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(54) **Title:** DIGITAL ANTENNA WITH MULTIPLE INTEGRATED TRANSCEIVERS

(57) **Abstract:** A digital antenna module including a combination of integrated peripheral devices, with communications multiplexed over a bidirectional serial communications link, is presented. The integrated peripheral devices (receivers or transceivers) may include one or all of satellite, GPS, V2V, and wireless communications network (e.g., LTE based) transceivers. In exemplary embodiments of the present invention, the digital antenna module may be provided in an automobile, or other moveable device, and be connected to a head unit also provided therein. The head unit may communicate with the antenna module via Ethernet, or other in-vehicle communications link, such as a 2-way twisted pair, a co-axial cable, or other IP compatible communications link. A user interacts with the head unit to access and operate various applications, including satellite radio, V2V, and cellular communications. The antenna module may include a plurality of cellular transceivers, each provisioned for a different cellular network, or some provisioned and some left un-provisioned, to be later provisioned over satellite using the satellite radio.



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IN THE PATENT CO-OPERATION TREATY
PCT PATENT APPLICATION FOR
DIGITAL ANTENNA WITH MULTIPLE INTEGRATED TRANSCEIVERS

CROSS REFERENCE TO RELATED APPLICATIONS:

This application claims the benefit of United States provisional Patent Application No. 62/116,138, filed on February 13, 2015, entitled "DIGITAL ANTENNA WITH MULTIPLE INTEGRATED TRANSCEIVERS", the entire disclosure from which is hereby incorporated herein by this reference. This application also claims the benefit of PCT application PCT/US2015/025830, filed on April 14, 2015, published as WO/2015/160859 A1, entitled "SYSTEMS, METHODS AND APPLICATIONS FOR USING AND ENHANCING VEHICLE TO VEHICLE COMMUNICATIONS INCLUDING SYNERGIES AND INTEROPERATION WITH SATELLITE RADIO," the entire disclosure of which is hereby incorporated herein by reference.

TECHNICAL FIELD:

The present invention relates to wireless communications, and in particular, to a digital antenna module which includes a combination of SAT, GPS, V2V and CELL transceivers integrated into the antenna with communications multiplexed over a bidirectional serial communications link within the vehicle.

BACKGROUND OF THE INVENTION

US Patent No. 7,606,526 describes, inter alia, a number of embodiments of an SDARS digital antenna module, which may be used to receive and process SDARS signals in a vehicle. The

digital antenna module can then output audio and data signals to, for example, a digital media player. Since the time that US Patent No. 7,606,526 issued, a number of additional in-vehicle communications pathways have become common or desirable, with still additional ones on the horizon, for use in vehicles that would also be equipped with a SDARS receiver.

What is thus needed in the art are improvements to in-vehicle wireless signal reception, processing and transmission that allow a user in a vehicle to receive a **variety** of signals of various types, and provide all of them to, for example, a media player, or an in-vehicle head unit, or other human machine interface (“HMI”) device. Exemplary signals that may be received and processed can include satellite signals, GPS signals, and signals or communications pathways where two-way communications may be supported such as vehicle to vehicle (“V2V”) communications as well as (ii) wireless communications over cellular networks, such as LTE based wireless communications. Addressing this need requires the development of more sophisticated communications processing circuitry, as well as enhanced integrated antenna modules.

Further, with multiple such peripheral devices in an antenna module, if the antenna is positioned on top of a vehicle’s roof, for example, separate cable must be laid to connect each peripheral device to the HMI or head unit, generally located in or near a vehicle’s dashboard.

What is needed in the art are technologies that addresses these issues.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 depicts an exemplary Antenna Module with a number of peripheral devices connected to a Head Unit according to exemplary embodiments of the present invention; and

Fig. 2 depicts provides further detail of the Communications Processor shown in the Antenna Module of Fig. 1.

