval 58.

To implement the present invention in a paging system employing a single broadcast station referencing a single time frame, the delay period between message receipt and broadcast of an acknowledge signal from the receiving remote pager 10 is a fixed delay FD, a multiple of time slots totalling approximately one second in duration. Fixed delay FD should be long enough for worst case message data processing by a remote pager 10. Consider

remote pager 10a referencing time frame 30, and receiving message data during time slot 40a occurring during major time interval 58. To verify message receipt, remote pager 10a broadcasts its acknowledge signal 14a during major time interval 60, offset from major interval 58 by the fixed delay FD. In a paging system employing a single broadcast station referencing time frame 30, each major interval 52 of time line 50 may be associated with a single time slot 40 of time frame 30. Clearinghouse 20 associates an acknowledge signal received during major time interval 60 with remote pager 10a by subtracting fixed delay FD from major interval 60 to derive major interval 58 which correlates uniquely with pager 10a, and more particularly, with a message sent to pager 10a.

To implement the present invention in a paging system employing multiple broadcast stations each referencing separate time frames, the delay period between message receipt and broadcast of an acknowledge signal by a remote pager 10 must depend on two factors. First, the predetermined fixed delay FD allowing for worst case message processing at the remote pager 10. Second, a station dependent delay SD providing an offset within each major interval 52 to derive a minor interval 54 corresponding to a given station. Each major interval 52 is associated with a column of concurrent time slots 40 by offsetting the fixed delay FD. Each minor interval 54 is associated with one of the concurrent time slots by

determining the station dependent delay SD, i.e., the offset within the major time interval 54. In this manner, every minor time interval 54 of time line 50 is uniquely associated with one time slot 40 in one of time frames 30, 32, 34, or 36.

To illustrate concurrence of time slots 40 among different time frames, the specific adddress values 12a 12c,12d, etc. of pagers 10a, 10c, and 10d has been chosen to cause time slots 40a, 40c, and 40d to coincide, i.e., to cause pagers 10a, 10c, and 10d to activate and monitor different stations or frequencies during the same major time interval 58. It should be understood, however, that remote pagers 10 are given address values 12 such that they tend to activate during non-concurrent time slots 40.

Recall that the frame offset F0 is equal to one sub-frame plus sixteen time slots 40. Note, as seen in FIG. 2, that the first time slot 40a in time frame 30 occurs in sub-frame 2, slot number 38; the first time slot 40c in time frame 30 occurs in sub-frame 1, slot number 22; and the first time slot 40d in time frame 30 occurs in sub-frame 0, slot number 6. The offset between time slots 40a, 40c, and 40d was chosen, for purposes of illustration, to be equal to one sub-frame plus sixteen time slots 40, equal to the frame offset F0. Because time frame 34 is offset or delayed relative to time frame

32 by frame offset F0, the first time slot 40d in time frame 34 is coincident with the first time slot 40c in time frame 32. Similarly, the first time slot 40c of time frame 32 is coincident with the first time slot 40a of time frame 30. Subsequent time slots 40a, 40c, and 40d in each of time frames 30, 32 and 34, i.e., the second through eighth, would also coincide as each bears the same relative offset as does the first. Thus, as shown in FIG. 3, time slots 40a, 40c, and 40d appear in the column 56 above major time interval 58 as concurrent time slots.

Consider a situation where remote pager 10d is tuned to a first station referencing time frame 34, remote pager 10c is tuned to a second station referencing time frame 32, and remote pager 10a is tuned to a third station referencing time frame 30. Furthermore, assume that clearinghouse 20 has message data for each of remote pagers 10a, 10c, and 10d, and, in accordance with normal operating procedures, causes transmission on separate stations of such message data during major time interval 58. Each of remote pagers 10a, 10c, and 10d receives, on separate broadcast stations, message data during major time interval 58. Assuming remote pagers 10a, 10c, and 10d process the message data and determine the data to be error-free, each must broadcast an acknowledge signal 14 to clearinghouse 20 to acknowledge receipt. In accordance with the above example, each remote pager 10a,

10c, and 10d broadcasts its acknowledge signal 14 during major time interval 60, offset relative to major time interval 58 by fixed delay FD. However, each remote pager 10a, 10c, and 10d broadcasts its acknowledge signal 14 during different minor time intervals 54 of major time interval 60. For example, remote pager 10d, being tuned to the first station, broadcasts its acknowledge signal 14d during the first minor time interval 64; remote pager 10c, being tuned to the second station, broadcasts its acknowledge signal 14c during the second minor time interval 66; and remote pager 10a, being tuned to the third station, broadcasts its acknowledge signal 14a during the third minor time interval 68. Accordingly, the station dependent delay SD0 for a remote pager 10, e.g., 10d, tuned to the first station is zero; the delay SD1 for remote pager 10, e.g., 10c, tuned to the second station is equal to one minor time interval 54; and the delay SD2 for a remote pager 10, e.g., 10d, tuned to the third station, is equal to two minor time intervals 54.

In a situation where clearinghouse 20 broadcasts message data on seven different stations, seven remote pagers 10 each can be tuned to a different station and each may receive message data during the same major time interval 52. In such case, each remote pager 10 broadcasts its acknowledge signal during a different minor time interval 54 of one major time interval 52. Clearinghouse 20 distinguishes among the seven acknowledge signals by

determining the minor time interval 54 in which each occurs. Generally, if a paging system uses n stations to broadcast message data, and up to n remote pagers 10 potentially receive message data during a single major time interval 52, each major time interval 52 must be divided into n minor time intervals 54 to distinguish among the possible n acknowledge signals during each major time interval 52.

A central concern in the Gaskill paging system is conservation of power consumption at remote pagers 10. In accordance with this concern, the acknowledge signal broadcast from a remote pager 10 should be a low wattage signal, however, such an acknowledge signal is not essential to practice of the present invention in its broader aspects. Furthermore, because an acknowledge signal 14 is associated with a remote pager 10 based upon the time at which the acknowledge signal is broadcast by the remote pager 10, the acknowledge signal 14 need only carry a single bit or binary valve. Broadcast of a single bit acknowledge signal is more power efficient than broadcast of an acknowledge signal carrying more information, such as conventional acknowledge signals carrying information identifying the remote pager, i.e., the signal source, to the paging system.

FIG. 4 illustrates a network of acknowledge signal receivers 70 distributed within a paging area occupied by

remote pagers 10. Acknowledge signal receivers 70 should be spaced closely enough to insure that an acknowledge signal 14 of a given wattage broadcast by one of the remote pagers 10 has a good chance of being received by at least one of the acknowledge signal receivers 70. Of course, local terrain and noise conditions must be considered. However, for a higher wattage acknowledge signal 14 the acknowledge signal receivers 70 may be more widely spaced, and for a lower wattage acknowledge signal the acknowledge signal receivers 70 must be more closely spaced.

Each of acknowledge signal receivers 70 communicates with clearinghouse 20 by way of communication link 72 which, for example, may be a telephone connection or a microwave connection. Each of acknowledge signal receivers 70 is responsible for determining the probability of occurrence of an acknowledge signal during each minor time interval 54 of time line 50. Each acknowledge signal receiver 70 then reports such probability of occurrence for each minor time interval 54 by way of link 72 to clearinghouse 20. Clearinghouse 20 processes the reported probabilities of acknowledge signal occurrence from all acknowledge signal receivers 70 and determines whether an acknowledge signal 14 has occurred during a particular minor time interval 54. Upon determining that an acknowledge signal 14 has occurred during a particular minor time interval 54, clearinghouse 20 is then able to

associate the particular minor time interval 54 with a particular time slot 40 and therefore with a particular message transmitted to a particular remote pager 10. The desired message receipt verification is thereby achieved.

