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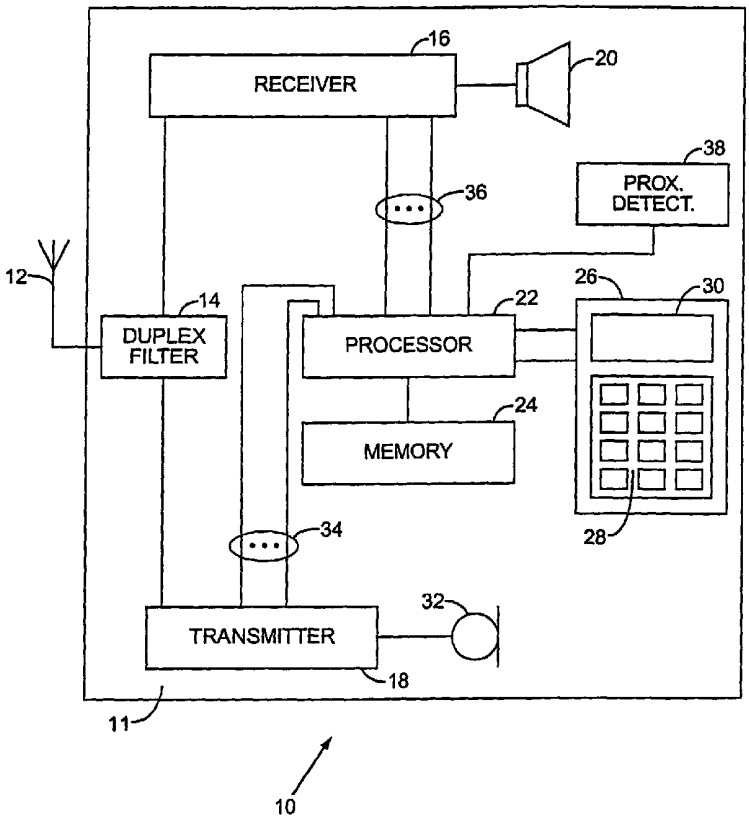
(54) Title: PORTABLE COMMUNICATION DEVICE WITH RF OUTPUT POWER CAPPED WHEN THE DEVICE OPERATES IN VERY CLOSE PROXIMITY TO A HUMAN BODY



(57) Abstract: A mobile terminal used in a wireless communication system is operable to limit transmitter power if proximate a human body. The mobile terminal includes a housing. A transmitter in the housing is connected to an antenna. The transmitter has a power control loop controlling transmitter power. A detector detects if the housing is proximate a human body. A control is operatively connected to the transmitter power control loop and to the detector, the control limiting transmitter power if the detector detects that the housing is proximate a human body.

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PORTABLE COMMUNICATION DEVICE WITH RF OUTPUT POWER CAPPED WHEN THE DEVICE OPERATES IN VERY CLOSE PROXIMITY TO A HUMAN BODY

FIELD OF THE INVENTION

This invention relates to a mobile terminal used in a wireless communication system and, more particularly, to a mobile terminal operable to limit transmitter power if proximate a human body.

BACKGROUND OF THE INVENTION

A mobile terminal used in wireless communication systems, such as cellular telephone systems, is generally a portable device. In fact, mobile terminals are becoming small enough to fit into a user's pocket, and therefore be very close to the user's body. The mobile terminal includes a transmitter for transmitting a radio frequency (RF) signal through the air.

In a cellular communication system the mobile terminal conducts radio communications with a base station located proximate the mobile terminal. Cellular communication systems include control systems for limiting power. Typically, the base station instructs the mobile terminal to use the least power to avoid interference with other mobile terminals. The base station does so by measuring signal strength and returning instructions to the mobile terminal to modify transmitter power output.

While conducting a voice call, the mobile terminal is placed in a "talk" position next to the user's head. Although there is no basis for concerns regarding an antenna being proximate the user, for psychological comfort the user can hold the mobile terminal spaced away or at an angle so that the antenna is farther from the user's head. Mobile

terminals are also used to provide wireless connection for personal computers and the like to gain access to the Internet. With smaller mobile terminals the user might slip the mobile terminal into a shirt pocket or the like while the call is being conducted.

Again, to provide psychological comfort regarding RF transmitters being very close to a human body, there is a need to control RF power output under such situations.

SUMMARY OF THE INVENTION

In accordance with the invention, there is provided a mobile terminal that caps or limits RF power output when the mobile terminal is very close to the user, and yet permit the mobile terminal to operate without a power cap otherwise.

Broadly, there is disclosed herein a portable communication device operable to limit transmitter power if proximate a human body. The device includes a housing. A transmitter in the housing is connected to an antenna. A detector detects if the housing is proximate a human body. A control is operatively connected to the transmitter and to the detector. The control controls transmitter power and limits transmitter power if the detector detects that the housing is proximate a human body.

It is a feature of the invention that the transmitter is connected to the antenna through a circulator and the detector senses reflected power from the circulator.