SUMMARY OF THE INVENTION

A digital antenna module including a combination of integrated peripheral devices, with communications multiplexed over a bidirectional serial communications link, is presented. The integrated peripheral devices (receivers or transceivers) may include one or all of satellite, GPS, V2V, and wireless communications network (e.g., LTE based) transceivers. In exemplary embodiments of the present invention, the digital antenna module may be provided in an automobile, or other moveable device, and be connected to a head unit also provided therein. The head unit may communicate with the antenna module via Ethernet, or other in-vehicle communications link, such as a 2-way twisted pair, a co-axial cable, or other IP compatible communications link. A user interacts with the head unit to access and operate various applications, including satellite radio, V2V, and cellular communications. The antenna module may include include a plurality of cellular transceivers, each provisioned for a different cellular network, or some provisioned and some left un-provisioned, to be later provisioned over satellite using the satellite radio.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In exemplary embodiments of the present invention, a digital antenna module for providing various received signals to a playback device may be provided. It is noted that the present disclosure extends, enhances and further improves digital antenna modules as described in US 7,606,526, under common assignment herewith, which is also incorporated herein by this reference.

An exemplary digital antenna module may include an antenna for receiving an SDARS signal; an SDARS receiver module comprising an SDARS tuner and a baseband processing device for processing the SDARS signal and recovering program channels therefrom; and a communications interface for connecting to the SDARS-compatible playback device, such as, for example, a SDARS-compatible playback device having a corresponding user interface, such as a head unit. When the digital antenna module and the SDARS-compatible playback device are connected together, the digital antenna module and the SDARS-compatible playback device transmit and receive signals between each other via their respective communication interfaces, the signals comprising at least one of control signals and at least part of the SDARS signal. The control signals comprise signals from the SDARS-compatible playback device to select from among the program channels that are transmitted to the digital antenna module in response to user input signals provided to the SDARS-compatible playback device, and the at least part of the SDARS signal comprises the selected program channels recovered by the digital antenna module and transmitted to the SDARS-compatible playback device.

Such an antenna module may similarly include antennae for receiving or transceiving numerous other signal types, such as (i) GNSS signals, (ii) vehicle-to-vehicle communications signals of various types, including those between two vehicles, or those between a vehicle and various roadside equipment ("RSE") installations, for example, and (iii) cellular network communications, such as, for example, from various LTE based cellular networks.

As to each type of wireless communications, in an analogous manner to the processing of SDARS signals, the exemplary antenna module may be provided with demodulation and

processing sub-modules, all of which, including the SDARS tuner and baseband processing device described above, output to a common communication processor, each over a respective communications link bus or connector. The communication processor then multiplexes the various signals, and provides them to a remote (or, in some embodiments, integrated) playback device, such as an in-vehicle head unit or other Human Machine Interface (“HMI”).

An exemplary block diagram of an exemplary system according to exemplary embodiments of the present invention is provided in Fig. 1. With reference thereto, there is shown an Antenna Module 110, which is provided with integrated satellite (SDARS), GNSS and one or more V2V antenna inputs, and a Head Unit 150, which communicates with the Antenna Module 110 over 2-wire Ethernet 145.

Next described is Antenna Module 110. With reference thereto, there are shown three peripheral devices integrated into an exemplary antenna module with communications from those devices multiplexed over a bi-directional serial communications link 2-wire Ethernet connection 145, which connects physical layer modules (PHY) 135 and 155. The SAT-V2V Module 110 has antenna inputs from one or two vehicle to vehicle antennas V2V 128, GNSS signal antenna 129 and satellite radio signal (SDARS) antenna 131. Each of these is respectively processed by a different processing interface as shown, respectively, the DSRC 117, GNSS 119 and Satellite Radio 121 sub-modules. Each of these signal processors outputs their processed signals to Communication Processor 115 into its various ports, including a USB port for the DSRC (Dedicated short-range communications) output, a UART ((Universal Asynchronous Receiver/Transmitter) port for the GNSS signal, and each of UART and I²S ports for the satellite

radio signals. The Communication Processor 115 multiplexes these various signals, sends them through, for example, an Ethernet Media Access Control layer or “MAC”, and then through Physical Interface PHY 135, which sends them over the 2-wire Ethernet 145 to Head Unit 150 located inside the vehicle. Head Unit 150 is generally located inside the vehicle, and thus generally in a different place than the Antenna Module 110. This multiplexing functionality is described below in greater detail with reference to Fig. 2.

