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(54) Title: SYSTEM AND METHOD FOR TRANSMITTING A WI-FI OR A BLUETOOTH SIGNAL USING A SHARED TRANSMITTER

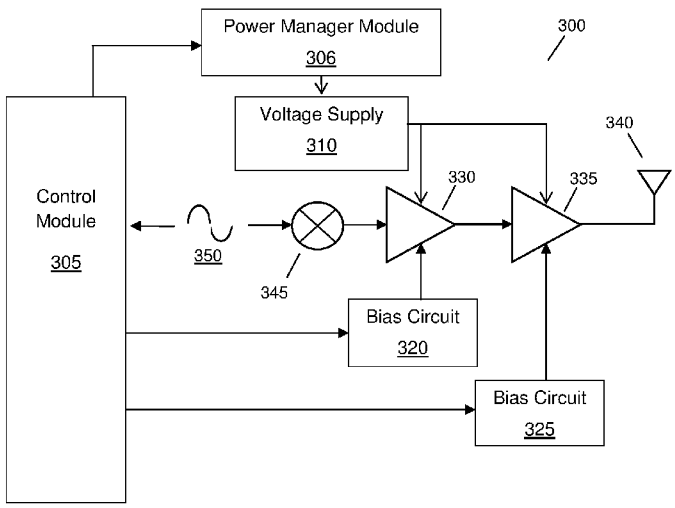

FIGURE 3

(57) Abstract: This document describes a system and method for transmitting a Wi-Fi signal or a Bluetooth signal using a shared transmitter. In particular, the system and method described in this document uses a shared transmitter to transmit a Wi-Fi signal or a Bluetooth signal whereby operating points of amplifying elements provided within the shared transmitter are selected based on the type of signal that is to be transmitted, i.e. a Wi-Fi signal or a Bluetooth signal.

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SYSTEM AND METHOD FOR TRANSMITTING A WI-FI OR A BLUETOOTH SIGNAL USING A SHARED TRANSMITTER

Field of the Invention

This invention relates to a system and method for transmitting a Wi-Fi signal or a Bluetooth signal using a shared transmitter. In particular, the invention relates to a system and method that uses a shared transmitter to transmit a Wi-Fi signal or a Bluetooth signal whereby operating points of amplifying elements provided within the shared transmitter are selected based on the type of signal that is to be transmitted, i.e. a Wi-Fi signal or a Bluetooth signal.

Summary of Prior Art

Existing mobile electronic devices such as smart phones, mobile computers, tablet computers, digital cameras, and etc. are typically configured to communicate wirelessly with other electronic devices by transmitting and receiving Wi-Fi signals and/or Bluetooth signals. For example, existing electronic devices usually connect to a wireless Local Area Network (WLAN) by sending Wi-Fi signals to access points which in turn then enable these devices to connect to the Internet and/or any other private networks. Existing electronic devices usually use Bluetooth signals to communicate with local devices such as headsets, printers, mouse, , keyboards, scanners, and the like. Wi-Fi communications are governed by the IEEE 802.11 family of standards while Bluetooth communications are governed by the IEEE 802.15 family of standards. As the overall size of electronic devices are becoming smaller and as more and more functions are integrated into these devices, there is an increasing demand for front-end-modules (FEMs) that have a single shared transmitter that is able to transmit both Wi-Fi and Bluetooth signals. By incorporating such a transmitter into front-end-modules, this will reduce the overall chip size, minimize costs and simplify hardware system solutions for the module.

In mobile devices, scheduled non-concurrent coexistence of transmitted 2.4 GHz Wi-Fi/Bluetooth signals are preferred over concurrent transmissions of these signals. To obtain optimal throughput performance in non-concurrent mode, a technique of scheduled coexistence mode (SCM) is applied to schedule Wi-Fi and Bluetooth traffic to avoid the occurrence of radio frequency (RF) signal collisions. SCM minimizes RF packet collision by dynamically adjusting the scheduling of Bluetooth and Wi-Fi packets based on packet type. As Bluetooth commonly supports control, audio and/or video applications, Bluetooth signals or packets warrant a higher priority than Wi-Fi signals. Wi-Fi signals are then only transmitted during a Bluetooth idle period, when no Bluetooth data packets are being transmitted or received. In non-concurrent transmission, Wi-Fi and Bluetooth signals are not transmitted simultaneously; therefore these signals may share a single antenna, and the RF transceivers can be merged extensively without sacrificing throughput performance.

In order to incorporate the function of transmitting Wi-Fi and Bluetooth signals using a single transmitter; those skilled in the art have proposed the use of a single shared external front end module (FEM) for the non-concurrent transmission of these signals. In operation, a single power amplifier in the front end module is shared between the Wi-Fi and Bluetooth signal transmission paths. By selectively issuing control signals to an interface circuitry in the FEM, an output from the Wi-Fi transmitter or an output from the Bluetooth transmitter is then selectively coupled to the input of the power amplifier. The output of the power amplifier is then subsequently coupled to the FEM's antenna. In the receive direction, the interface circuitry steers the antenna input to the respective Wi-Fi or Bluetooth receivers based on the received control signals.

When the FEM is configured to be in Wi-Fi mode, a Wi-Fi power amplifier will be utilized to transmit the high power Wi-Fi signal. When the FEM is configured to be in Bluetooth mode, the Wi-Fi power amplifier will be bypassed and the Bluetooth signal will be directly transmitted instead. The downside of such an arrangement is that the FEM has to incorporate switching mechanisms into the FEM, which take up valuable space in the FEM. Another disadvantage is that the external FEM will also require an additional switch to be connected in series with the antenna to allow the transmission path to be switched between Wi-Fi and Bluetooth signal transmissions. This additional switch is deleterious because it contributes to the FEM's loss and results in higher power consumption.

Another system that has been proposed by those skilled in the art is a shared Bluetooth and Wi-Fi transmitter chain having a dedicated Power Amplifier for transmitting Wi-Fi signals whereby this Power Amplifier may be bypassed when a Bluetooth signal is to be transmitted. The main drawback of such a system is that an additional Power Amplifier stage has to be designed for the transmission of Wi-Fi signals and this takes up valuable die space on the chip. Furthermore, the switch which allows the transmission mode to be changed between Wi-Fi and Bluetooth modes involves a complex balun with three differential terminal outputs.