FIG. 5 illustrates the process of receiving message data at one of remote pagers 10 and broadcasting an acknowledge signal 14 to verify receipt of the message data. Process blocks 80, 82 and 83 represent the normal operating procedures of the Gaskill paging system. In process block 80, remote pager 10 activates during a predetermined time slot occurring during major time interval Tx. Remote pager 10 monitors a broadcast station Z for message data occurring during that time slot. Processing then continues into decision block 82. In decision block 82, remote pager 10 determines whether or not valid message data containing its address value 12 has been received. If such message data has not been received, processing returns to block 80 where remote pager 10 reactivates during a subsequent time slot and attempts to again intercept message data during its assigned time slot.

If a remote pager 10 receives valid message data containing its address value 12 during a major time interval Tx, processing branches from decision block 82 into blocks 83 and 84. In process block 83, the message is displayed for the user and processing continues in

block 84. In process block 84, remote pager 10 broadcasts and acknowledges signal 14 during a later minor time interval as determined by the interval Tx in which the message data was received, the fixed delay FD, and the station dependent delay SDz. To calculate the total delay period, remote pager 10 first adds the fixed delay FD to major time interval Tx. The station dependent delay SD is a function of the broadcast station from which the message was received. For example, if the message was received on the first station, delay SDz is zero; if the message was received on the second station, delay SDz is equal to one minor time interval 54; if the message was received on the third station, delay SDz is equal to two minor time intervals 54. After broadcasting the acknowledge signal, processing then returns to block 80.

FIG. 6 illustrates the spectrum of subband fb in which an acknowledge signal 14 occurs. Due to temperature variations and imperfections in the crystal used as a frequency reference to generate the acknowledge signal 14, the acknowledge signal 14 may occur at any frequency within frequency subband fb. The maximum duration for acknowledge signal 14 is equal to one minor time interval 54. That is to say, the maximum duration is dependent on the duration of major time intervals 52 and the number of potential stations upon which the paging system can broadcast. For a system employing a major time interval

of approximately fourteen milliseconds, and 7 possible broadcast stations or frequencies, the maximum duration for the acknowledge signal 14 is approximately two milliseconds.

The task of determining the probability of occurrence of an acknowledge signal 14 during one of minor time intervals 54 requires that acknowledge signal receiver 70 detect a low wattage signal of small band width at an unknown location within a much larger band width.

FIG. 7 illustrates the procedure for determining the probability of occurrence or of acknowledge signals 14 during each of minor time intervals 54. In FIG. 7, each of acknowledge signal receivers 70 performs the following steps. Upon synchronization or resynchronization with clearinghouse 20, acknowledge signal receiver 70 sets, in blocks 90 and 92, a variable Z and a variable Y to index intervals of time line 50. Variables Z and Y provide both clearinghouse 20 and acknowledge signal receiver 70 with a common mechanism for identifying minor time intervals 54 of time line 50. The variable Z refers to major time intervals 52 and the variable Y refers to minor time intervals 54 with each major time interval 52.

In process block 94, acknowledge signal receiver 70 monitors frequency subband fb for an acknowledge signal

14 during minor time interval Ty of major time interval Tz. In block 96, receiver 70 calculates as described below, a probability of acknowledge signal occurrence for that minor time interval. In block 98 acknowledge signal receiver 70 reports to clearinghouse 20 the probability of occurrence of an acknowledge signal 14 during this minor time interval.

Processing then continues with block 100 where acknowledge signal receiver 70 increments the variable Y to index the next minor time interval on time line 50. In decision block 102, acknowledge signal receiver 70 determines whether the variable Y has reached the value n+1, where n is the number of possible broadcast stations employed by the paging system. If the variable Y has reached the value n+1, the last minor time interval 54 of a major time interval 52 has been reached. It is then necessary to index the variable Z to reference the next major time interval 52. Therefore, in process block 104, the variable Y is reset to reference the first minor time interval 54 of the next major time interval 52. If, in decision block 102, the variable Y had not yet reached the value n+1, processing skips block 104. In any case, processing returns to block 94 where acknowledge signal receiver 70 again monitors frequency subband fb for an acknowledge signal 14 during the next minor time interval 54. Thus, each acknowledge signal receiver 70 simply increments variables Z and Y in a suitable manner to

reference each minor time interval 54 of time line 50 and calculate a probability of acknowledge signal occurrence.

FIG. 8 is a block diagram of an acknowledge signal receiver 70. In FIG. 8, a remote pager 10 is shown broadcasting an acknowledge signal 14. Acknowledge signal receiver 70 includes an antenna 112 for receiving an acknowledge signal 14. A radio frequency receiver with a band pass filter 114 filters signals outside frequency band fb and feeds its output signal into a fast fourier transform processor 116. Processor 116 decomposes its input signal from filter 114 into approximately two hundred frequency bins 118 (FIG. 6). The number of frequency bins 118 is chosen to provide a frequency range for each bin 118 of approximately one-fifth of the main lobe band width expected for acknowledge signal 14. Processor 116 analyzes the energy level of each frequency bin 118 and provides a separate output signal for each bin 118, each output signal representing the energy level of the associated bin 118.

In the example shown in FIG. 6, the main lobe of the acknowledge signal spans six frequency bins, bins 120, 121, 122, 123, 124 and 125. Processor 116 determines that frequency bins 120 and 125 carry low range energy, bins 121 and 124 carry mid-range energy, and bins 122 and 123 carry high-range energy. The remaining frequency

bins 118 carry energy levels range correlating to adjacent signal lobes and expected noise levels.

The two hundred output signals of processor 116 are fed into a spectral shape recognizer logic block 130 (FIG. 8). Logic block 130 determines, based upon the reported energy levels from processor 116, the probability that an acknowledge signal 14 has occurred. Thus, logic 130 performs the step represented by block 96 of FIG. 7. More particularly, logic 130 determines with high probability that an acknowledge signal 14 has occurred within frequency subband fb by detecting the presence of a sequence of energy bins having zero or nominal energy levels followed by a sequence of approximately six bins, e.g., bins 120-125, of expected relative energy levels which are in turn followed by a sequence of nominal energy level bins 118. The frequency bin energy levels may not clearly indicate the presence of an acknowledge signal, and logic 130 would calculate a lesser probability of acknowledge signal occurrence. In other cases, the frequency bin energy levels might indicate that no acknowledge signal has occurred and logic 130 would calculate a low, or zero, probability of acknowledge signal occurrence. For instance, if logic 130 detects high energy levels across all or much more than six frequency bins 118, it may conclude that the signal received was not likely to be an acknowledge signal 14. In any case, acknowledge signal receivers 70

calculate a probability of acknowledge signal occurrence based on the expected frequency domain pulse shape as indicated by the energy levels in frequency bins 118.

Acknowledge signal receiver 70 performs the above described analysis of frequency subband fb for every minor time interval 54 of time line 50. For each minor time interval 54, logic 130 reports to clearinghouse 20, by way of communication 72, the probability that an acknowledge signal occurred.

Fig. 9 illustrates the procedure at clearinghouse 20 for processing reports received from acknowledge signal receivers 70. In this procedure clearinghouse 20 must gather reports sent by acknowledge signal receivers 70 for each minor time interval 54 of time line 50. Accordingly, this procedure begins, with respect to a given minor time interval 54, following sufficient time for all acknowledge signal receivers 70 to report an acknowledge signal probability for the given minor time interval 54. Clearinghouse 20 uses variables Z and Y to index time intervals along time line 50.