It is noted that in addition to the antennas and corresponding transceivers/signal processors shown, an exemplary Antenna Module may also include antennae and transceivers for cellular network communications. Thus, it is noted that Fig. 1 is not intended to be limiting in any way, and various additional transceivers and other peripheral devices that are not shown in Fig. 1, either in addition to, or instead of, those depicted may be integrated into Antenna Module 110. These can include, for example, one or more cellular transceivers for two-way communications with one or more cellular networks. In fact, in some embodiments it could include a plurality of cellular transceivers, each provisioned for a different network, or some provisioned and some left un-provisioned. The use of multiple cellular transceivers in a vehicle is described in greater detail in PCT patent application PCT/US2015/018792, filed on March 4, 2015, and published as WO/2015/134644A1, entitled “SATELLITE PROVISIONING OF CELL SERVICE”, under common assignment herewith. This patent application describes multiple integrated cellular modems in a vehicle allowing each modem to be separately provisioned for a different carrier, thereby allowing cellular communications on the networks of multiple carriers. Because the present invention includes a satellite radio in its integrated antenna module, i.e., SAT Radio 121 in Fig. 1, the methods, disclosure and techniques of PCT/US2015/018792, which is based upon U.S.

Provisional Patent Application No. 61/947,955, are equally applicable to multiple cellular modems provided in Antenna Module 110 of Fig. 1.

In alternate exemplary embodiments, SAT-V2V Module 110 and Head Unit 150 may be integrated, and in still other embodiments, instead of a Head Unit 150, a portable media player/UI may be used, similar to that described in US Patent No. 7,606,526.

Head Unit 150 may be provided with, for example, various applications 157 such as, for example, a satellite radio application ("SAT Apps") and various vehicle to vehicle applications ("V2V Apps") which are respectively used to tune and display both audio and visual information to a user who interacts with a head unit via a user interface ("UI", not shown).

A system controller may be provided within Communication Processor 115, which may receive commands from the Head Unit 150 via the communication cable 145, allowing the Head Unit 150 to thereby control the SAT-V2V module 110. Thus, for example, a user can use controls on the Head Unit 150 to tune to different SDARS stations, interact with other vehicles or RSE in various V2V applications, make cellular phone calls over the cellular modems in SAT-V2V Module 110, interact with GNSS based navigation applications (e.g., applications showing moving maps and information about location, speed, direction, and nearby streets and points of interest), and download data from each of an SDARS signal and an Internet Protocol (IP) channel sent over one of the cellular networks the modems are provisioned for. The data may include, for example, compressed audio data and ancillary data. The ancillary data may comprise, for example, updated stock quotes, sports scores, weather information, traffic information, news, firmware updates, compressed still images, compressed video, or the artist name and song title

to be displayed on the Head Unit 150. Uses of coordinated satellite broadcast or delivered and IP delivered data to enhance or support various features are described in U.S. Patent Application No. 14/232,698, published as US 2014/0227964, under common assignment herewith, the disclosure of which is hereby incorporated herein by this reference in its entirety.

Communication Processor 115 may be configured to prioritize certain of the plurality of communication types while a user is playing back one of the other communication types, and this configuration may be partially, or fully, programmable by a user. For example, when listening to an SDARS channel, an emergency transmission received over a V2V path may interrupt the SDARS programming, and the user will then hear the V2V sent message. Alternatively, incoming cellular phone calls may also be prioritized, or, alternatively, the incoming caller's number simply displayed, and the user given the opportunity to answer the call, which will then pause or silence the SDARS transmission.

It is noted that there are a large number of possible synergies and interactions between a V2V transceiver and an SDARS receiver, and even more when a GNSS receiver is also integrated in a given antenna module. Exemplary V2V synergies, applications and interactions are disclosed in commonly owned U.S. Provisional Patent Application Nos. 61/979,369, filed 4/14/14, and 61/988,304, filed 5/4/14, each entitled SYSTEMS, METHODS AND APPLICATIONS FOR, OR USING, VEHICLE TO VEHICLE COMMUNICATIONS, and the PCT application based thereon, PCT/US2015/025830, published as WO/2015/160859 A1, referred to above.