For the above reasons, those skilled in the art are constantly striving to come up with a system and method that allows Wi-Fi and Bluetooth signals to be transmitted using shared hardware when a non-concurrent transmission scheme is adopted.

Summary of the Invention

We provide systems and methods to improve the efficiency of shared hardware for the non-concurrent transmission of Wi-Fi and Bluetooth signals from a single antenna in accordance with embodiments of the invention.

A first advantage of embodiments of systems and methods in accordance with the invention is that a single shared hardware may be used for the non-concurrent transmission of Wi-Fi and Bluetooth signals.

A second advantage of embodiments of systems and methods in accordance with the invention is that the shared transmission path does not require the use of lossy switches in order to switch the shared hardware between Wi-Fi transmission mode and Bluetooth transmission mode.

A third advantage of embodiments of systems and methods in accordance with the invention is that the single shared hardware requires less chip space and hence simplifies the overall design of the FEM.

The above improvements are provided by embodiments of a method in accordance with the invention operating in the following manner.

According to a first aspect of the invention, a method for non-concurrent transmission of a Wi-Fi signal and a Bluetooth signal using shared hardware comprises coupling an output from a first amplifying element to an input of a second amplifying element; coupling an output from the second amplifying element to an output of the shared hardware; receiving a transmission request signal at an input of the first amplifying element; determining if the received transmission request signal comprises a Wi-Fi signal or a Bluetooth signal; if the received transmission request signal comprises a Wi-Fi signal, operating the first amplifying element in a high gain mode and operating the second amplifying element in a high current mode; and if the received transmission request signal comprises a Bluetooth signal, operating the first amplifying element in a low gain mode and operating the second amplifying element in a low current mode

With reference to the first aspect, in a first possible implementation of the first aspect, the first amplifying element comprises a first cascoded differential amplifier and the second amplifying element comprises a second cascoded differential amplifier.

With reference to the first possible implementation manner of the first aspect, in a second possible implementation manner of the first aspect, the first cascoded differential amplifier comprises a first amplifier operating as a Class A amplifier and a second amplifier operating as a Class B amplifier.

With reference to the first possible implementation manner of the first aspect, in a third possible implementation manner of the first aspect, the second cascoded differential amplifier comprises a first amplifier operating as a Class A amplifier and a second amplifier operating as a Class B amplifier.

With reference to the first aspect, in a fourth possible implementation of the first aspect, the operating the first amplifying element in the high gain mode and the operating the second amplifying element in the high current mode comprises biasing the first and the second amplifying elements with a drain voltage of at least 3.0 Volts.

With reference to the first aspect, in a fifth possible implementation manner of the first aspect, the operating the first amplifying element in the low gain mode and the operating the second amplifying element in the low current mode comprises biasing the first and the second amplifying elements with a drain voltage of less than 1.7 Volts.

With reference to the first aspect, in a sixth possible implementation manner of the first aspect, the coupling the output from the first amplifying element to the input of a second amplifying element further comprises inverting the output from the first amplifying element by 180 degrees; coupling the output from the first amplifying element to an input of a third cascoded differential amplifier; coupling the inverted output from the first amplifying element to an input of a fourth cascoded differential amplifier; whereby an output of the third cascoded differential amplifier is coupled to a first input of a differential to single end balun, an output of the fourth cascoded differential amplifier is coupled to a second input of the differential to single end balun, and an output of the differential to single end balun is coupled to the output of the shared hardware.

According to a second aspect of the invention, a device for non-concurrent transmission of a Wi-Fi signal and a Bluetooth signal is provided, the device comprising: a first amplifying element having an output coupled to an input of a second amplifying element, the first amplifying element configured to: receive a transmission request signal at an input of the first amplifying element; a control circuitry coupled to the first and second amplifying elements, the control circuitry configured to: determine if the received transmission request signal at the input of the first amplifying element comprises a Wi-Fi signal or a Bluetooth signal; operating the first amplifying element in a high gain mode and operating the second amplifying element in a high current mode when the received transmission request signal comprises a Wi-Fi signal; and operating the first amplifying element in a low gain mode and operating the second amplifying element in a low current mode when the received transmission request signal comprises a Bluetooth signal.

With reference to the second aspect, in accordance with embodiments of the invention, the first amplifying element comprises a first cascoded differential amplifier and the second amplifying element comprises a second cascoded differential amplifier.

With reference to the second aspect, in accordance with embodiments of the invention, the first cascoded differential amplifier comprises a first amplifier operating as a Class A amplifier and a second amplifier operating as a Class B amplifier.\

With reference to the second aspect, in accordance with embodiments of the invention, the second cascoded differential amplifier comprises a first amplifier operating as a Class A amplifier and a second amplifier operating as a Class B amplifier.

With reference to the second aspect, in accordance with embodiments of the invention, the operating the first amplifying element in the high gain mode and the operating the second amplifying element in the high current mode comprises: the control circuitry being configured to: bias the first and the second amplifying elements with a drain voltage of at least 3.0 Volts.

With reference to the second aspect, in accordance with embodiments of the invention, the operating the first amplifying element in the low gain mode and the operating the second amplifying element in the low current mode comprises: the control circuitry being configured to: bias the first and the second amplifying elements with a drain voltage of less than 1.7 Volts.

With reference to the second aspect, in accordance with embodiments of the invention, the device further comprising: an inverter provided at the output of the first amplifying element, the inverter configured to: invert the output from the first amplifying element by 180 degrees; couple the inverted output from the first amplifying element to an input of a fourth cascoded differential amplifier; couple the output from the first amplifying element to an input of a third cascoded differential amplifier; and a differential to single end balun configured to: receive an output of the third cascoded differential amplifier using a first input of the differential to single end balun; receive an output of the fourth cascoded differential amplifier using a second input of the differential to single end balun; and couple an output of the differential to single end balun to an input of an antenna.

Brief Description of the Drawings

The above and other problems are solved by features and improvements of a system and method in accordance with the present invention described in the detailed description and shown in the following drawings.

Figure 1 illustrating electronic devices within which embodiments of the invention may be utilized;

Figure 2 illustrating a block diagram representative of processing systems providing embodiments in accordance with embodiments of the invention;

Figure 3 illustrating a high level block diagram of modules provided within an electronic device for non-concurrent transmission of Wi-Fi and Bluetooth signals in accordance with embodiments of the invention;

Figure 4 illustrating a circuit diagram of a cascoded differential amplifier in accordance with embodiments of the invention; and

Figure 5 illustrating a flow diagram of a process for non-concurrent transmission of a Wi-Fi and a Bluetooth signal using shared hardware in accordance with embodiments of the invention.