Processing begins in blocks 140 and 142 where the variables Z and Y, respectively, are set to address a given minor time interval 54. Clearinghouse 20 maintains the reports received from acknowledge signal receivers 70 in a data structure enabling access based on the

variables Z and Y. In block 144 clearinghouse 20 analyzes the data structure to determine the reported probabilities of acknowledge signal occurrence during minor time interval Ty of major time interval Tz.

Clearinghouse 20 then determines in decision block 146 whether the probabilities found in the data structure indicate that a valid acknowledge signal occurred during minor time interval Ty of major time interval Tz, i.e., the current minor time interval. If all acknowledge signal receivers 70 report a very low or zero acknowledge signal probability during the current minor time interval, then clearinghouse 20 assumes that no valid acknowledge signal occurred during the current minor time interval and processing branches from decision block 146 to process block 148. If one acknowledge signal receiver 70 reports with high probability that an acknowledge signal occurred during the current minor time interval then processing branches from decision block 146 to process block 150.

If, however, several acknowledge signal receivers 70 report with mid-level probability that an acknowledge signal occurred during the current minor time interval, the reports could indicate a valid or an invalid acknowledge signal depending on the location of the acknowledge signal receivers 70 reporting the mid-level probability of an acknowledge signal. If two or more widely separated acknowledge signal receivers 70 report a

mid-level acknowledge signal probability during the current minor time interval, and the separation is beyond the capability of the low wattage acknowledge signal of the remote pagers 10, then it may be assumed that interference caused the acknowledge signal receivers 70 to incorrectly report the possibility that an acknowledge signal occurred. In such case, processing branches from decision block 146 to block 148. On the other hand, if the separation between a group of acknowledge signal receivers 70 reporting a mid-range acknowledge signal probability during the current minor time interval is within the capability of the low wattage acknowledge signal of the remote pagers 10, then the reports are taken to indicate a valid acknowledge signal. In this case processing branches from decision block 146 to block 150.

If clearinghouse 20 determines that no valid acknowledge signal is indicated for the minor time interval Ty of major time interval Tz, and processing reaches block 148, the variable Y is indexed in block 148 to reference the next minor time interval 54. Then in decision block 152 the variable Y is tested against the value n+1, where n equals the number of minor time intervals 54 in each major time interval 52. If the variable Y has reached the value n+1 , then in block 154 the variable Z is indexed to reference the next major time interval and the variable Y is reset to reference the first minor time

interval thereof. If the variable Y has not yet reached the value n+1, then block 154 is skipped. In any case processing returns to block 144 where probability reports for the next minor time interval 54 are analyzed.

If clearinghouse 20 determines that a valid acknowledge signal is indicated, then, in process block 150, clearinghouse 20 associates the current minor time interval with a remote pager 10. Because the fixed delay FD is a multiple of major time intervals 52, that number of major time intervals 52 is subtracted or offset from the variable Z to identify a major time interval 52, hereafter the "target major time interval", in which message data associated with the reported acknowledge signal was broadcast. Those remote pagers receiving message data during the target major time interval 52 received message data on different stations. The variable Y differentiates among the remote pagers 10 receiving message data concurrently on different stations during the target major time interval. If the variable Y is at its initial value, e.g., one, then it is known that the reported acknowledge signal is associated with a remote pager 10 receiving data by way of the first station and referencing time frame 34. Similarly, if the variable Y is at a next value, then it is known that the acknowledge signal is associated with a remote pager 10 tuned to the second station and referencing time frame

32. Subsequent values for the variable Y indicate association with other time frames 30 and 36.

Once the time frame and target major time interval are determined, it is possible to uniquely associate a remote pager 10 with the reported acknowledge signal. Only one time slot 40 of the identified time frame occurs during the target major time interval. Having determined a particular time slot 40 within a particular time frame, the associated remote pager is determined as being the pager to which the message data of that time slot is directed. Having received an acknowledge signal relative to that remote pager, it is known that the message was properly received.

From the foregoing description, it can be seen that the present invention relates to a paging system in which message verification is provided by way of an acknowledge signal broadcast from a remote pager following a predetermined time delay relative to receiving the message. According to the method of the present invention, a single frequency subband may be employed for broadcasting acknowledge signals from remote pagers without competition for the acknowledge signal frequency. A network of acknowledge signal receivers allows for a low wattage acknowledge signal, thereby conserving power consumption at each remote pager.

The method of message receipt verification of the present invention is possible in any communication system in which a sending device provides a message to a receiving device at a known time. For example, consider a time multiplexed communication system wherein receiving devices monitor a common message medium, e.g. a common radio frequency, for message data, sending devices provide message data on the communication medium for a particular receiving device by tagging data frames with a suitable identification number, and receiving devices detect the presence of appropriate message data by message frames bearing a matching identification number. The time at which a receiving device receives the message is known by the sending device because the sending device determines when the message is provided. In accordance with the present invention, the receiving device provides an acknowledge signal following a predetermined, or known, delay relative to receipt of the message. The sending device has sufficient information to determine the source of the acknowledge signal based on the time at which it receives the acknowledge signal, and thereby verify message receipt.

While the present invention has been shown in the context of the Gaskill paging system, it should be understood that the scope of the present invention should not be so limited. Since other modifications and changes varied to fit particular operating requirements and environments

will be apparent to those skilled in the art, the invention is not considered limited to the example chosen for purposes of disclosure, and covers all changes and modifications which do not constitute departures from the true spirit and scope of this invention.

WE CLAIM:

1. In a communication system including a sending device and a receiving device, a method of verifying receipt of a message comprising the steps:

- o providing the message from the sending device to the receiving device at a message time known to said sending device;
- o providing an acknowledge signal from the receiving device to the sending device following a known delay relative to said message time; and
- o verifying at the sending device receipt of the message at the receiving device by offsetting the time of receiving the acknowledge signal at the sending device with the known delay to derive the message time and thereby associate the acknowledge signal with the receiving device.

2. The method according to claim 1 wherein said communication system is a paging system, said sending device is a message broadcast facility, said receiving device is a remote pager, and said

receiving and sending devices communicate by radio signal means.

3. The method according to claim 1 wherein said sending device provides messages to a plurality of receiving devices on separate communication mediums, each of said receiving devices provides an acknowledge signal relative to a message received from the sending device following a delay dependent on a fixed delay period plus a communication medium dependent delay period.

4. The method according to claim 4 wherein the separate communication mediums are radio signal stations and the communication dependent delay period is a function of the station from which the message to be acknowledged was received.

5. The method according to claim 1 wherein said message time is a predetermined message time for said receiving device.

6. In a pager system having a clearinghouse for broadcasting message data and a plurality of remote pagers each programmed to receive message data from the clearinghouse during an associated time slot, a method of acknowledging receipt of

message data by one of said remote pagers comprising the steps:

- o receiving message data at said one remote pager during a time slot associated with said one remote pager;
- o broadcasting an acknowledge signal from said one remote pager at a given time, said given time being offset from said time slot by a predetermined delay time;
- o receiving said acknowledge signal at said given time; and
- o offsetting said predetermined delay time from said given time to derive said time slot associated with said one remote pager and thereby associate said acknowledge signal with said one remote pager.

7. The method according to claim 6 wherein said step of receiving said acknowledge signal comprises the steps:

- o providing a network of acknowledge signal receivers distributed through an area in which said one remote pager may be located, each of said acknowledge signal receivers being in communication with said clearinghouse;

- o determining the probability of acknowledge signal occurrence at each of said acknowledge signal receivers during predetermined time intervals, each of said predetermined time intervals being time intervals in which said given time may potentially occur; and
- o reporting from each of said acknowledge signal receivers to said clearinghouse the probability of acknowledge signal occurrence during each of said predetermined time intervals,

whereby said clearinghouse performs the step of offsetting said predetermined delay time from one of said predetermined time intervals in which one or more acknowledge signal receivers indicate the probability of acknowledge signal occurrence.