The SAT Radio 121 in Antenna Module 110 preferably comprises three receiver arms for processing an SDARS broadcast stream received from two satellites and a terrestrial repeater,

such as that broadcast by Sirius XM Radio. These signals may be demodulated, combined, decoded and de-multiplexed to recover channels from the SDARS broadcast stream, and reference is made to US 7,606,526 for further details of this functionality.

In exemplary embodiments of the present invention, a digital antenna module can receive power from the head unit, or alternatively, the digital antenna module may be provided with battery power and/or a connection to an external power source.

Details of Communication Processor In The Antenna Module

Fig. 2 illustrates software processes performed within the Communications Processor 115 of Antenna Module 110 (as shown in Fig. 1) to multiplex various incoming signals over the Ethernet connection 145 (also in Fig. 1) to Head Unit 150. As shown at the top of Fig. 2 there are provided Peripheral Interfaces 210. In this example embodiment, there are three peripheral interfaces: a SDARS Module, a GNSS Module, and a DSRC Transceiver. These are merely exemplary, however, and there can be any reasonable number of peripheral interfaces in an exemplary Antenna Module 200 connected to a UART, as shown. There could be, for example, a USB interface to which an LTE module is connected. The system can thus support two or more peripheral interfaces of various types, and can convert the data from (or to) those interfaces to IP for transmission within the vehicle. The Servers 220 have no knowledge who they are “talking to”, they merely “speak” the UART protocol, and there is a server for each type of peripheral device. This is a key aspect of the flexibility of the inventive Antenna Module, as the Communication Processor does not have any specific software to a given peripheral device; it only has UART specific software. This is what allows the addition or

substitution of any UART compatible peripheral device, and no software changes being necessary to implement such addition or change. Thus, as shown in Fig. 2, the Communication Processor contains multiple Servers 220, and uses those servers to convert data from each peripheral interface to IP format and then multiplexes those IP streams over the 2-Wire Ethernet connection 145 to the Head Unit.

Thus, the exemplary embodiment shown in Figs. 1-2 effectively remotes the various Peripheral Interfaces 210 to Antenna Module 200. As a result, the software on the Head Unit speaks to each driver (such as, for example, I2S, UART, I2C, GPIO and USB, and any others that may be provided) as if the driver were on the Head Unit itself, but in actuality it is on the Antenna Module. Thus we have a remote UART device over IP within the vehicle.

Thus, in exemplary embodiments of the present invention there may be a remote (relative to the Head Unit) UART in an Antenna Module 110, and any device which can connect to a UART can connect to the Communications Processor 115 in the Antenna Module 110 without any needed change in the peripheral driver software of the Head Unit or of the Communications Processor. Besides this flexibility, this arrangement also allows command and control of those peripheral interfaces to be multiplexed onto a common Ethernet connection. This obviates the need for long coaxial connections between each peripheral device and its respective antenna(s), which saves time, weight and cost, including the labor costs of installing all of that coaxial cabling, all of which can be significant.

It is noted that while the example embodiment of Figs. 1-2 shows specific Peripheral Devices, and specific Servers to convert their respective data, the present invention includes *any* type

of peripheral device and any server needed to convert that peripheral device's data to IP. It is understood that the Ethernet connection between Antenna Module and Head Unit should be of sufficient capacity in terms of bitrate to adequately support each of the peripheral devices' bit rates in the aggregate.

It is also noted that the Broad-Reach PHY in Fig. 2 is an example of Physical Interface 235 (or 135 in Fig. 1), and is also not limiting. There may be any of a variety of physical interfaces used, as may be known, to send the IP data form the Antenna Module to the Head Unit. As shown in Fig. 2, the multiplexed signals are sent over Unshielded Twisted Pair 245 to the Head Unit.

It should be appreciated that one or more of the elements depicted in the drawings/figures may also be implemented in a more separated or integrated manner, or even removed or rendered as inoperable in certain cases, as is useful in accordance with a particular application. It is also within the spirit and scope to implement a program or code that may be stored in a machine-readable medium, such as a storage device, to permit a data processor to perform any of the various tasks and methods described above.