Detailed Description

This invention relates to a system and method for transmitting a Wi-Fi signal or a Bluetooth signal using a single shared transmitter path in a Front-End-Module (FEM). In particular, the invention relates to a system and method that uses a shared transmitter to transmit a Wi-Fi signal or a Bluetooth signal whereby operating points of amplifying elements provided within the shared transmitter are selected based on the type of signal that is to be transmitted, i.e. a Wi-Fi signal or a Bluetooth signal. Further, the shared transmitter does not require the use of lossy switches in the transmission path to switch between Wi-Fi transmission and Bluetooth transmission modes thereby improving the overall efficiency of the system.

One skilled in the art will recognize that many functional units in this description have been labelled as modules throughout the specification. The person skilled in the art will also recognize that a module may be implemented as circuits, logic chips or any sort of discrete component. Further, one skilled in the art will also recognize that a module possibly may be implemented in software which may then be executed by a variety of processors. In embodiments of the invention, a module may also comprise computer instructions or executable code that may instruct a computer processor to carry out a sequence of events based on instructions received. The choice of the implementation of the modules is left as a design choice to a person skilled in the art and does not limit the scope of this invention in any way.

The following description describes the transmission of Wi-Fi signals and Bluetooth signals through shared hardware that includes two amplifying elements that are coupled in series to an antenna. One skilled in the art should recognize that such an arrangement is selected for simplicity only and the person skilled in the art would understand that other various wireless standards or protocols may also be transmitted using this shared hardware arrangement without departing from this invention. Further, the person skilled in the art would also understand that the term “coupled” as used throughout the description relates to an act of connecting directly to or connecting through one or more intervening components or circuits with the objective of transmitting through electrical signals. Furthermore, it should be noted that any of the signals provided over various buses described herein may be time-multiplexed with other signals and provided over one or more common buses. These buses may comprise a single signal line, and a single line or bus might represent any one or more means for establishing a connection between various components or modules in a system in accordance with embodiments of the invention.

Figure 1 illustrates system 100 comprising electronic devices that utilize both Wi-Fi signals and Bluetooth signals to perform an assortment of communicative functions. In particular, system 100 comprises mobile computer 105 and mobile electronic device 110 that may be configured to use a single shared hardware to non-concurrently transmit Wi-Fi and Bluetooth signals. Although Figure 1 only illustrates these two types of electronic devices, one skilled in the art will recognize that mobile computer 105 and mobile electronic device 110 may be replaced with any wireless enabled electronic device having an electronic module provided within that enables the device to carry out wireless communications using at least the Wi-Fi and Bluetooth standards together with the usual computing functions. Such devices include, but are not limited to, smartphones, tablet computers, netbooks, wearable electronic devices such as smart watch, and etc.

In system 100, mobile device 110 is configured to communicate with mobile computer 105 which is located near to mobile device 110 using Bluetooth signals. Mobile device 110 utilizes Bluetooth signals to communicate with mobile computer 105 because the Bluetooth standard allows mobile device 110 to communicate with several other local devices simultaneously without facing any synchronization issues. Mobile device 110 and mobile computer 105 are also both configured to wirelessly communicate to the Internet or wireless networks via Wi-Fi access points using the Wi-Fi standard.

Figure 2 illustrates a block diagram representative of components of processing system 200 that may be provided within any electronic device described in Figure 1 or any wireless enabled electronic device for implementing personifications in accordance with embodiments of the invention. One skilled in the art will recognize that the exact configuration of each processing system provided within these electronic devices may be different and the exact configuration of processing system 200 may vary and Figure 2 is provided by way of example only.

In embodiments of the invention, module 200 comprises controller 201 and user interface 202. User interface 202 is arranged to enable manual interactions between a user and module 200 and for this purpose includes the input/output components required for the user to enter instructions to control module 200. A person skilled in the art will recognize that components of user interface 202 may vary from embodiment to embodiment but will typically include one or more of display 240, keyboard 235 and track-pad 236.

Controller 201 is in data communication with user interface 202 via bus 215 and includes memory 220, processor 205 mounted on a circuit board that processes instructions and data for performing the method of this embodiment, an operating system 206, an input/output (I/O) interface 230 for communicating with user interface 202 and a communications interface, in this embodiment in the form of a network card 250. Network card 250 may, for example, be utilized to send data from electronic device 200 via a wired or wireless network to other processing devices or to receive data via the wired or wireless network. Wireless networks that may be utilized by network card 250 include, but are not limited to, Wireless-Fidelity (Wi-Fi), Bluetooth, Near Field Communication (NFC), cellular networks, satellite networks, telecommunication networks, Wide Area Networks (WAN) and etc.

Memory 220 and operating system 206 are in data communication with CPU 205 via bus 210. The memory components include both volatile and non-volatile memory and more than one of each type of memory, including Random Access Memory (RAM) 220, Read Only Memory (ROM) 225 and a mass storage device 245, the last comprising one or more solid-state drives (SSDs). Memory 220 also includes secure storage 246 for securely storing secret keys, or private keys. It should be noted that the contents within secure storage 246 are only accessible by a super-user or administrator of module 200 and may not be accessed by any user of module 200. One skilled in the art will recognize that the memory components described above comprise non-transitory computer-readable media and shall be taken to comprise all computer-readable media except for a transitory, propagating signal. Typically, the instructions are stored as program code in the memory components but can also be hardwired. Memory 220 may include a kernel and/or programming modules such as a software application that may be stored in either volatile or non-volatile memory.

Herein the term “processor” is used to refer generically to any device or component that can process such instructions and may include: a microprocessor, microcontroller, programmable logic device or other computational device. That is, processor 205 may be provided by any suitable logic circuitry for receiving inputs, processing them in accordance with instructions stored in memory and generating outputs (for example to the memory components or on display 240). In this embodiment, processor 205 may be a single core or multi-core processor with memory addressable space. In one example, processor 205 may be multi-core, comprising—for example—an 8 core CPU.