It is another feature of the invention that the transmitter is connected to the antenna through a directional coupler and the detector measures voltage standing wave ratio using the directional coupler.

It is a further feature of the invention that the control comprises a programmed processor and the detector is implemented by the programmed processor.

It is yet another feature of the invention that the detector comprises a photo detector proximate an opening in the housing. The photo detector is proximate a speaker

opening in the housing so that if the device is in a "talk" position next to a user's head, then amount of light at the photo detector decreases.

It is still another feature of the invention that the detector comprises a touch-sensitive detection circuit. The detection circuit comprises a conductive element proximate speaker openings in the housing so that if a device is in a "talk" position next to a user's head, then the conductive element is in contact with the user's head.

It is still a further feature of the invention that the portable communication device comprises an AMPS mobile terminal and the controller resets a mobile attenuation code if the detector detects that the housing is proximate a human body

It is still an additional feature of the invention that the control integrates transmitter power if the detector detects that the housing is proximate a human body and limits transmitter power after the integrated transmitter power exceeds a select threshold.

There is disclosed in accordance with another aspect of the invention a mobile terminal used in a wireless communication system and operable to limit transmitter power if proximate a human body. The mobile terminal includes a housing. A transmitter in the housing is connected to an antenna. The transmitter has a power control loop controlling transmitter power. A detector detects if the housing is proximate a human body. A control is operatively connected to the transmitter power control loop and to the detector, the control limiting transmitter power if the detector detects that the housing is proximate a human body. Further features and advantages of the invention will be readily apparent from the specification and from the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a mobile terminal in accordance with the invention;

Fig. 2 is a general block diagram of the mobile terminal of Fig. 1 specifically illustrating the power limiting feature of the invention;

Fig. 3 is a flow diagram illustrating a program implemented in the processor of Fig. 1 for limiting transmitter power output;

Fig. 4 is a flow diagram illustrating a program implemented in the processor of Fig. 1, in accordance with an alternative embodiment of the invention, for limiting transmitter power output;

Fig. 5 is a block diagram, similar to Fig. 2, illustrating a detector according to a first embodiment of the invention;

Fig. 6 is a block diagram, similar to Fig. 2, illustrating a detector according to a second embodiment of the invention;

Fig. 7 is a front elevation view of a mobile terminal including a detector according to a third embodiment of the invention;

Fig. 8 is a sectional view taken along the line 8-8 of Fig. 7;

Fig. 9 is a front elevation view of a mobile terminal including a detector according to a fourth embodiment of the invention; and

Fig. 10 is a sectional view taken along the line 10-10 of Fig. 9.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 is a block diagram of a typical mobile terminal shown generally at 10. The mobile terminal includes a housing 11, an antenna 12, a receiver 16, a transmitter 18, a speaker 20, a processor 22, a memory 24, a user interface 26 and a microphone 32. The antenna 12 is mounted to and can be extended from the housing 11. Alternatively, the antenna 12 could be internal to the housing 11. The antenna 12 is configured to send and receive radio signals between the mobile terminal 10 and a wireless network (not shown),

such as a cellular communications system. The antenna 12 is connected to a duplex filter 14 which enables the receiver 16 and the transmitter 18 to receive and broadcast, respectively, on the same antenna 12. The receiver 16 demodulates, demultiplexes and decodes the radio signals into one or more channels. Such channels includes a control channel and a traffic channel for speech or data. The speech or data are delivered to the speaker 20 (or other output device, such as a modem or fax connector).

The receiver 16 delivers messages from the control channel to the processor 22. The processor 22 controls and coordinates the functioning of the mobile terminal 10 responsive to messages on the control channel using programs and data stored in the memory 24, so that the mobile terminal 10 can operate within the wireless network. The processor 22 also controls the operation of the mobile terminal 10 responsive to input from the user interface 26. The user interface 26 includes a keypad 28 as a user-input device and a display 30 to give the user information. Other devices are frequently included in the user interface 26, such as lights and special purpose buttons. The processor 22 controls the operations of the transmitter 18 and the receiver 16 over control lines 34 and 36, respectively, responsive to control messages and user input.

The microphone 32 (or other data input device) receives speech signal input and converts the input into analog electrical signals. The analog electrical signals are delivered to the transmitter 18. The transmitter 18 converts the analog electrical signals into digital data, encodes the data with error-detection and correction information and multiplexes this data with control messages from the processor 22. Alternatively, the mobile terminal 10 may be connected to a laptop computer or the like which transfers digital signals to the transmitter 18. The transmitter 18 modulates this combined data stream and broadcasts the resultant radio signals to the wireless network through the duplex filter 14 and the antenna 12.

In accordance with the invention, the mobile terminal 10 includes a proximity detector 38 for detecting if the housing 11, and thus antenna 12, is proximate a human body. The detector 38 is operatively connected to the processor 22. The processor 22 operates in accordance with a control program, as described more specifically below, to limit or cap transmitter power output if the antenna 12 is proximate a human body. Particularly, the power is capped, rather than reduced, so that a power control loop operates properly when the expected transmitter power falls below the cap even though the antenna 12 is proximate the user.