As used in the description herein and throughout the claims that follow, "a", "an", and "the" includes plural references unless the context clearly dictates otherwise. Also, as used in the description herein and throughout the claims that follow, the meaning of "in" includes "in" and "on" unless the context clearly dictates otherwise.

While there has been described various exemplary embodiments of a digital antenna which includes a combination of integrated SAT, GPS, V2V and CELL transceivers, with communications

multiplexed over a bidirectional serial communications link, it is to be understood that many changes may be made therein without departing from the spirit and scope of the invention. Insubstantial changes from the claimed subject matter as viewed by a person with ordinary skill in the art, no known or later devised, are expressly contemplated as being equivalently within the scope of the claims. Therefore, obvious substitutions now or later known to one with ordinary skill in the art are defined to be within the scope of the defined elements. The described embodiments of the invention are presented for the purpose of illustration and not of limitation.

WHAT IS CLAIMED:

1. An antenna module for receiving and processing wireless signals, comprising:

a satellite radio antenna and a satellite radio baseband processor;

a GPS signal antenna and processor;

at least one of:

(i) a dedicated short range communications antenna and transceiver, or

(ii) one or more cellular communications antennas and modems;

a communication processor; and

a connection to a bidirectional serial communications link,

wherein, in operation, the antenna module receives or transceives wireless signals compatible with each of its antenna and processor combinations, and multiplexes them to a playback device over the bidirectional serial communications link.

2. The antenna module of claim 1, comprising both (i) a dedicated short range communications antenna and transceiver, and (ii) one or more cellular communications antennas and modems.

3. The antenna module of claim 2, comprising two cellular communications antennas and modems.

4. The antenna module of claim 3, wherein at least one cellular modem is unprovisioned.

5. The antenna module of claim 4, wherein, in operation, an unprovisioned cellular modem is provisioned over the air using the SDARS communications channel received by the antenna module.
6. A system, comprising:
 - any of the antenna modules of claims 1-5;
 - a head unit; and
 - a bidirectional serial communications link connecting the antenna module and the head unit.
7. The system of claim 6, wherein the bidirectional serial communications link is a 2-wire Ethernet connection.
8. The system of claim 6, wherein the head unit and antenna module are remote one from the other.
9. The antenna module of any of claims 1-5, wherein incoming signals or two-way communications over one of the available communications pathways accessible by the antenna module is prioritized over one or more of the others.
10. The antenna module of claim 9, wherein the communications processor is configured with said prioritizations.

11. The antenna module of claim 10, wherein the prioritizations are either fully or partially programmable by a user.

12. An antenna module for receiving and processing wireless signals, comprising:

two or more peripheral devices, each provided with an antenna;

a communications processor including a server for each peripheral device to convert the data received from the peripheral device to Internet Protocol ("IP") format;

a multiplexer; and

a physical interface to an IP based communications channel,

wherein, in operation, the servers convert the peripheral device data to IP format, and the multiplexer sends all of the respective data to (and from) a remote device for playback.