8. The method according to claim 6 wherein said clearing house broadcasts message data on a plurality of stations, said remote pagers selectively tune to said stations to receive message data, and said predetermined delay between receipt of message data and broadcast of an acknowledge signal relative thereto is a function of the station from which the message data is received.

9. A pager system comprising:

- a plurality of remote pagers each programmed to receive message data during time slots associated therewith and to broadcast an acknowledge signal at a time following a predetermined delay relative to receipt of message data; and
- a clearinghouse for broadcasting message data to selected ones of said plurality of remote pagers, said message data for a selected remote pager being broadcast during a time slot associated with said selected remote pager, said clearinghouse receiving acknowledge signals from ones of said plurality of remote pagers and associating a given acknowledge signal with a given remote pager by offsetting the time of receiving the given acknowledge signal by said predetermined delay interval to identify a time slot associated with the given remote pager and thereby identify the given remote pager broadcasting the given acknowledge signal.

10. The paging system according to claim 9 wherein said clearing house broadcasts message data on a plurality of stations, said remote pagers

selectively tune to said stations to receive message data, and said predetermined delay interval is a function of the station from which the message is received.

11. A paging system comprising:

- a clearinghouse for broadcasting message data during time slots, said message data being provided on a plurality of stations each referencing a cyclic time frame comprising a sequence of said time slots, the time frames being offset in time by a multiple of time slots whereby time slots of different time frames coincide;
- a plurality of remote pagers each being associated with time slots of each time frame and programmed to select from said stations for receiving message data during associated time slots, said remote pagers being programmed to provide an acknowledge signal to said clearinghouse relative to receipt of a message following an acknowledge delay period dependant on the station from which said message data was received.

12. The paging system according to claim 11 wherein said acknowledge delay period is a fixed delay period plus a station dependent delay period.

13. The paging system according to claim 11 wherein said clearinghouse comprises a network of acknowledge signal receivers distributed through an area in which said remote pagers are located and said acknowledge signal receivers calculate a probability of acknowledge signal occurrence for each time interval in which an acknowledge signal potentially occurs.