Referring to Fig. 2, a block diagram illustrates the power limiting aspect of the invention. Particularly, the transmitter 18 is expanded to generally illustrate a power control loop 40 for controlling transmitter power output. A baseband block 42 generates an RF signal to be transmitted. The RF signal is provided to an RF driver stage 44. The RF driver stage 44 supplies sufficient signal level to a power amplifier 46. The power amplifier 46 amplifies the signal and provides it to the antenna 12.

The driver stage 44 and power amplifier 46 are operatively connected to the processor 22. The processor 22 conventionally controls operation of the driver stage 44 and power amplifier 46 to control transmitter power output.

In an advanced mobile phone system (AMPS), for example, the base station with which the mobile terminal 10 is communicating transmits a mobile attenuation code (MAC) identifying one of eight power levels. The processor 22 controls the power control loop 40 so that power output satisfies the MAC.

In accordance with the invention, the processor 22 implements a logic function so that if the proximity detector 38 senses that the antenna 12 is proximate the user, then the processor 22 establishes a power level cap that the power amplifier 46 is not permitted to exceed. For example, in an AMPS mobile terminal, mobile attenuation codes 000, 001,

010 and 011 could be reset to 100 if the antenna 12 is near the user. This establishes a 100-milliwatt power cap on the power amplifier 46. The other mobile attenuation codes, i.e., 100, 101, 110 and 111, would be processed unaltered, regardless of proximity to the user, as the power output amounts generated from these codes are less than the cap.

As is apparent, the power limiting feature of the invention is not limited to AMPS mobile terminals. This feature can be used with other types of mobile terminals by limiting transmitter power output using codes or commands particular to the particular type mobile terminal.

In a first aspect of the invention, the processor 22 intervenes instantaneously in the power control loop 40. Thus, as soon as proximity is detected by the detector 38, then transmit power is capped. This is illustrated in the flow diagram of Fig. 3.

The flow diagram begins at a block 50 that checks proximity using the proximity detector 38. A decision block 52 determines if the antenna 12 is proximate a user. If not, then a decision block 54 determines if power was previously capped. If not, then control loops back to the block 50. If so, then the power cap is undone at a block 56 and control then loops back to the block 50.

If the antenna 12 is proximate the user, as determined at the decision block 52, then a decision block 58 determines if power is greater than a select threshold. The threshold can be a factory-set value or user-set value that defines the power cap. In the example discussed above, the threshold is 100 milliwatts, represented by MAC 100. If power is not greater than the threshold, then it is not necessary to limit or cap power output and control loops back to the block 50. If power is greater than the threshold, then power is capped at a block 60. The power is capped by reducing the power command signals to the driver stage 44 and/or the power amplifier 46, see Fig. 2. Control then loops back to the block 50.

In accordance with a second aspect of the invention power is integrated as by accumulating sample values over time before the processor 22 intervenes. In this aspect of the invention, energy, represented by power over a specified integration interval, is the driving factor rather than power. This aspect is illustrated by the flow diagram of Fig. 4.

The flow diagram begins at a block 70 which awaits transmitter activity along with a decision block 72. If there is no activity, then control continually loops between the block 70 and the decision block 72. If there is transmitter activity, then a block 74 starts a clock. The clock is used to set a specified integration interval. A block 76 performs the integration by accumulating the product of power and time. A decision block 78 determines if the accumulated amount is greater than a select threshold. If so, then power is capped at a block 80 and the routine ends. If the accumulated amount is not greater than the select threshold, then a decision block 82 determines if the transmitter is active. If not, then the clock and accumulator are reset at a block 84 and control loops back to the block 70. If the transmitter is active, then a decision block 86 determines if the loop has reached the end of a time-based interval. If not, then control loops back to block 76 to continue the integration function. If so, then the accumulator is reset at a block 88 and control loops back to the block 76 to begin another integration interval.

The block diagram of Fig. 2 is a functional diagram illustrating power limitation in accordance with the invention. Specific embodiments for detecting proximity are illustrated below relative to Figs. 5-10. Elements corresponding to those in Fig. 2 are identified with like reference numerals and are not described in detail.

Referring initially to Fig. 5, it is known that close proximity to the user's body detunes the mobile terminal's antenna 12. In this embodiment a circulator 90 is connected between the power amplifier 46 and the antenna 12. Reflected power from the circulator 90 is measured by the processor 22. The processor 22 compares reflected power with a

select threshold. When reflected power exceeds the select threshold, then the processor 22 detects that the antenna 12 is proximate a human body.