13. The antenna module of claim 12, wherein the antenna module and the remote device are in a vehicle.

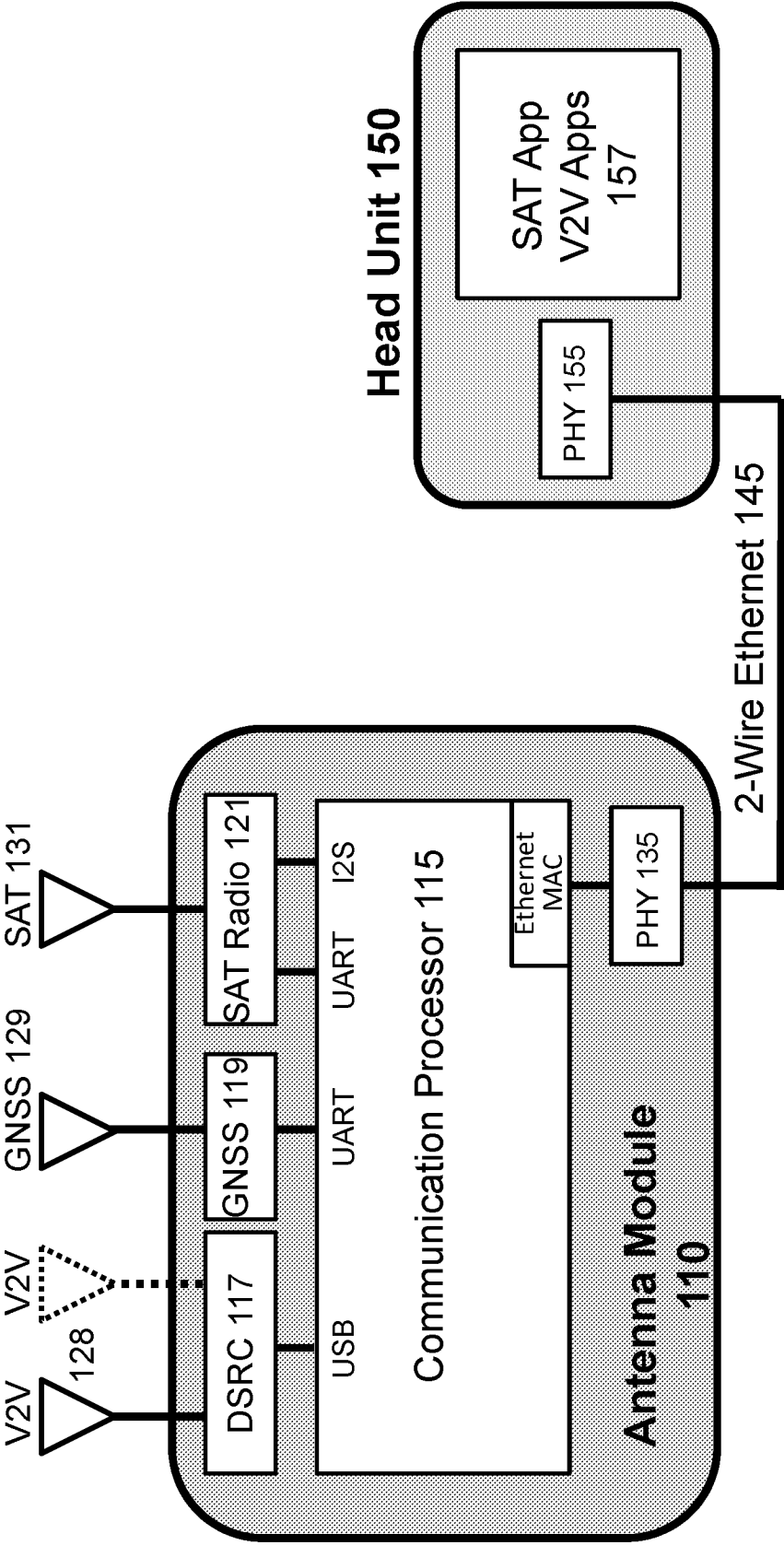
14. The antenna module of claim 13, wherein the remote device is a head unit, including a user interface.