Figure 3 illustrates Front-End-Module (FEM) 300 that may be provided within an electronic device for non-concurrent transmission of Wi-Fi and Bluetooth signals in accordance with embodiments of the invention. FEM 300 includes first amplifying element 330, second amplifying element 335 and antenna 340. An output of first amplifying element 330 is coupled to an input of second amplifying element 335 and an output of the second amplifying element 335 is coupled to antenna 340. Biasing circuit 320 is configured to provide the DC bias for amplifying element 330 while biasing circuit 325 is similarly configured to provide the DC bias for amplifying element 335. Biasing circuit 320 and 325 are both connected to control module 305 and this module is configured to vary the biasing currents provided by biasing circuits 320 and 325. In embodiments of the invention, control module 305 may vary the biasing current provided by biasing circuits 320 and 325 by changing the voltage supplied to these two biasing circuits accordingly.

Control module 305 is also connected to power manager module 306. This module is configured to control the voltage provided by voltage supply 310 to amplifying elements 330 and 335. Depending on the signal received from power manager module 306, voltage supply 310, which is connected to both amplifying elements 330 and 335, will provide a voltage of at least 3.0 Volts to amplifying elements 330 and 335 or a voltage of less than 1.7 Volts to amplifying elements 330 and 335. In embodiments of the invention, voltage supply 310 is preferably configured to provide either 3.3 Volts or 1.4 Volts to amplifying elements 330 and 335.

Control module 305 is able to control the operating points of amplifying elements 330 and 335 by controlling the voltage supplied by voltage supply 310 and by controlling the currents provided by biasing circuits 320 and 325 respectively. For example, if a large peak-to-peak voltage swing is to be amplified by amplifying elements 330 and 335, then the operating points of these two amplifying elements have to be increased accordingly and the voltage and biasing currents supplied to these two amplifying elements have to be increased as required.

Conversely, if a low peak-to-peak voltage swing is to be amplified instead, the operating points of amplifying elements 330 and 334 will be lowered instead by lowering the voltage and biasing currents supplied to these two amplifying elements accordingly. This lowers the overall gain but improves the overall efficiency of FEM 300 during Bluetooth transmission mode.

In embodiments of the invention, the operating points of amplifying elements 330 and 335 are typically set to ensure that the input signal coupled to the inputs of these amplifying elements always remain below the threshold voltage of these two amplifying elements. This ensures that amplifying elements 330 and 335 will always operate in a linear manner. It is important to ensure that amplifying elements 330 and 335 operate in the linear region, especially during the transmission of Wi-Fi signals, so that the amplitude of the output signal from the amplifying elements is proportional to the amplitude of the input signal provided to these amplifying elements. When this happens, it means that a relatively constant gain is provided by these amplifying elements for various values of the input signal. If the input signal to amplifying elements 330 and 335 increases beyond the threshold voltage set for these amplifying elements, the overall transfer function of these amplifying elements becomes non-linear and begins to level off, thereby decreasing the amplifier gain as the input voltage increases beyond the threshold voltage. Therefore, in accordance with embodiments of the invention, it is important that amplifying elements 330 and 335 operate in a linear manner during the transmission of RF signals in order to minimize undesirable out-of-band signals such as first or third order intermodulation products that may cause distortion of the data that is transmitted.

Before signal 350 (i.e. the signal that is to be transmitted) is coupled to the input of amplifying element 330, signal 350 is provided to an input of passive mixer 345. Passive mixer 345 up converts signal 350 into the RF band and then provides the up-converted RF signal to the input of amplifying element 330. In embodiments of the invention, signal 350 may be low-pass filtered before signal 350 is provided to mixer 345. This ensures that any high frequency spurious signals will be removed from signal 350.

In operation, when control module 305 detects signal 350, i.e. a signal that is to be transmitted by FEM 300, control module 305 will first determine if signal 350 comprises a Wi-Fi signal or a Bluetooth signal. In the situation whereby signal 350 is a Wi-Fi signal, control module 305 will instruct power manager module 306 to configure voltage supply 310 to provide at least 3.0 Volts, or preferably 3.3 Volts, to amplifying elements 330 and 335. Simultaneously, control module 305 will control biasing circuits 320 and 325 to provide a sufficient biasing DC current to amplifying elements 330 and 335 respectively. In other words, the operating points of these two amplifying elements will be set to a sufficiently high level so that these two amplifying elements will operate in a linear manner when the Wi-Fi signal is received at the input of amplifying element 330. Once amplifying elements 330 and 335 have been provided with the appropriate biasing currents and supply voltage, amplifying element 330 will work in high gain mode while amplifying element 335 will work in high current mode. The amplified signal 350 is then coupled from the output of amplifying element 335 to antenna 340 where the signal is then radiated to its target.

Alternatively, when control module 305 determines that signal 350 comprises a Bluetooth signal, control module 305 will instruct power manager module 306 to configure voltage supply 310 to provide less than 1.7 Volts, or preferably 1.4 Volts, to amplifying elements 330 and 335. Simultaneously, control module 305 will control biasing circuits 320 and 325 to provide a lower DC biasing current to amplifying elements 330 and 335 respectively. In other words, the operating points of these two amplifying elements will be set to a lower level as a Bluetooth signal has a lower peak-to-peak voltage as compared to a Wi-Fi signal. It should be noted that even though these two amplifying elements are biased to have lower operating points, these two amplifying elements will still operate in a linear manner when the Bluetooth signal is received at the input of amplifying element 330. Once amplifying elements 330 and 335 have been provided with the appropriate biasing currents and supply voltage, amplifying element 330 will work in low gain mode while amplifying element 335 will work in low current mode. The amplified signal 350 is then coupled from the output of amplifying element 335 to antenna 340 where the signal is then radiated to its intended receiver.

In embodiments of the invention, amplifying elements 330 and 335 may comprise a cascoded differential amplifier. A circuit diagram of such a cascoded differential amplifier is illustrated in Figure 4. Cascoded differential amplifier 400 comprises power amplifier 402 that is connected in a differential configuration with power amplifier 404. Power amplifiers 402 and 404 are both connected to power amplifier 406 in a cascode connection whereby amplifier 406 acts as an active load for these two power amplifiers. Biasing circuit 412 is used to set the DC bias for power amplifier 402, biasing circuit 414 is used to set the DC bias for power amplifier 404 and biasing circuit 410 is used to set the DC bias for power amplifier 406. Further, it should be noted that biasing circuit 412 biases power amplifier 402 as a Class A amplifier while biasing circuit 414 biases power amplifier 404 as a Class B amplifier. In operation, signal 350 (from Figure 3) would be applied to nodes A and B and the amplified output would be obtained from node “Out”.