Referring to Fig. 6, a functional block diagram illustrates a second embodiment for proximity detection. In the embodiment of Fig. 6, the power amplifier 46 is connected to the antenna 12 through directional couplers 92. The directional couplers are operatively connected to the processor 22. The processor 22 measures the voltage standing wave ratio (VSWR) using the directional couplers 92. When the VSWR exceeds a select threshold, then the processor 22 detects that the antenna 12 is proximate a human body. The VSWR is computed in accordance with the following:

$$VSWR = \frac{V_F + V_R}{V_F - V_R} = \frac{1 + \sqrt{\frac{P_R}{P_F}}}{1 - \sqrt{\frac{P_R}{P_F}}}$$

where V_F is forward voltage, V_R is reflected voltage, P_F is forward power and P_R is reflected power.

In either embodiment of Fig. 5 or Fig. 6, the processor 22 controls the power control loop 40 by establishing a power level cap that the power amplifier 46 is not permitted to exceed, as discussed above relative to Figs. 3 and 4.

Referring to Fig. 7, the mobile terminal housing 11 includes openings 94 for the speaker 20, see Fig. 1, and an opening 96 for a photodetector 98. As shown in Fig. 8, the speaker 20 and photo detector 98 are mounted to a printed circuit board 100 in the housing 11.

The photo detector 98 uses a photo-conductive element, such as cadmium selanide, whose electrical resistance decreases as incident illumination increases. The change in resistance can be detected by the processor 22, see Fig. 1, to function as a proximity detector.

The photo detector opening 96 allows light to pass through the housing 11 to the photo detector 98, as shown generally in Fig. 8. When the mobile terminal 10 is placed in the "talk" position next to the user's head, then the amount of light to the photo detector 98 decreases. The detection of this decrease in light, representing proximity of the housing 11 to a human body, can be used by the processor 22 to cap or limit output power, as discussed above. With the exception of total darkness, there is always a decrease in light when the phone is placed next to the user's head. As is apparent, if the housing 11 is proximate the user's head, then the antenna 12 is also proximate the user's head.

Alternatively, the embodiment of Fig. 7 may be operable to detect the presence of a user by incorporating a photo-conductive element that is sensitive to infrared, i.e., the thermal output of a user.

Referring to Figs. 9 and 10, the mobile terminal 10 uses proximity detection in accordance with a fourth embodiment of the invention. The housing includes a conductive element 102 surrounding the speaker openings 94. In the illustrated embodiment of the invention, the conductive element 102 is a metallic ring. The ring 102 is connected to a touch-sensitive detection circuit 104 mounted on the printed circuit board 100. When the mobile terminal 10 is placed in the "talk" position next to the user's head, then the metallic ring 102 comes in contact with the user's ear. The touch-sensitive detection circuit 104 senses this change in contact and sends a signal to the processor 22 for capping or limiting power output, as discussed above.

Thus, in accordance with the invention a proximity detector and logic functions are used for capping or limiting transmitted power output responsive to an indication of close proximity to a human body

CLAIMS

WE CLAIM:

1. A portable communication device operable to limit transmitter power if proximate a human body, comprising:

an antenna;

a transmitter connected to the antenna;

a detector for detecting if the antenna is proximate a human body; and

a control operatively connected to the transmitter and to the detector, the control controlling transmitter power and limiting transmitter power if the detector detects that the antenna is proximate a human body.

2. The portable communication device of claim 1 wherein the transmitter is connected to the antenna through a circulator and the detector senses reflected power from the circulator.

3. The portable communication device of claim 1 wherein the transmitter is connected to the antenna through a directional coupler and the detector measures voltage standing wave ratio using the directional coupler.

4. The portable communication device of claim 1 wherein the control comprises a programmed processor and the detector is implemented by the programmed processor.

5. The portable communication device of claim 1 further comprising a housing and wherein the detector comprises a photo detector proximate an opening in the housing.

6. The portable communication device of claim 5 wherein the photo detector is proximate a speaker opening in the housing so that if the device is in a talk position next to a users head, then amount of light at the photo detector decreases.

7. The portable communication device of claim 1 further comprising a housing and wherein the detector comprises a touch-sensitive detection circuit.

8. The portable communication device of claim 7 wherein the detection circuit comprises a conductive element proximate speaker openings so that if the device is in a talk position next to a users head, then the conductive element is in contact with the users head.

9. The portable communication device of claim 1 wherein the portable communication device comprises a cellular mobile terminal and the control resets a mobile attenuation code if the detector detects that the antenna is proximate a human body.

10. The portable communication device of claim 1 wherein the control integrates transmitter power if the detector detects that the antenna is proximate a human body and limits transmitter power after the integrated transmitter power exceeds a select threshold.

11. A mobile terminal used in a wireless communication system and operable to limit transmitter power if proximate a human body, comprising:

an antenna;

a housing;

a transmitter in the housing connected to the antenna, the transmitter having a power control loop controlling transmitter power;

a detector for detecting if the antenna is proximate a human body; and

a control operatively connected to the transmitter power control loop and to the detector, the control limiting transmitter power if the detector detects that the antenna is proximate a human body.

12. The mobile terminal of claim 11 wherein the transmitter is connected to the antenna through a circulator and the detector senses reflected power from the circulator.

