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Awater et al.

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(54) INTEROPERABILITY FOR BLUETOOTH/IEEE 802.11

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(22) Filed: **Jan. 16, 2001**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
H04Q 7/24 (2006.01)

(52) **U.S. Cl.** **370/338**; 370/341; 370/347

(58) **Field of Classification Search** 370/277, 370/278, 280, 282, 294, 310, 339, 345, 349, 370/352, 389, 466, 468, 498, 478, 344, 347, 370/328, 338, 337, 465; 455/78, 83
See application file for complete search history.

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Primary Examiner—Andrew C. Lee
Assistant Examiner—Soon D. Hyun

(57) **ABSTRACT**

The key of the invention is to introduce an interoperability device in a communication system which integrates an IEEE 802.11 transceiver and a Bluetooth transceiver. The device prevents that one transceiver is transmitting while the other is receiving, which would cause interference at the receiving transceiver. In addition, the device preferably prevents that both systems are transmitting at the same time to avoid interference at the receiving device(s). Optionally the device prohibits simultaneous reception of both transceivers. In that way the radio receiver can be shared between the devices, allowing a cheaper and smaller hardware design.

44 Claims, 3 Drawing Sheets

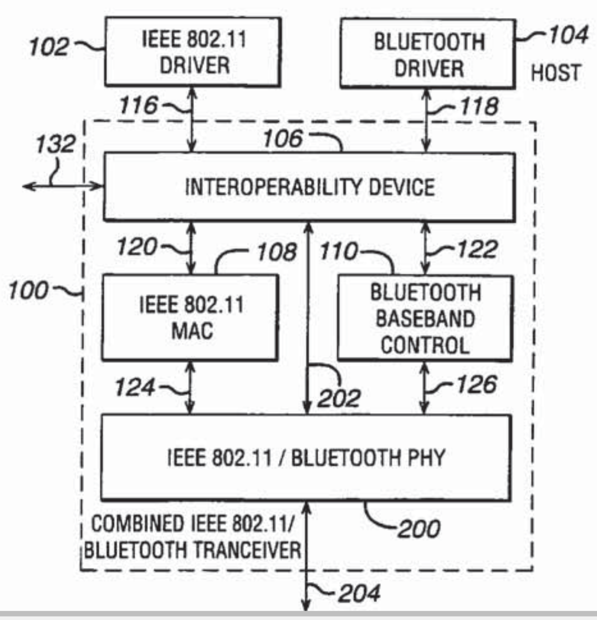


FIG. 1

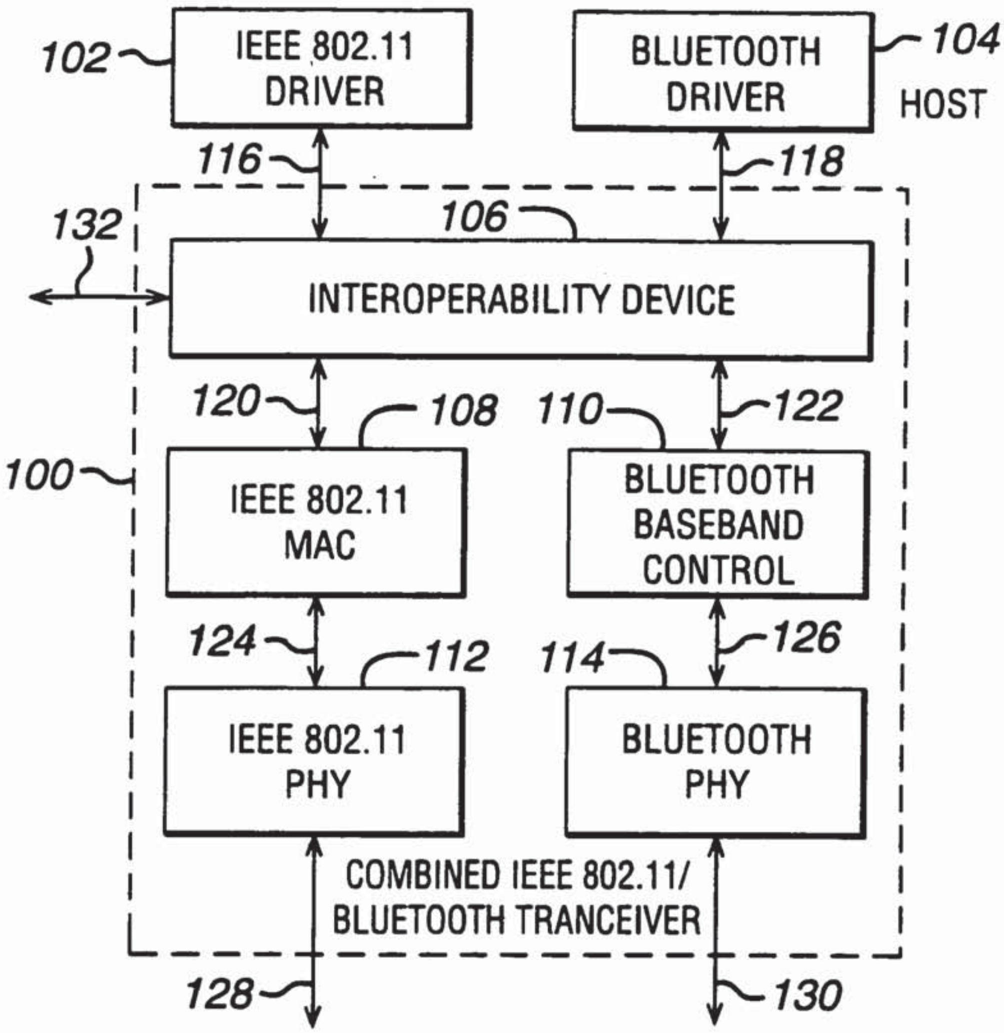

102
IEEE 802.11 DRIVER
BLUETOOTH DRIVER
104
HOST
116
118
132
106
INTEROPERABILITY DEVICE
120
108
110
122
100
IEEE 802.11 MAC
BLUETOOTH BASEBAND CONTROL
124
112
114
126
IEEE 802.11 PHY
BLUETOOTH PHY
COMBINED IEEE 802.11/ BLUETOOTH TRANCEIVER
128
130

FIG. 3

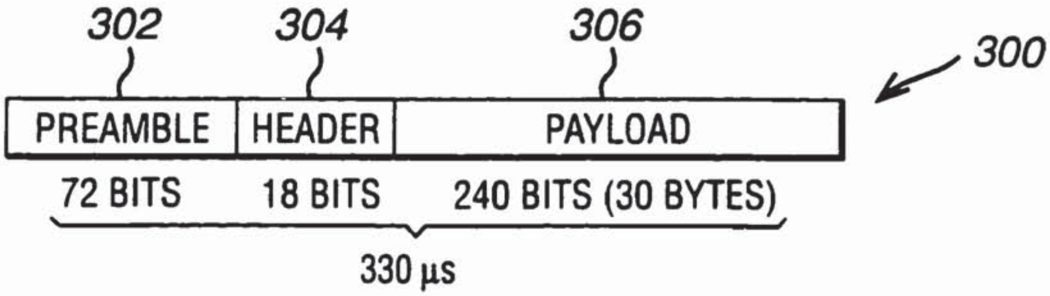
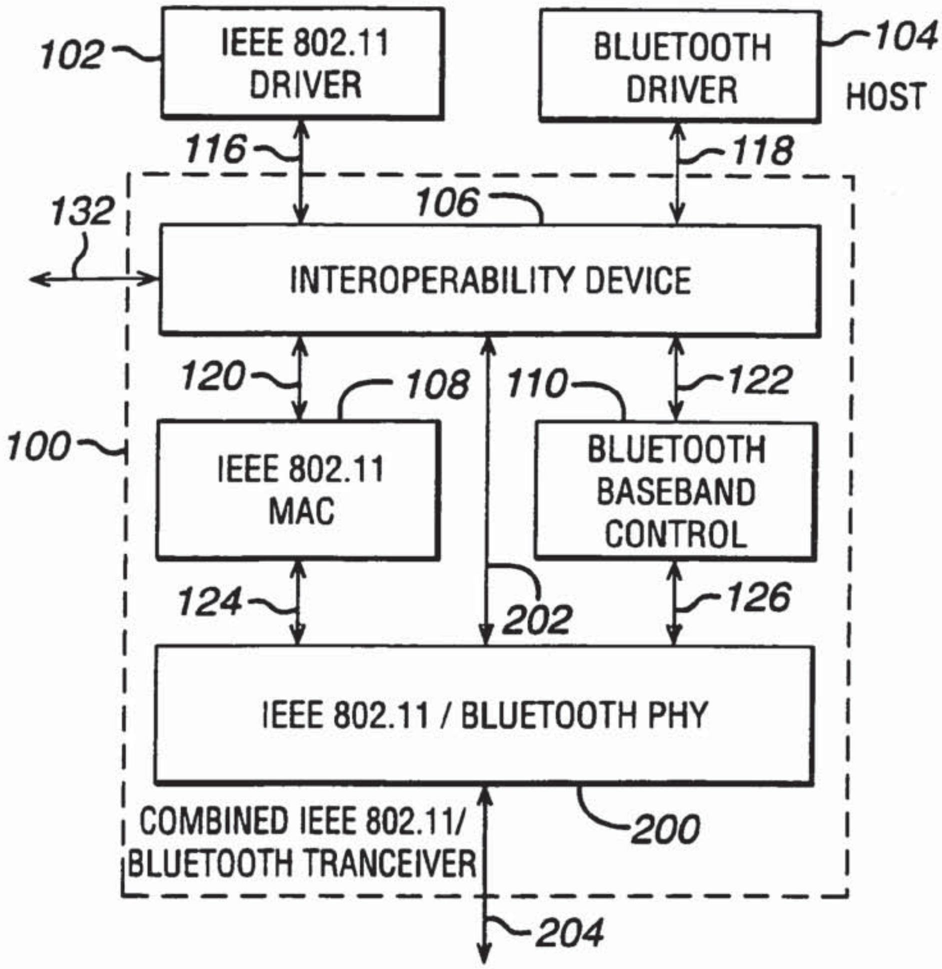
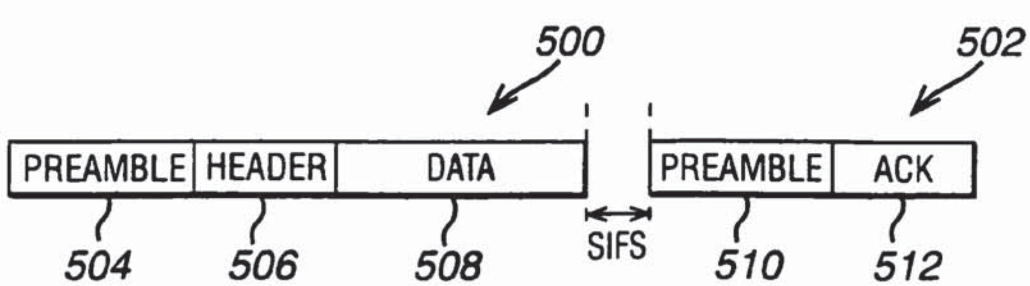