In another embodiment of the invention, amplifying elements 330 and 335 each comprise two cascoded differential amplifiers 400. In this embodiment of the invention, signal 350 would be coupled to nodes A and B of the first cascoded differential amplifier while an inverted signal 350 would be coupled to nodes A and B of the second cascoded differential amplifier. The output from the first cascoded differential amplifier would then be coupled to a first input of a differential-to-single end balun (not shown) while the output from the second cascoded differential amplifier would be coupled to a second input of the differential-to-single end balun. An output from the differential-to-single end balun is then coupled to either the input of the series amplifying element or the antenna.

In accordance with embodiments of the invention, a method for non-concurrent transmission of a Wi-Fi signal and a Bluetooth signal using shared hardware comprises the following six steps:

Step 1, coupling an output from a first amplifying element to an input of a second amplifying element;

Step 2, coupling an output from the second amplifying element to an input of an antenna;

Step 3, receiving a transmission request signal at an input of the first amplifying element;

Step 4, determining if the received transmission request signal comprises a Wi-Fi signal or a Bluetooth signal;

Step 5, if the received transmission request signal comprises a Wi-Fi signal, operating the first amplifying element in a high gain mode and operating the second amplifying element in a high current mode; and

Step 6, if the received transmission request signal comprises a Bluetooth signal, operating the first amplifying element in a low gain mode and operating the second amplifying element in a low current mode.

In embodiments of the invention, a process is needed for the non-concurrent transmission of a Wi-Fi signal and a Bluetooth signal using shared hardware. The following description and Figure 5 describes an embodiment of a process in accordance with this invention.

Figure 5 illustrates process 500 that is performed by a FEM within an electronic device to transmit in a non-concurrent manner Wi-Fi and Bluetooth signals using shared hardware within the FEM. Process 500 begins at step 505 by receiving a transmission request. Process 500 analyses the received transmission request and determines at step 510 whether the request comprises a Bluetooth signal or a Wi-Fi signal.

If the request comprises a Bluetooth signal, process 500 proceeds to step 535 whereby process 500 causes a supply voltage, or a drain voltage of less than 1.70 Volts be supplied to amplifying elements in the FEM. Process 500 then causes biasing circuits supplying biasing currents to the amplifying elements to operate in low current mode. This takes place at step 540. At step 545, once the biasing currents and the supply voltage have been provided to the amplifying elements, process 500 then configures the amplifying elements to operate in low gain and low current mode. Process 500 then couples the received signal through the amplifying elements and transmits the amplified signal at step 550. Process 500 then ends.

Alternatively, if the request comprises a Wi-Fi signal, process 500 proceeds to step 515 whereby process 500 causes a supply voltage, or a drain voltage at least 3.0 Volts be supplied to amplifying elements in the FEM. Process 500 then causes biasing circuits supplying biasing currents to the amplifying elements to operate in high current mode. This takes place at step 520. At step 525, once the biasing currents and the supply voltage have been provided to the amplifying elements, process 500 then configures the amplifying elements to operate in high gain and high current mode. Process 500 then couples the received signal through the amplifying elements and transmits the amplified signal at step 530. Process 500 then ends.

The above is a description of embodiments of a system and process in accordance with the present invention as set forth in the following claims. It is envisioned that others may and will design alternatives that fall within the scope of the following claims.

CLAIMS

1. A method for non-concurrent transmission of a Wi-Fi signal and a Bluetooth signal using shared hardware comprising:

   coupling an output from a first amplifying element to an input of a second amplifying element;

   coupling an output from the second amplifying element to an output of the shared hardware;

   receiving a transmission request signal at an input of the first amplifying element;

   determining if the received transmission request signal comprises a Wi-Fi signal or a Bluetooth signal;

   if the received transmission request signal comprises a Wi-Fi signal, operating the first amplifying element in a high gain mode and operating the second amplifying element in a high current mode; and

   if the received transmission request signal comprises a Bluetooth signal, operating the first amplifying element in a low gain mode and operating the second amplifying element in a low current mode.

2. The method according to claim 1 wherein the first amplifying element comprises a first cascoded differential amplifier and the second amplifying element comprises a second cascoded differential amplifier.

3. The method according to claim 2 wherein the first cascoded differential amplifier comprises a first amplifier operating as a Class A amplifier and a second amplifier operating as a Class B amplifier.

4. The method according to claim 2 wherein the second cascoded differential amplifier comprises a first amplifier operating as a Class A amplifier and a second amplifier operating as a Class B amplifier.

5. The method according to claim 1 wherein the operating the first amplifying element in the high gain mode and the operating the second amplifying element in the high current mode comprises:

   biasing the first and the second amplifying elements with a drain voltage of at least 3.0 Volts.

6. The method according to claim 1 wherein the operating the first amplifying element in the low gain mode and the operating the second amplifying element in the low current mode comprises:

    biasing the first and the second amplifying elements with a drain voltage of less than 1.7 Volts.

7. The method according to claim 1 wherein the coupling the output from the first amplifying element to the input of a second amplifying element further comprises:

    inverting the output from the first amplifying element by 180 degrees;

    coupling the output from the first amplifying element to an input of a third cascoded differential amplifier;

    coupling the inverted output from the first amplifying element to an input of a fourth cascoded differential amplifier;

    whereby an output of the third cascoded differential amplifier is coupled to a first input of a differential to single end balun, an output of the fourth cascoded differential amplifier is coupled to a second input of the differential to single end balun, and an output of the differential to single end balun is coupled to the output of the shared hardware.

8. A device for non-concurrent transmission of a Wi-Fi signal and a Bluetooth signal comprising:

    a first amplifying element having an output coupled to an input of a second amplifying element, the first amplifying element configured to:

        receive a transmission request signal at an input of the first amplifying element;

    a control circuitry coupled to the first and second amplifying elements, the control circuitry configured to:

        determine if the received transmission request signal at the input of the first amplifying element comprises a Wi-Fi signal or a Bluetooth signal;

        operating the first amplifying element in a high gain mode and operating the second amplifying element in a high current mode when the received transmission request signal comprises a Wi-Fi signal; and

        operating the first amplifying element in a low gain mode and operating the second amplifying element in a low current mode when the received transmission request signal comprises a Bluetooth signal.

9. The device according to claim 8 wherein the first amplifying element comprises a first cascoded differential amplifier and the second amplifying element comprises a second cascoded differential amplifier.