13. The mobile terminal of claim 11 wherein the transmitter is connected to the antenna through a directional coupler and the detector measures voltage standing wave ratio using the directional coupler.

14. The mobile terminal of claim 11 wherein the control comprises a programmed processor and the detector is implemented by the programmed processor.

15. The mobile terminal of claim 11 wherein the detector comprises a photo detector proximate an opening in the housing.

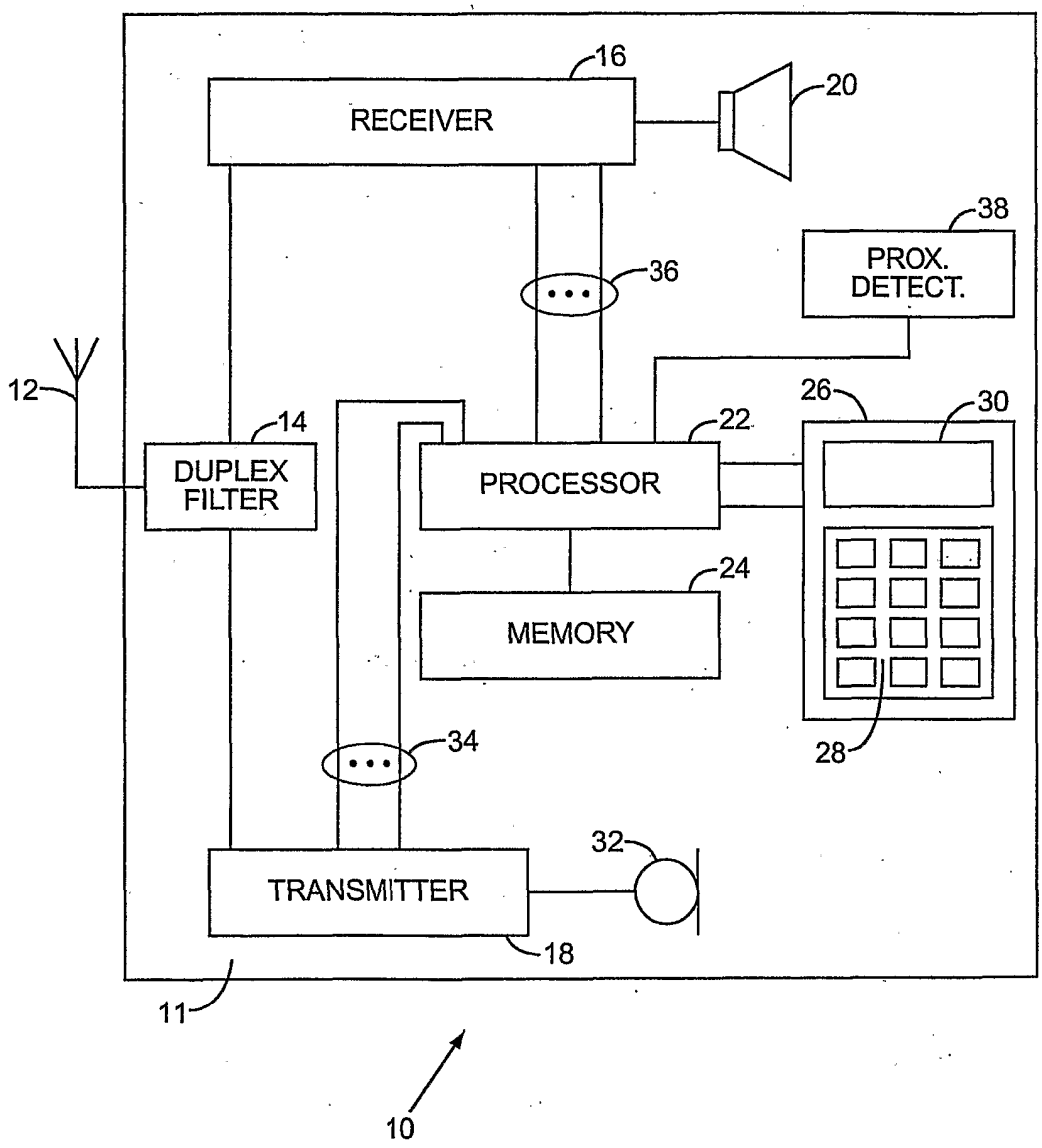
16. The mobile terminal of claim 15 wherein the photo detector is proximate a speaker opening in the housing so that if the device is in a talk position next to a user's head, then amount of light at the photo detector decreases.

17. The mobile terminal of claim 11 wherein the detector comprises a touch-sensitive detection circuit.

18. The mobile terminal of claim 17 wherein the detection circuit comprises a conductive element proximate speaker openings in the housing so that if the device is in a talk position next to a users head, then the conductive element is in contact with the users head.

19. The mobile terminal of claim 11 wherein the mobile terminal comprises a cellular mobile terminal and the control resets a mobile attenuation code if the detector detects that the antenna is proximate a human body.