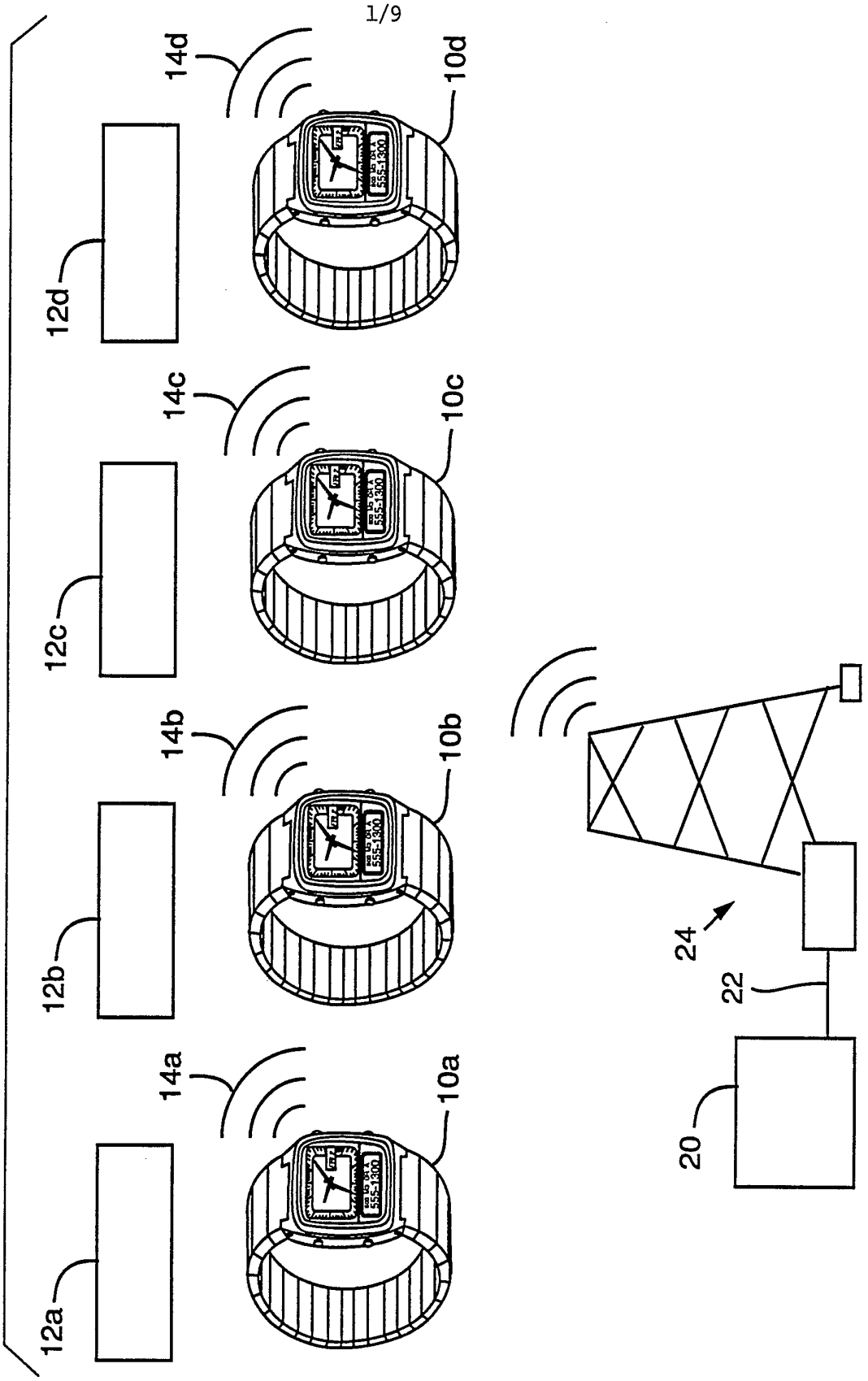


FIG. 1

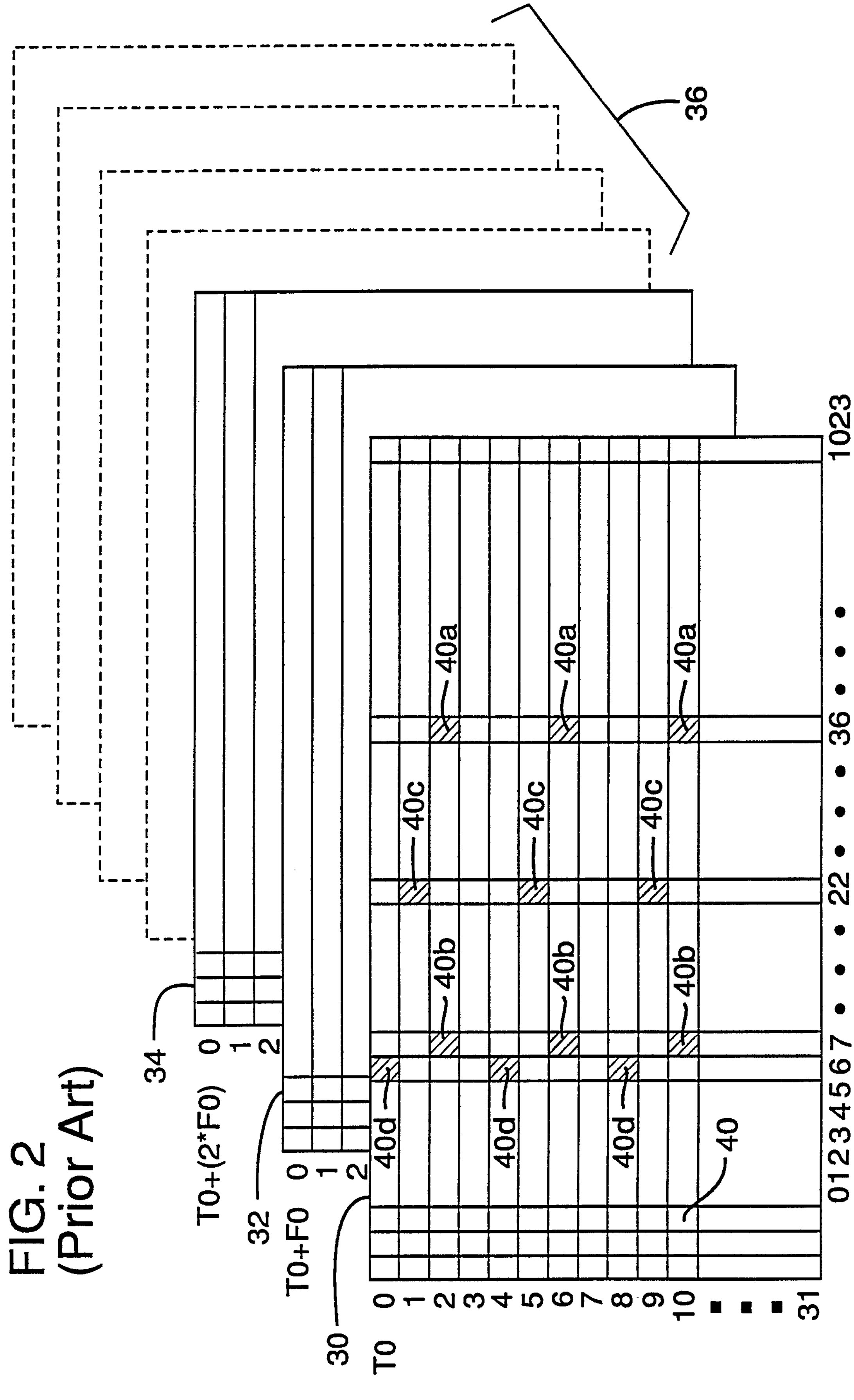
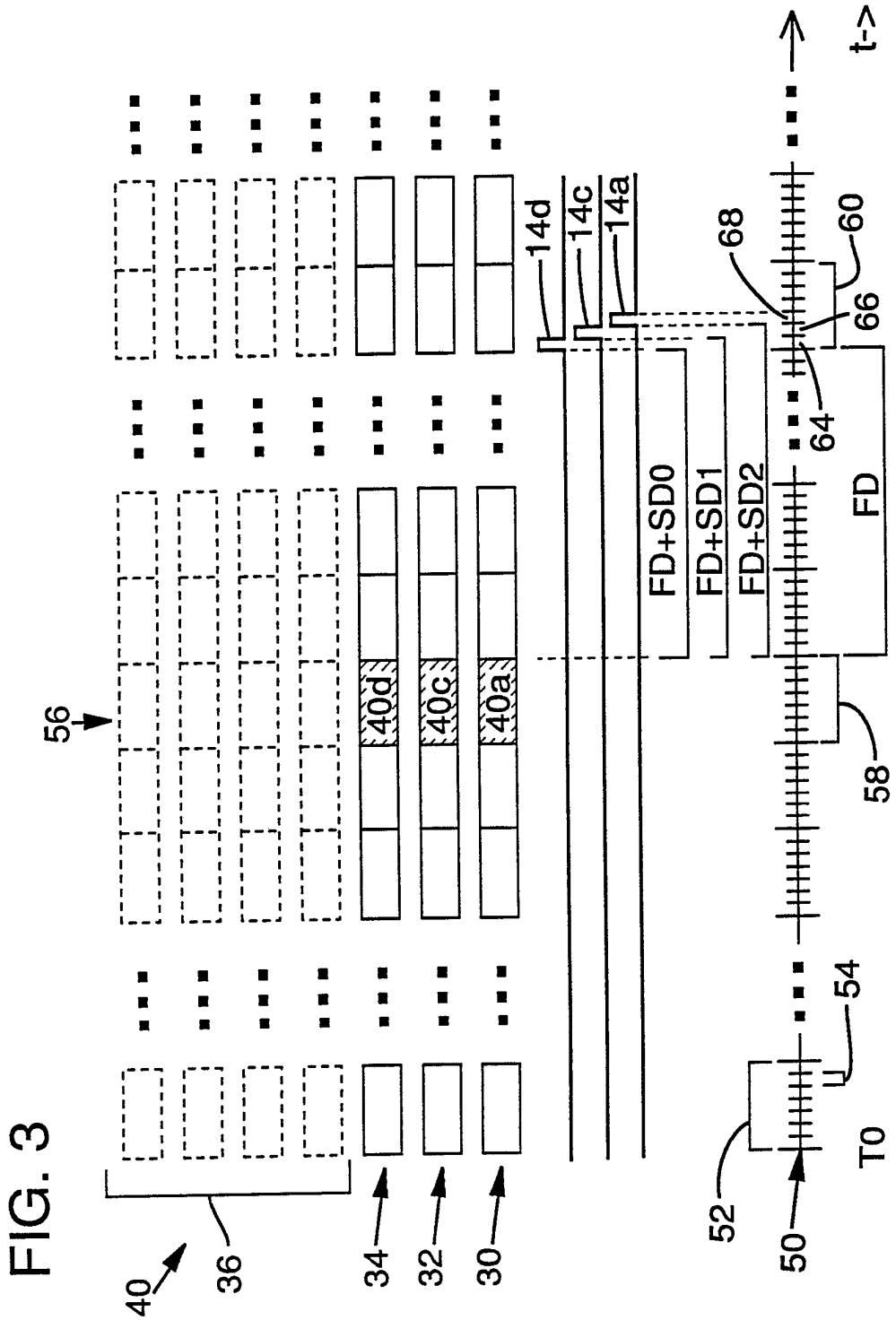


FIG. 2
(Prior Art)

FIG. 3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40d
40c
40a
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14c
14a
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FD+SD1
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FD
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30