10. The device according to claim 9 wherein the first cascoded differential amplifier comprises a first amplifier operating as a Class A amplifier and a second amplifier operating as a Class B amplifier.

11. The device according to claim 9 wherein the second cascoded differential amplifier comprises a first amplifier operating as a Class A amplifier and a second amplifier operating as a Class B amplifier.

12. The device according to claim 8 wherein the operating the first amplifying element in the high gain mode and the operating the second amplifying element in the high current mode comprises:

    the control circuitry being configured to:

    bias the first and the second amplifying elements with a drain voltage of at least 3.0 Volts.

13. The device according to claim 8 wherein the operating the first amplifying element in the low gain mode and the operating the second amplifying element in the low current mode comprises:

    the control circuitry being configured to:

    bias the first and the second amplifying elements with a drain voltage of less than 1.7 Volts.

14. The device according to claim 8 further comprising:

    an inverter provided at the output of the first amplifying element, the inverter configured to:

        invert the output from the first amplifying element by 180 degrees;

        couple the inverted output from the first amplifying element to an input of a fourth cascoded differential amplifier;

        couple the output from the first amplifying element to an input of a third cascoded differential amplifier; and

    a differential to single end balun configured to:

receive an output of the third cascoded differential amplifier using a first input of the differential to single end balun;

receive an output of the fourth cascoded differential amplifier using a second input of the differential to single end balun; and

couple an output of the differential to single end balun to an input of an antenna.