20. The mobile terminal of claim 11 wherein the control integrates transmitter power if the detector detects that the antenna is proximate a human body and limits transmitter power after the integrated transmitter power exceeds a select threshold.


16
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20
38
PROX.
DETECT.
36
12
14
DUPLEX
FILTER
22
PROCESSOR
26
30
24
MEMORY
34
28
32
TRANSMITTER
18
11
10

FIG. 1

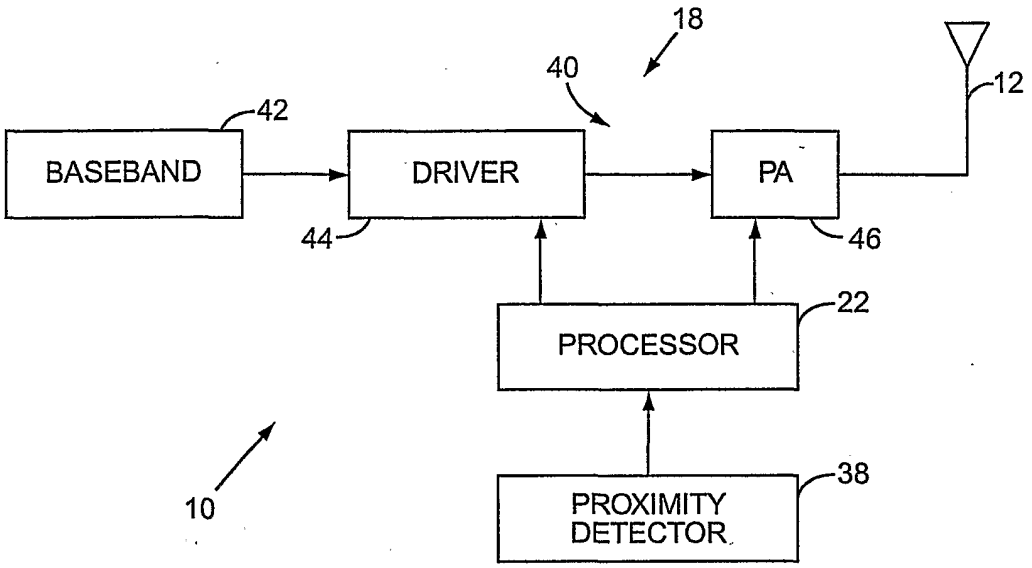
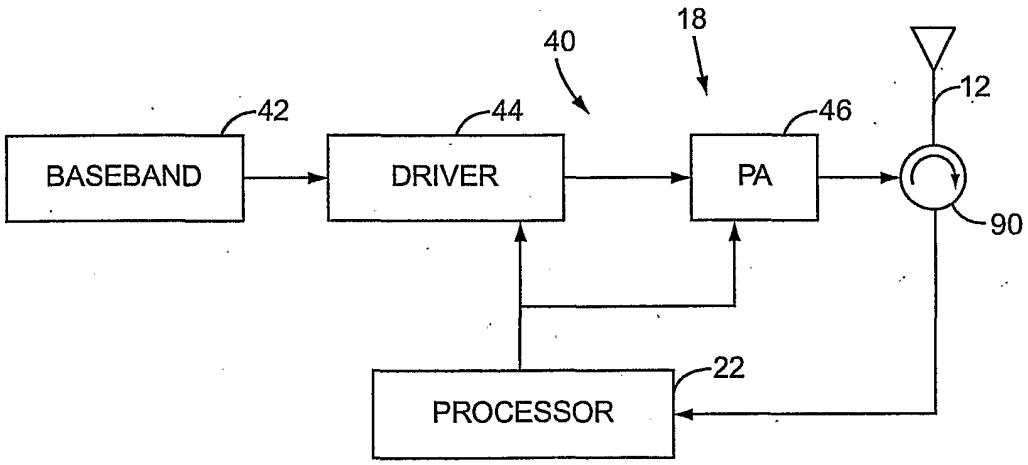