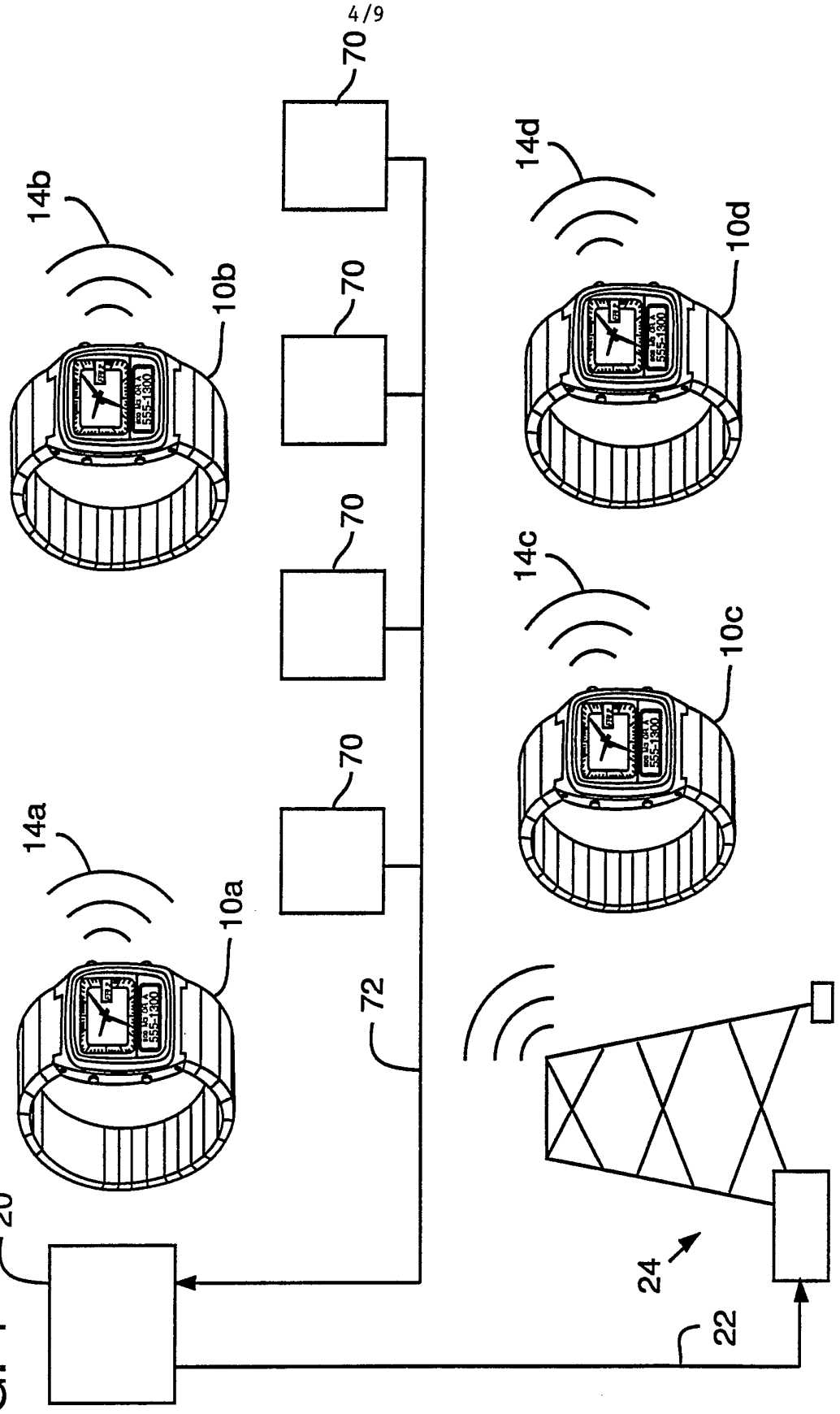
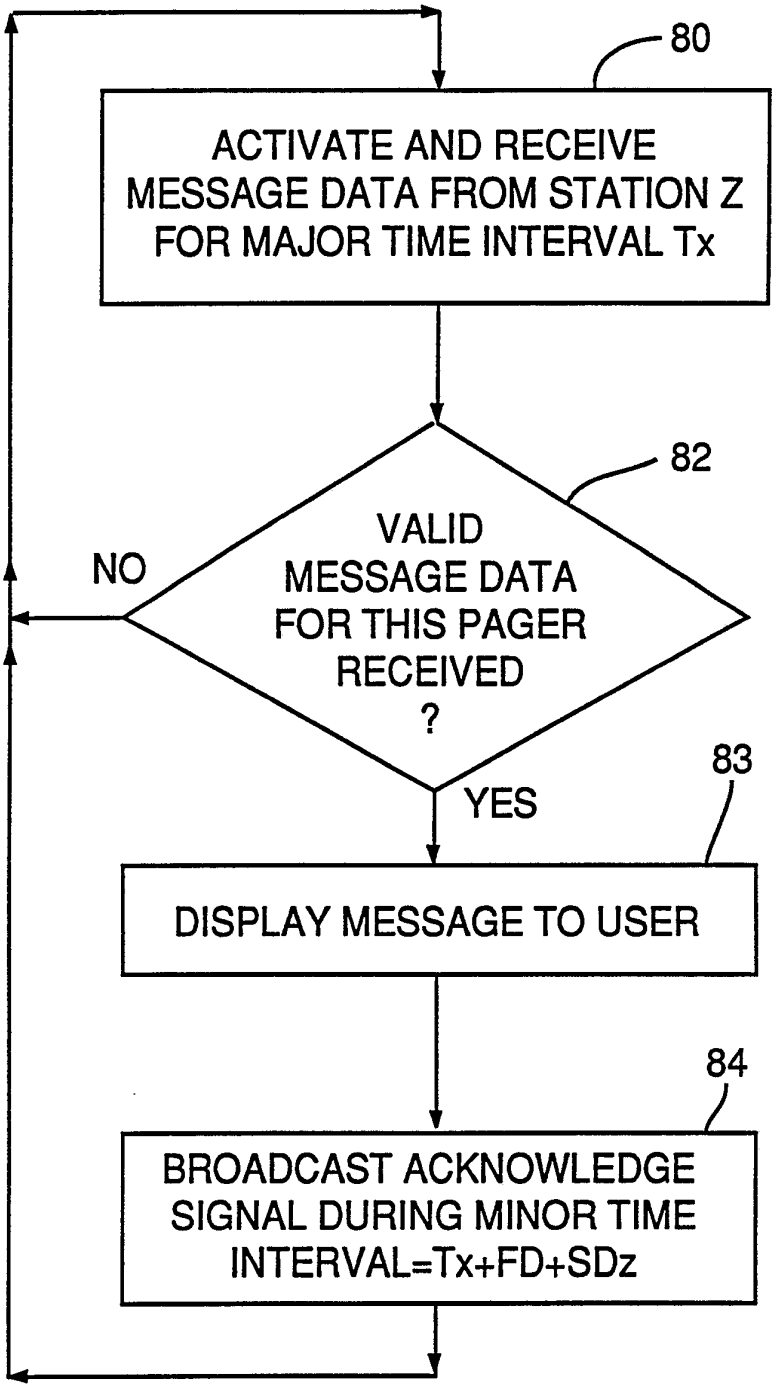


FIG. 4

FIG. 5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ACTIVATE AND RECEIVE MESSAGE DATA FROM STATION Z FOR MAJOR TIME INTERVAL Tx
82
VALID MESSAGE DATA FOR THIS PAGER RECEIVED ?
NO
YES
83
DISPLAY MESSAGE TO USER
84
BROADCAST ACKNOWLEDGE SIGNAL DURING MINOR TIME INTERVAL=Tx+FD+SDz