302
304
306
300
PREAMBLE
HEADER
PAYLOAD
72 BITS
18 BITS
240 BITS (30 BYTES)
330 μs

FIG. 2



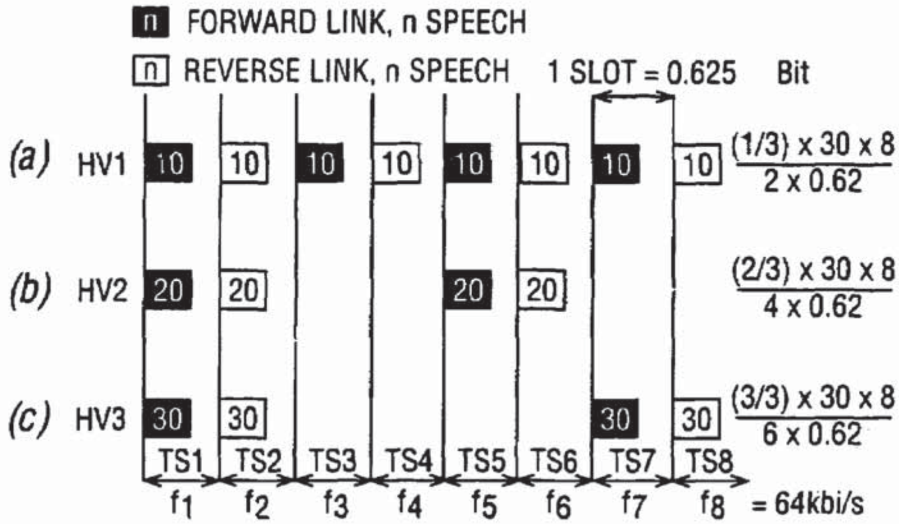
102
IEEE 802.11 DRIVER
BLUETOOTH DRIVER
104
HOST
116
118
106
132
INTEROPERABILITY DEVICE
120
108
110
122
100
IEEE 802.11 MAC
BLUETOOTH BASEBAND CONTROL
124
202
126
IEEE 802.11 / BLUETOOTH PHY
COMBINED IEEE 802.11/ BLUETOOTH TRANCEIVER
200
204