18
40
12
42
BASEBAND
DRIVER
PA
44
46
22
PROCESSOR
10
38
PROXIMITY
DETECTOR

FIG. 2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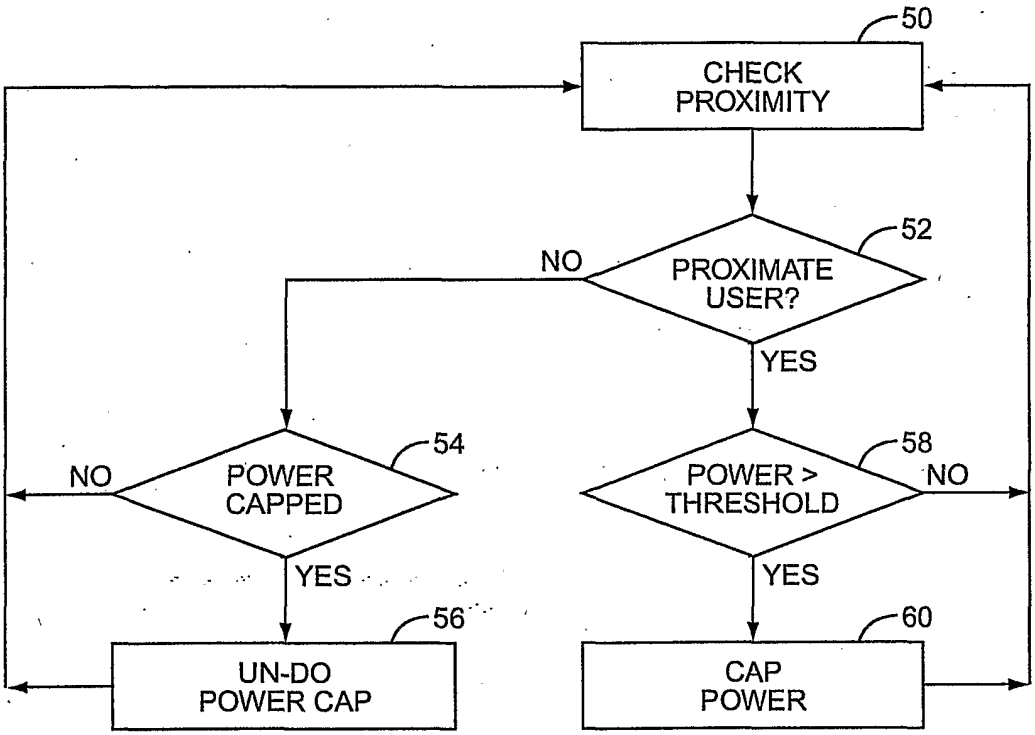
40
12
42
44
46
BASEBAND
DRIVER
PA
90
22
PROCESSOR

FIG. 5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52
PROXIMATE USER?
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YES
54
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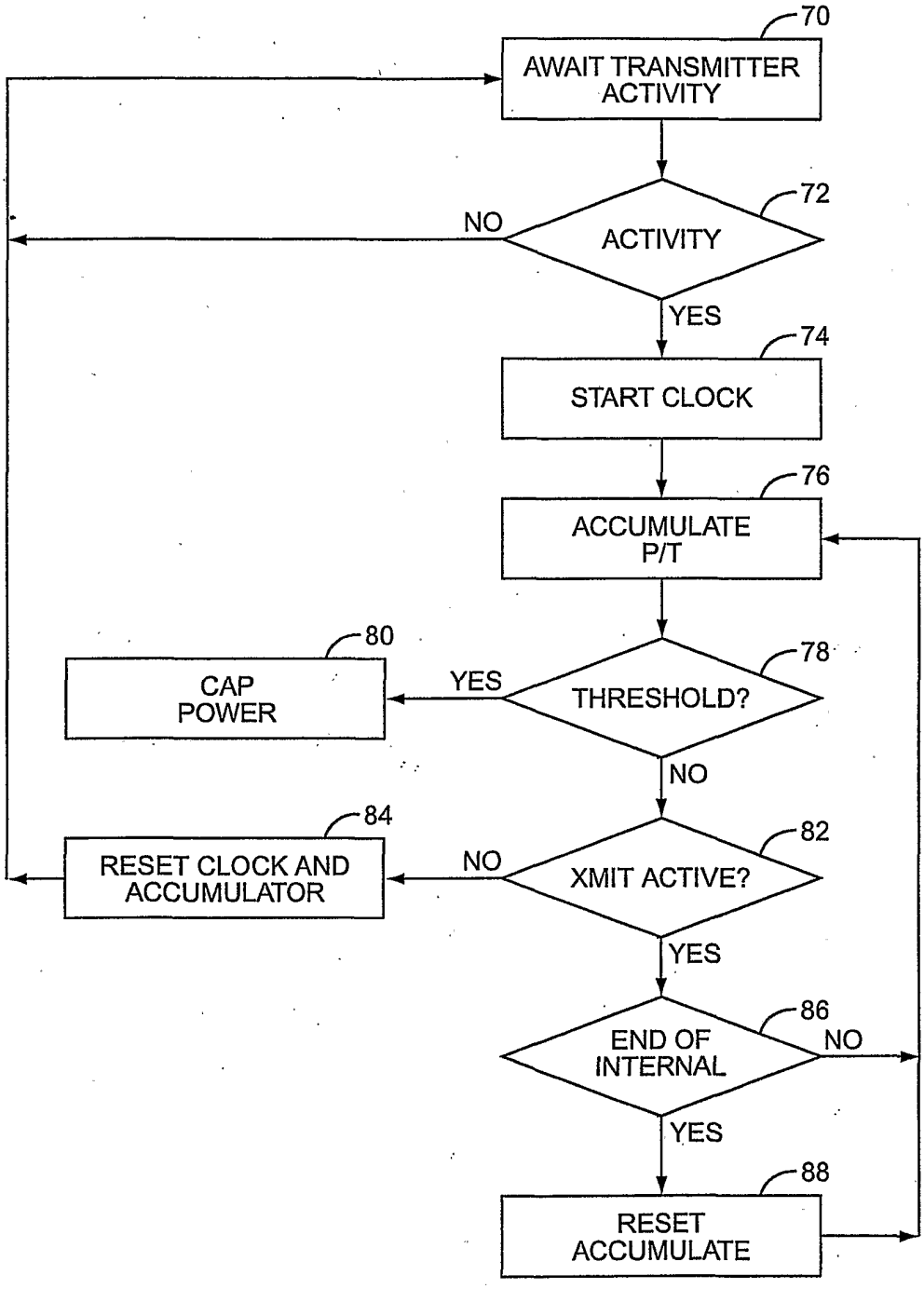
NO
YES
56
UN-DO POWER CAP
58
POWER > THRESHOLD
NO
YES
60
CAP POWER