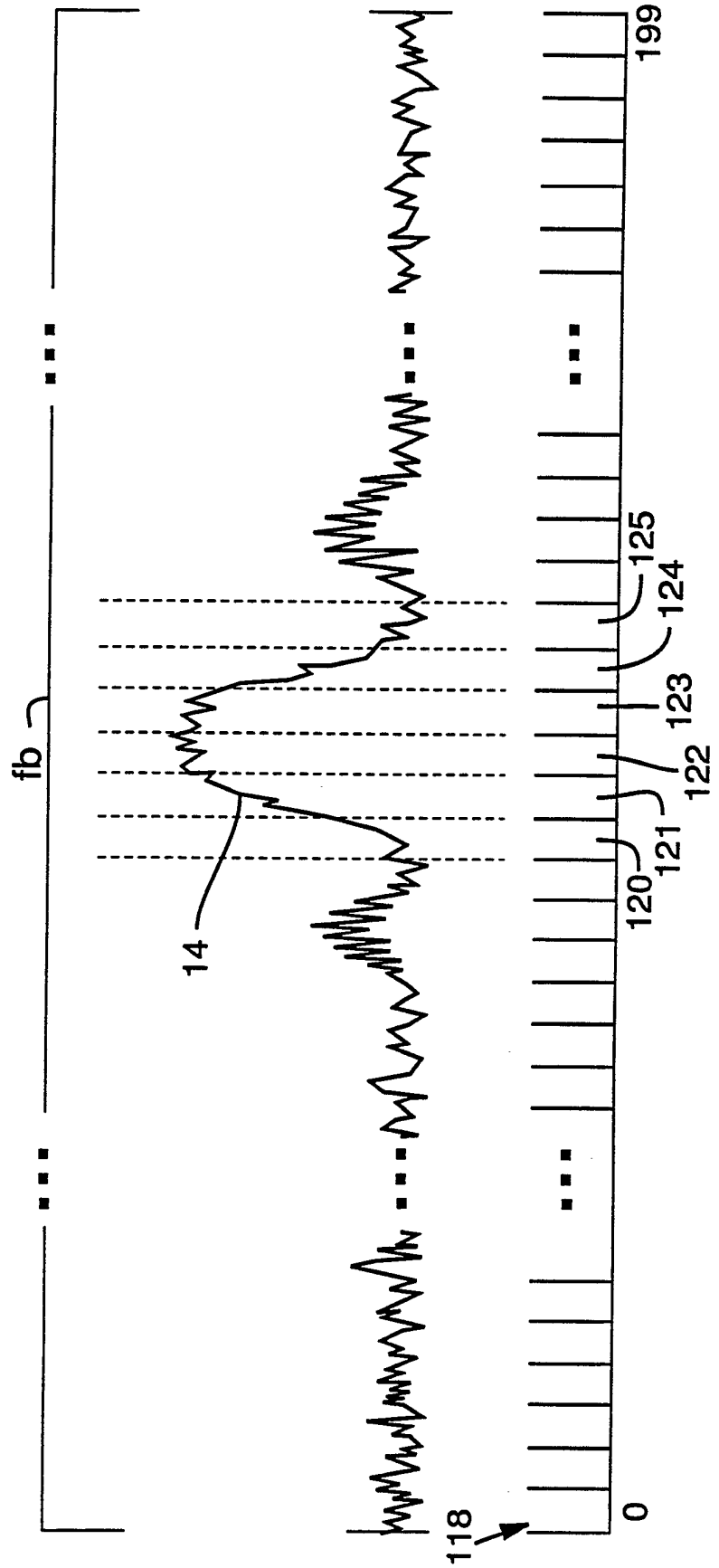
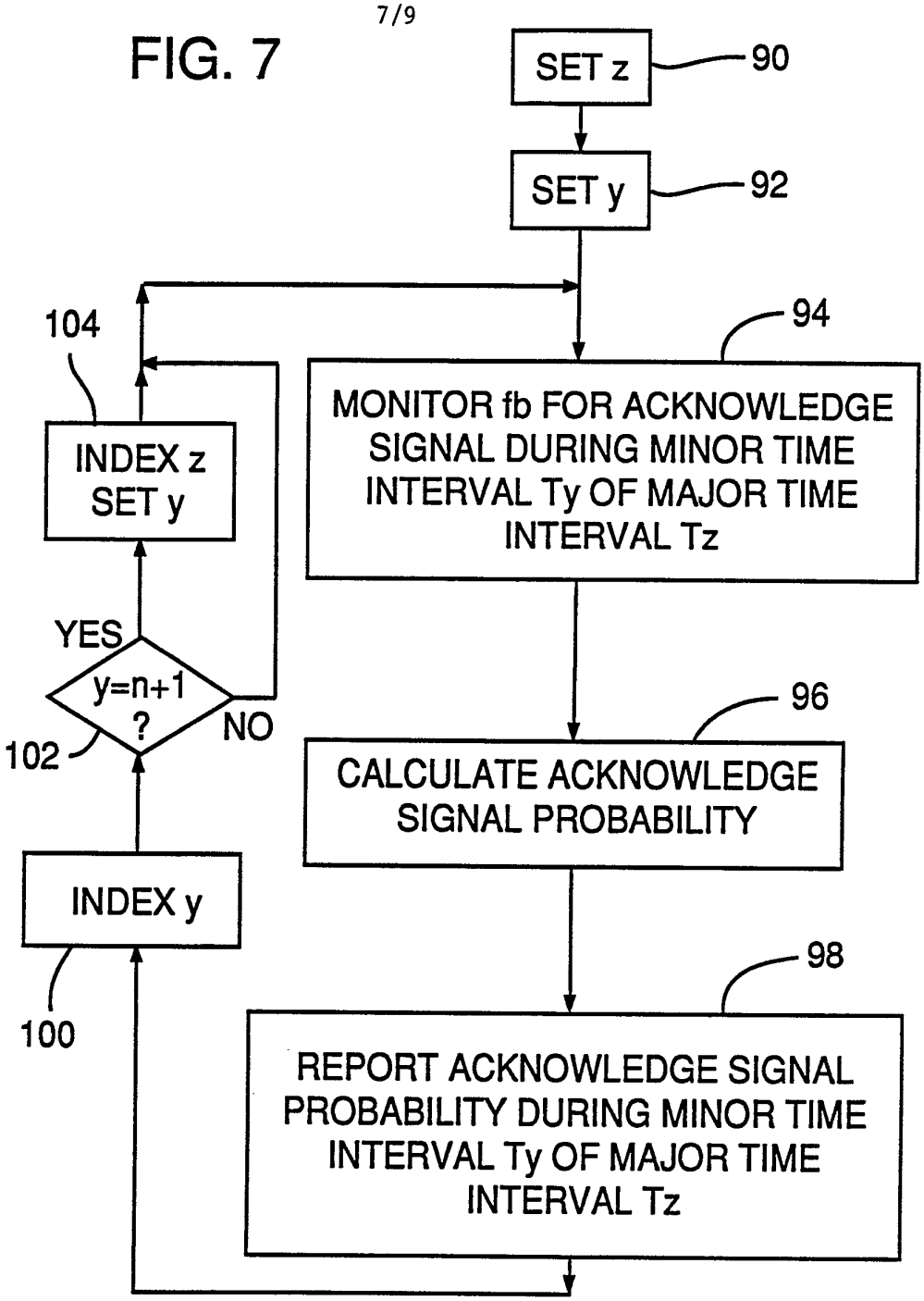


FIG. 6

FIG. 7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SET y
92
94
MONITOR fb FOR ACKNOWLEDGE SIGNAL DURING MINOR TIME INTERVAL Ty OF MAJOR TIME INTERVAL Tz
96
CALCULATE ACKNOWLEDGE SIGNAL PROBABILITY
98
REPORT ACKNOWLEDGE SIGNAL PROBABILITY DURING MINOR TIME INTERVAL Ty OF MAJOR TIME INTERVAL Tz
104
INDEX z SET y
YES
y=n+1 ?
NO
102
INDEX y
100