FIG. 5



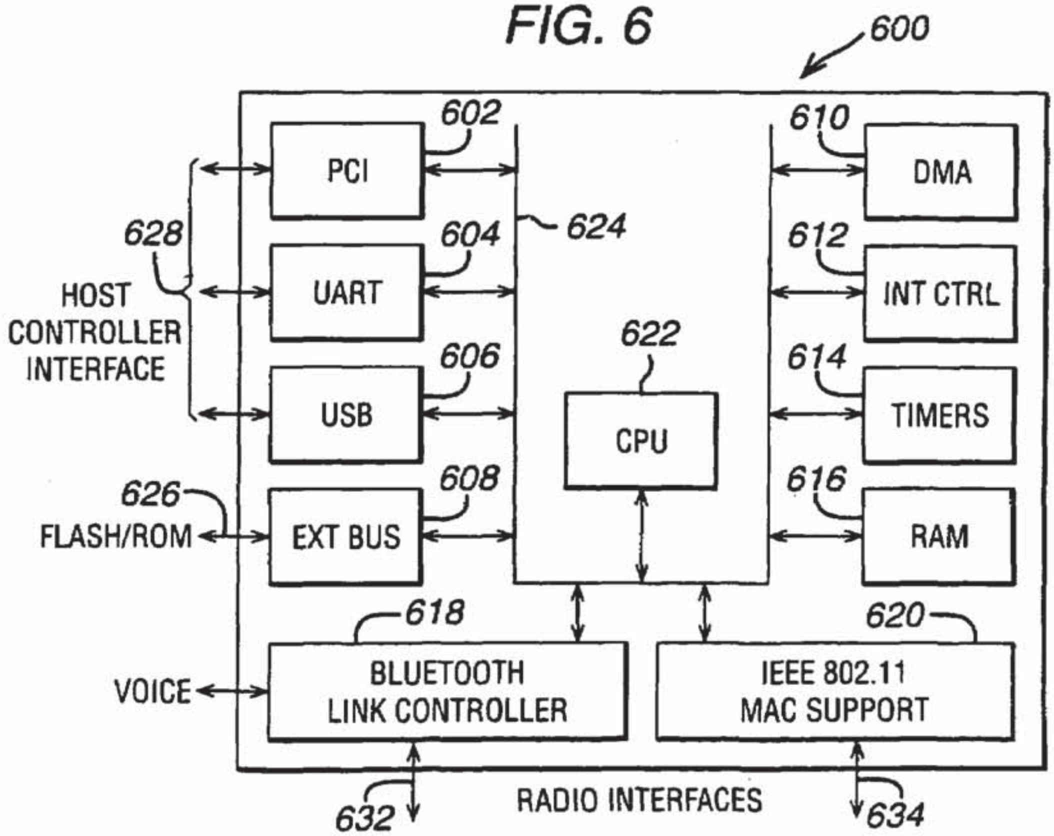
500
502
PREAMBLE
HEADER
DATA
PREAMBLE
ACK
504
506
508
SIFS
510
512

FIG. 4



FORWARD LINK, n SPEECH
REVERSE LINK, n SPEECH
1 SLOT = 0.625 Bit
(a) HV1
(b) HV2
(c) HV3
10
20
30
(1/3) x 30 x 8 / 2 x 0.62
(2/3) x 30 x 8 / 4 x 0.62
(3/3) x 30 x 8 / 6 x 0.62
TS1 TS2 TS3 TS4 TS5 TS6 TS7 TS8
f1 f2 f3 f4 f5 f6 f7 f8 = 64kbi/s

FIG. 6



600
PCI
602
UART
604
USB
606
EXT BUS
608
624
622
CPU
DMA
610
INT CTRL
612
TIMERS
614
RAM
616
628
HOST CONTROLLER INTERFACE
626
FLASH/ROM
VOICE
618
BLUETOOTH LINK CONTROLLER
620
IEEE 802.11 MAC SUPPORT
RADIO INTERFACES
632
634

INTEROPERABILITY FOR BLUETOOTH/IEEE 802.11

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority of European Patent Application No. 00300397.7, which was filed on Jan. 20, 2000.

FIELD OF THE INVENTION

The present invention relates to both Bluetooth and IEEE 802.11 radio communication systems.

DESCRIPTION OF THE RELATED ART

IEEE 802.11 is a standard for wireless systems that operate in the 2.4–2.5 GHz ISM (industrial, scientific and medical) band. This ISM band is available world-wide and allows unlicensed operation for spread spectrum systems. For both the US and Europe, the 2,400–2,483.5 MHz band has been allocated, while for some other countries, such as Japan, another part of the 2.4–2.5 GHz ISM band has been assigned. The 802.11 standard focuses on the MAC (medium access control) protocol and PHY (physical layer) protocol for access point (AP) based networks and ad-hoc networks.