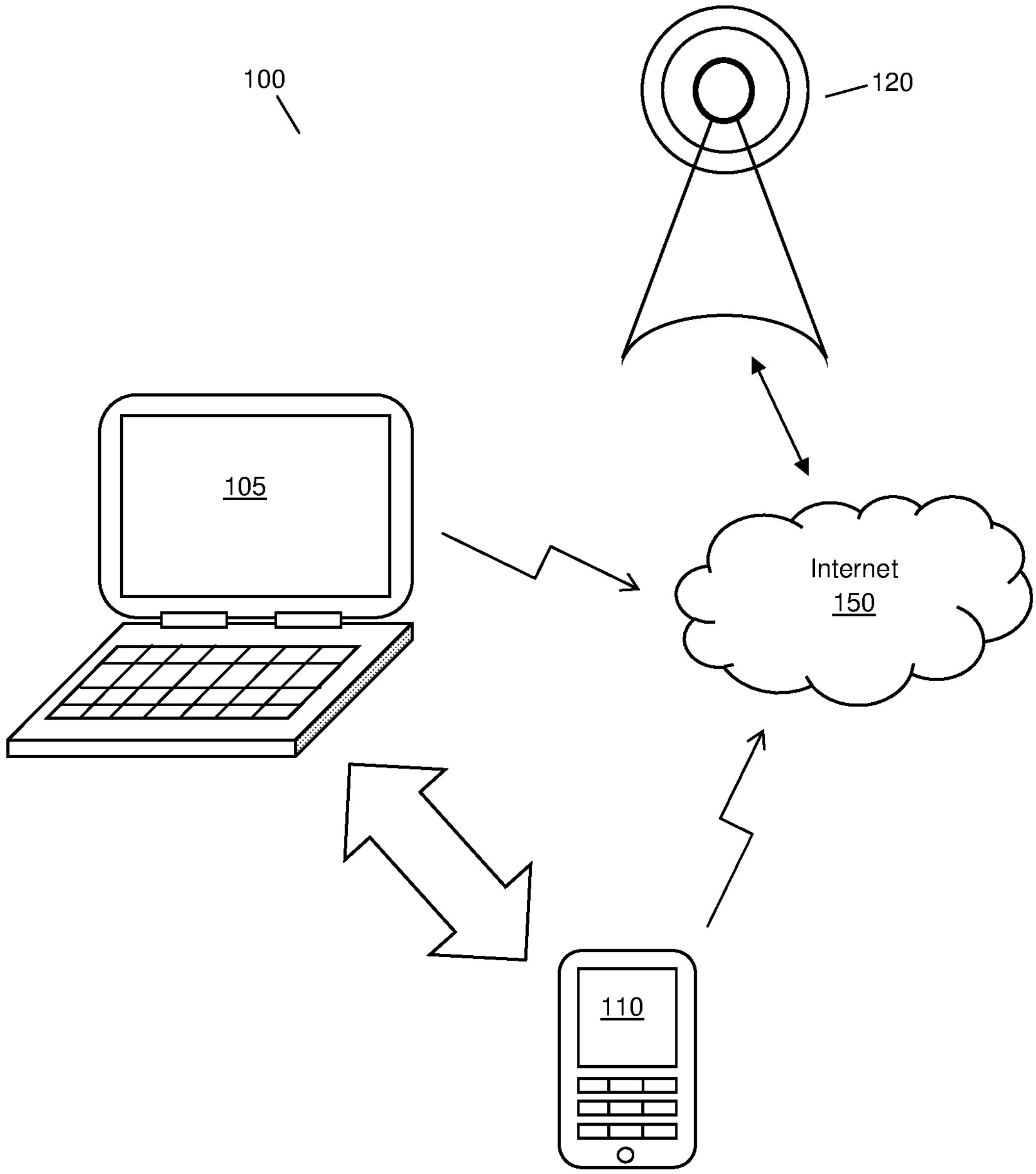


FIGURE 1

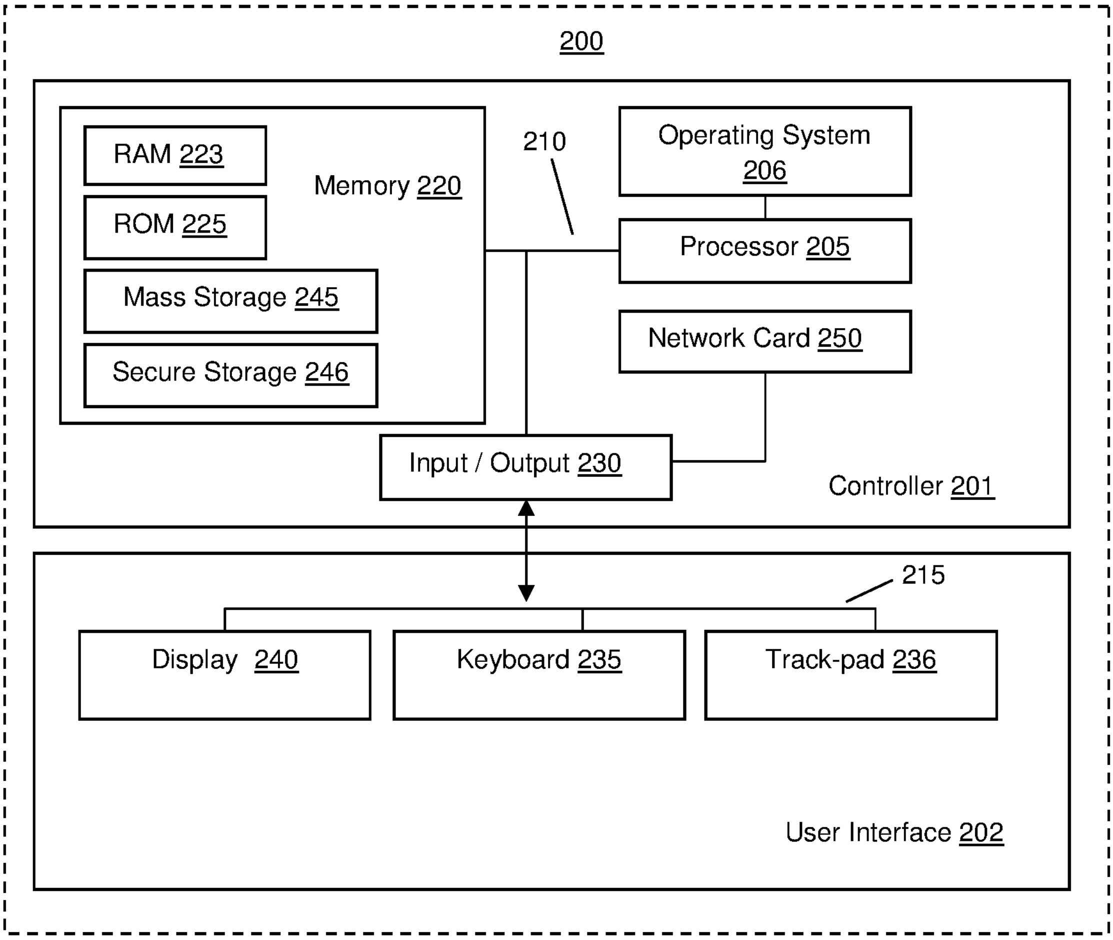
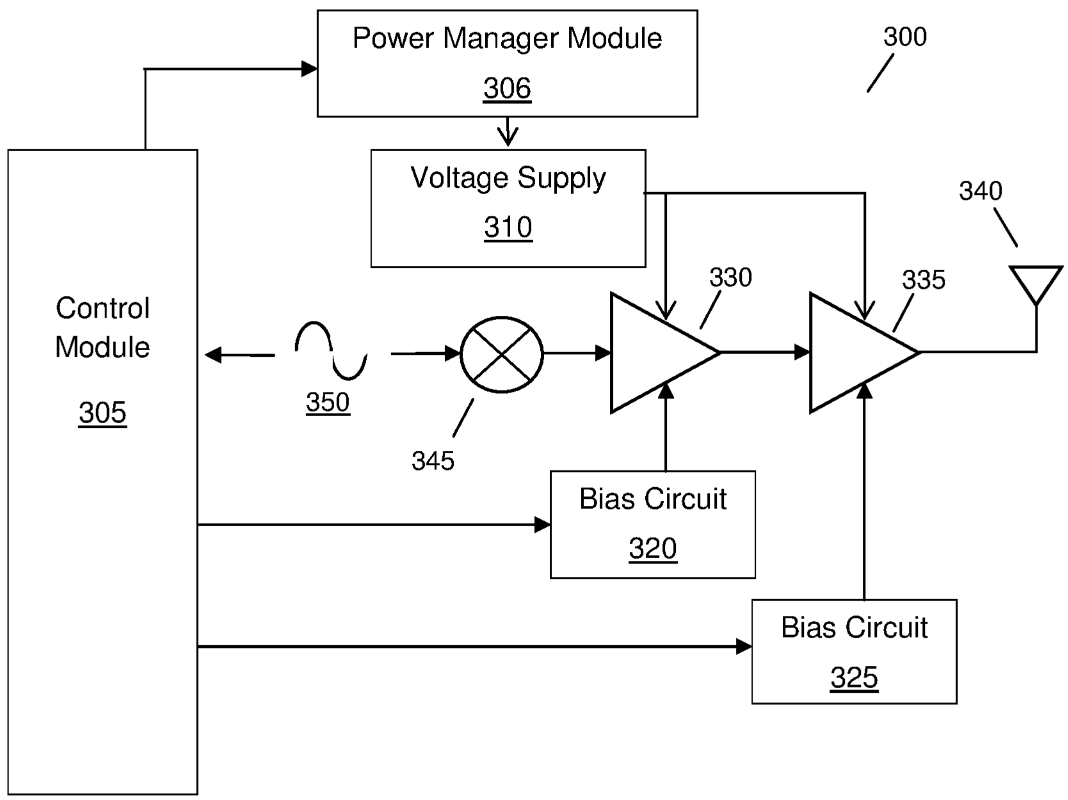

200
RAM 223
ROM 225
Memory 220
Mass Storage 245
Secure Storage 246
210
Operating System 206
Processor 205
Network Card 250
Input / Output 230
Controller 201
215
Display 240
Keyboard 235
Track-pad 236
User Interface 202

FIGURE 2



Power Manager Module
306
300
Voltage Supply
310
340
330
335
Control
Module
305
350
345
Bias Circuit
320
Bias Circuit
325