FIG. 3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72
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YES
74
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76
ACCUMULATE P/T
80
CAP POWER
YES
78
THRESHOLD?
NO
84
RESET CLOCK AND ACCUMULATOR
NO
82
XMIT ACTIVE?
YES
86
END OF INTERNAL
NO
YES
88
RESET ACCUMULATE

FIG. 4

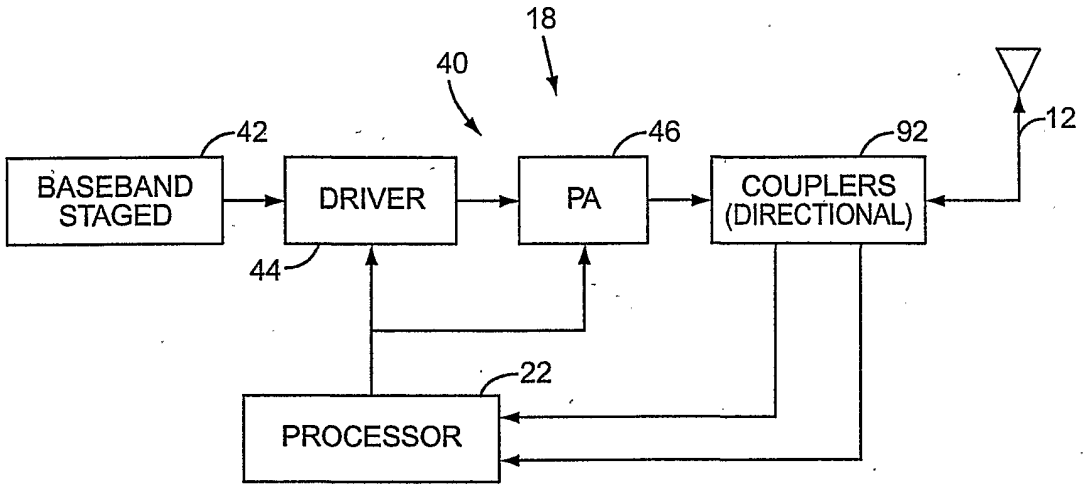

FIG. 6

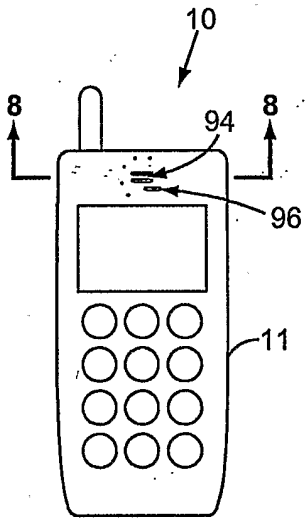

FIG. 7

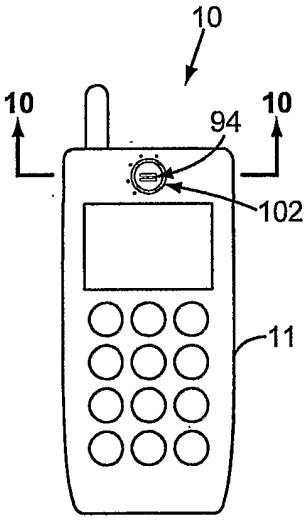

FIG. 9

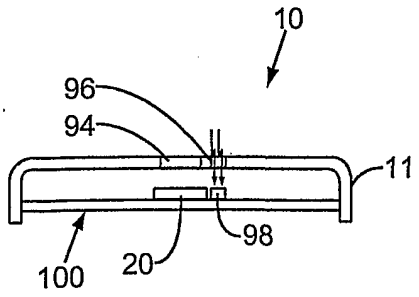

FIG. 8

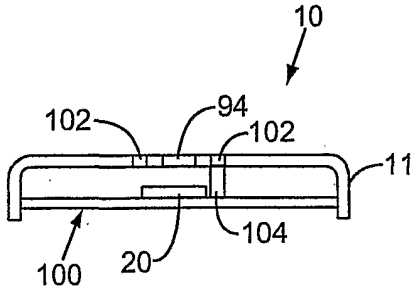

FIG. 10