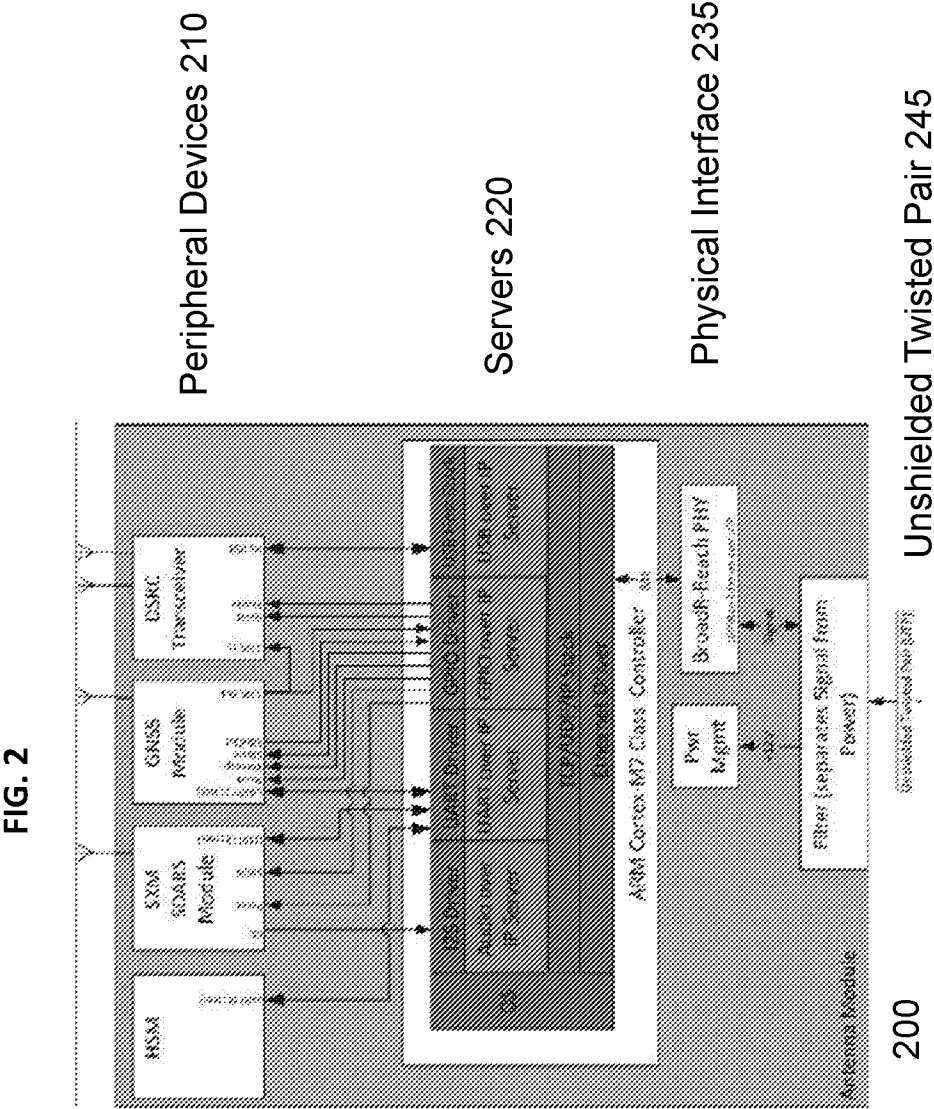
15. The antenna module of claim 12, wherein the peripheral devices are two or more of a satellite radio receiver, a GNSS module, a DSRC module, and an LTE module.

16. The antenna module of claim 12, wherein the peripheral devices include multiple cellular modules, wherein at least one cellular modem is un-provisioned.

17. The antenna module of any of claims 12-16, wherein additional peripheral devices may be added to the antenna module without changing the software in the communications processor or the remote device.
18. The antenna module of any of claims 12-16, further comprising a UART.
19. A system, comprising:
- the antenna module of claim 17;
- a remote device including a user interface; and
- a connection between the antenna module and remote device supporting IP communications.
20. The system of claim 19, wherein the antenna module is provided on top of a vehicle, and the remote device is a head unit provided in or near a dashboard of the vehicle.
21. The system of claim 19, wherein the connection is one of an Ethernet cable, a co-axial cable, or a 2-way Unshielded Twisted Pair.

FIG. 1





INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2016/018074

A. CLASSIFICATION OF SUBJECT MATTER

*H04H 20/74 (2008.01)**H04H 40/90 (2008.01)*

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)

H04H 20/74, 40/90

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)

PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE, Information Retrieval System of FIPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7286502 B1 (RAMAN K.RAO et al.) 23.10.2007, abstract, col.2, lines 55-60, col.4, lines 52-67, col.10, lines 6-9, 15-25, 31-35, col.11, lines 37-47	12-21
A		1-11
A	Warren L.Stutzman et al. Antenna Theory and Design. Third Edition. 2012	1-21
A	US 2010/0099396 A1 (QUALCOMM INCORPORATED) 22.04.2010	1-21
A	US 2007/077882 A1 (STELIOS M.PATSIOKAS et al.) 05.04.2007	1-21



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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