FIGURE 3

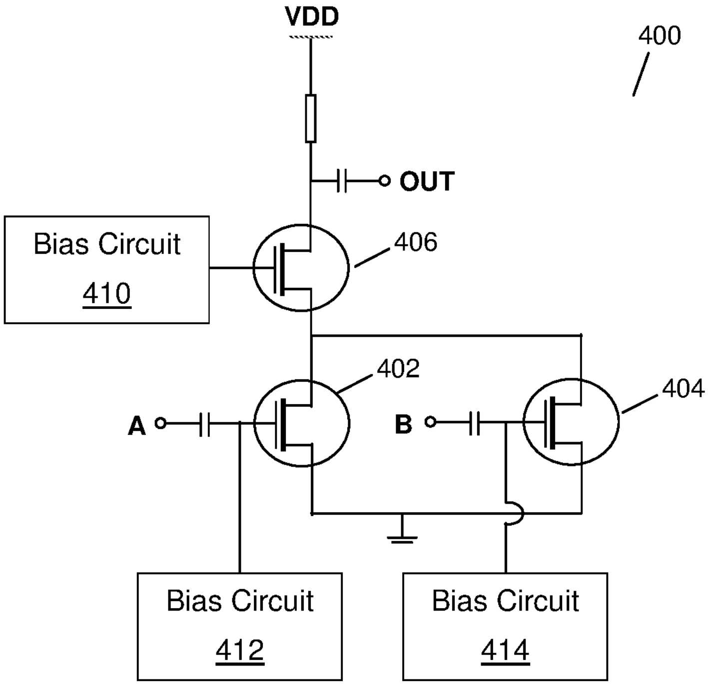

VDD
400
OUT
Bias Circuit
410
406
402
404
A
B
Bias Circuit
412
Bias Circuit
414

FIGURE 4

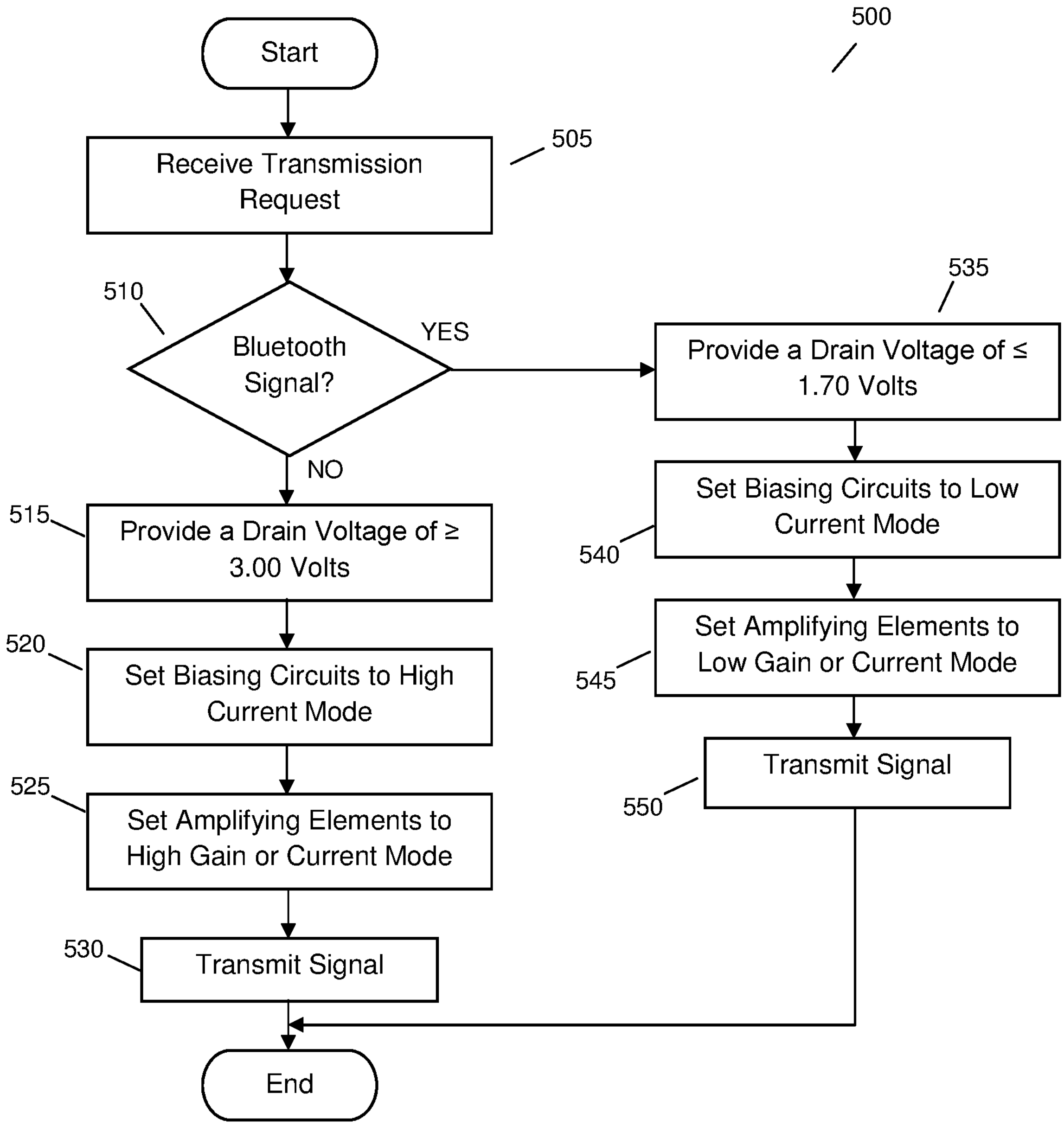

500
Start
Receive Transmission Request
505
510
Bluetooth Signal?
YES
NO
535
Provide a Drain Voltage of ≤ 1.70 Volts
540
Set Biasing Circuits to Low Current Mode
545
Set Amplifying Elements to Low Gain or Current Mode
550
Transmit Signal
515
Provide a Drain Voltage of ≥ 3.00 Volts
520
Set Biasing Circuits to High Current Mode
525
Set Amplifying Elements to High Gain or Current Mode
530
Transmit Signal
End

FIGURE 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/SG2017/050613

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B1/04 H04B1/401
ADD.

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)
H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2016/036390 A1 (LIN SAIHUA [US] ET AL) 4 February 2016 (2016-02-04) paragraphs [0015] - [0031]; figures 1-3	1-14
A	WO 2012/148416 A1 (QUALCOMM ATHEROS INC [US]; PEIRIS BEMINI HENNADIGE JANATH [US]; SANKAR) 1 November 2012 (2012-11-01) paragraphs [0017] - [0038]; figures 1-6	1-14
A	EP 0 457 737 A2 (TEXAS INSTRUMENTS INC [US]; TEXAS INSTRUMENTS ITALIA SPA [IT]) 21 November 1991 (1991-11-21) column 3, line 17 - column 4, line 16	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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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"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

Date of the actual completion of the international search	Date of mailing of the international search report
30 January 2018	20/02/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ciccarese, Corrado

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/SG2017/050613

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		IT 1240103 B	27-11-1993