FIG. 8

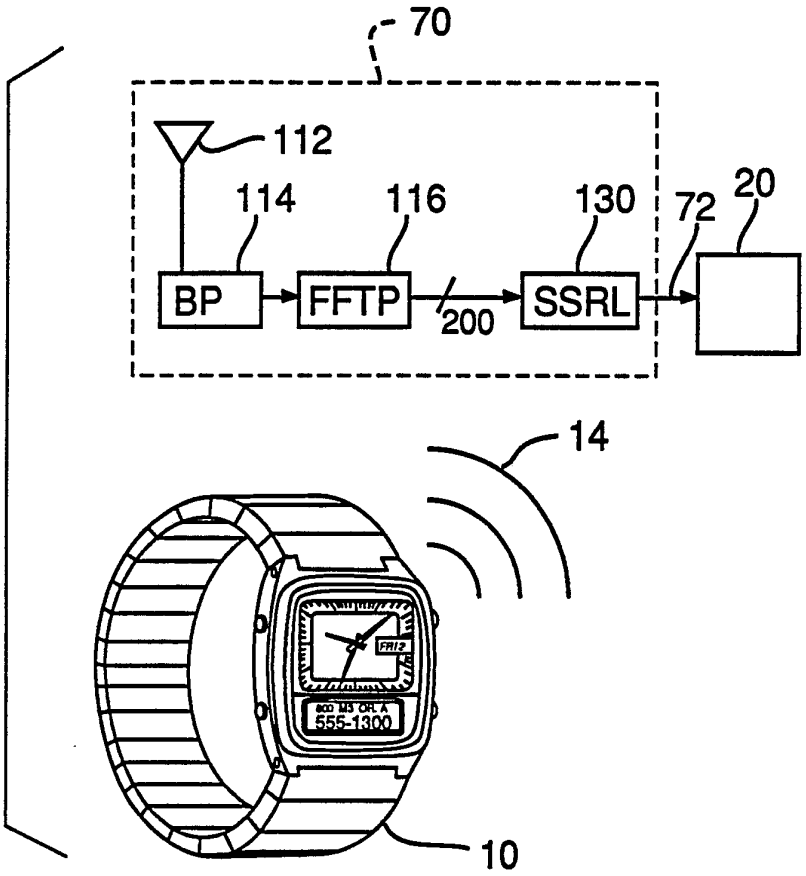
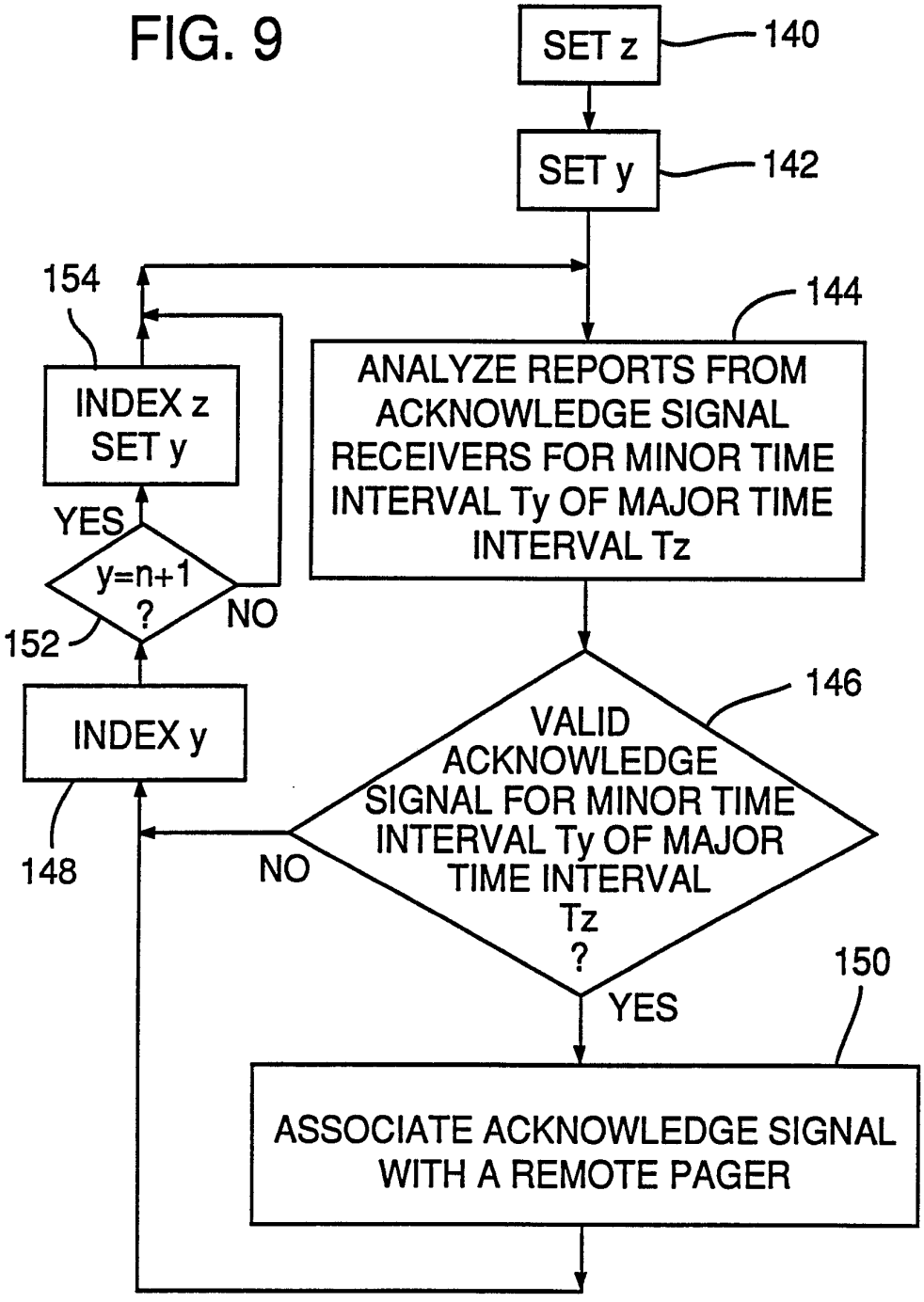


FIG. 9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SET y
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154
144
INDEX z
SET y
ANALYZE REPORTS FROM ACKNOWLEDGE SIGNAL RECEIVERS FOR MINOR TIME INTERVAL Ty OF MAJOR TIME INTERVAL Tz
YES
y=n+1
?
NO
152
INDEX y
146
VALID ACKNOWLEDGE SIGNAL FOR MINOR TIME INTERVAL Ty OF MAJOR TIME INTERVAL Tz
?
148
NO
YES
150
ASSOCIATE ACKNOWLEDGE SIGNAL WITH A REMOTE PAGER

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/04141

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

Accerding to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): H04Q 7/00
US Cl.: 340/825.44

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System [4]	Classification Symbols
US	340/825.44, 825.49, 825.54, 311.1, 502, 504 371/32

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US, A, 4,713,808 GASKILL ET AL., 15 DECEMBER 1987 See the entire document	1-13
Y	US, A, 4,604,618 AKIBA ET AL., 05 AUGUST 1986 See the entire document	1-13
Y	US, A, 4,646,082 ENGEL ET AL., 24 FEBRUARY 1987 See the entire document	7, 13
Y	US, A, 3,973,200 AKERBERG, 03 AUGUST 1976 See the entire document	1-13
Y	US, A, 3,668,640 DRISCOLL, 06 JUNE 1972 See the entire document	1-13
A	US,A, 4,754,262 HACKETT ET AL , 28 JUNE 1988 See the entire document	1-13
A P	US,A, 4,918,437 JASINAKI ET AL., 17 APRIL 1990 See the entire document	1-13

* Special categories of cited documents: [15]

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"T" later document published after the international or priority date and not in conflict with the application cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"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.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]

01 OCTOBER 1990

Date of Mailing of this International Search Report

07 JAN 1991

International Searching Authority [1]

ISA/US

Signature of Authorized Officer [20]

PETER WEISSMAN

Form PCT/ISA/210 (second sheet) (May 1986)