In access point based networks, the stations within a group or cell can communicate only directly to the access point. This access point forwards messages to the destination station within the same cell or through a wired distribution system to another access point, from which such messages arrive finally at the destination station. In ad-hoc networks, the stations operate on a peer-to-peer level and there is no access point or (wired) distribution system.

The 802.11 standard supports: DSSS (direct sequence spread spectrum) with differential encoded BPSK and QPSK; FHSS (frequency hopping spread spectrum) with GFSK (Gaussian FSK); and infrared with PPM (pulse position modulation). These three physical layer protocols (DSSS, FHSS and infrared) all provide bit rates of 2 and 1 Mbit/s. The 802.11 standard further includes extensions **11***a* and **11***b*. Extension **11***b* is for a high rate CCK (Complementary Code Keying) physical layer protocol, providing bit rates 11 and 5.5 Mbit/s as well as the basic DSSS bit rates of 2 and 1 Mbit/s within the same 2.4–2.5 GHz ISM band. Extension **11***a* is for a high bit rate OFDM (Orthogonal Frequency Division Multiplexing) physical layer protocol standard providing bit rates in the range of 6 to 54 Mbit/s in the 5 GHz band.

The 802.11 basic medium access behavior allows interoperability between compatible physical layer protocols through the use of the CSMA/CA (carrier sense multiple access with a collision avoidance) protocol and a random back-off time following a busy medium condition. In addition all directed traffic uses immediate positive acknowledgement (ACK frame), where a retransmission is scheduled by the sender if no positive acknowledgement is received. The 802.11 CSMA/CA protocol is designed to reduce the collision probability between multiple stations accessing the medium at the point in time where collisions are most likely occur. The highest probability of a collision occurs just after the medium becomes free, following a busy medium. This is because multiple stations would have been waiting for the medium to become available again. There-

defines: special functional behavior for fragmentation of packets; medium reservation via RTS/CTS (request-to-send/clear-to-send) polling interaction; and point co-ordination (for time-bounded services).

The IEEE 802.11 MAC also defines Beacon frames, sent at a regular interval by an AP to allow STAs to monitor the presence of the AP. IEEE 802.11 also defines a set of management frames including Probe Request frames which are sent by an STA, and are followed by Probe Response frames sent by the AP. Probe Request frames allow an STA to actively scan whether there is an AP operating on a certain channel frequency, and for the AP to show to the STA what parameter settings this AP is using.

Bluetooth technology allows for the replacement of the many proprietary cables that connect one device to another with one universal short-range radio link. For instance, Bluetooth radio technology built into both a cellular telephone and a laptop would replace the cumbersome cable used today to connect a laptop to a cellular telephone. Printers, personal digital assistant's (PDA's), desktops, computers, fax machines, keyboards, joysticks and virtually any other digital device can be part of the Bluetooth system. But beyond un-tethering devices by replacing the cables, Bluetooth radio technology provides a universal bridge to existing data networks, a peripheral interface, and a mechanism to form small private ad-hoc groupings of connected devices away from fixed network infrastructures.

Designed to operate in a noisy radio frequency environment, the Bluetooth radio system uses a fast acknowledgement and frequency hopping scheme to make the link robust. Bluetooth radio modules avoid interference from other signals by hopping to a new frequency after transmitting or receiving a packet. Compared with other systems operating in the same frequency band, the Bluetooth radio system typically hops faster and uses shorter packets. This makes the Bluetooth radio system more robust than other systems. Short packets and fast hopping also limit the impact of domestic and professional microwave ovens. Use of Forward Error Correction (FEC) limits the impact of random noise on long-distance links. The encoding is optimised for an uncoordinated environment. Bluetooth radios operate in the unlicensed ISM band at 2.4 GHz. A frequency hop transceiver is applied to combat interference and fading. A shaped, binary FM modulation is applied to minimise transceiver complexity. The gross data rate is 1 Mb/s.

A Time-Division Duplex scheme is used for full-duplex transmission. The Bluetooth baseband protocol is a combination of circuit and packet switching. Slots can be reserved for synchronous packets. Each packet is transmitted in a different hop frequency. A packet nominally covers a single slot, but can be extended to cover up to five slots. Bluetooth can support an asynchronous data channel, up to three simultaneous synchronous voice channels, or a channel which simultaneously supports asynchronous data and synchronous voice. Each voice channel supports 64 kb/s synchronous (voice) link. The asynchronous channel can support an asymmetric link of maximally 721 kb/s in either direction while permitting 57.6 kb/s in the return direction, or a 432.6 kb/s symmetric link.

The IEEE 802.11 standard is well-established and local area networks are already implemented based on the standard, typically in office environments. As Bluetooth comes into the market, it is likely to be implemented in a domestic environment for communications within the home, for

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