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(54) **TRANSMISSION POWER NORMALIZATION**

(76) Inventor: **Rony Ross**, Haifa (IL)

Correspondence Address:
LEE & HAYES, PLLC
P.O. BOX 52050
MINNEAPOLIS, MN 55402

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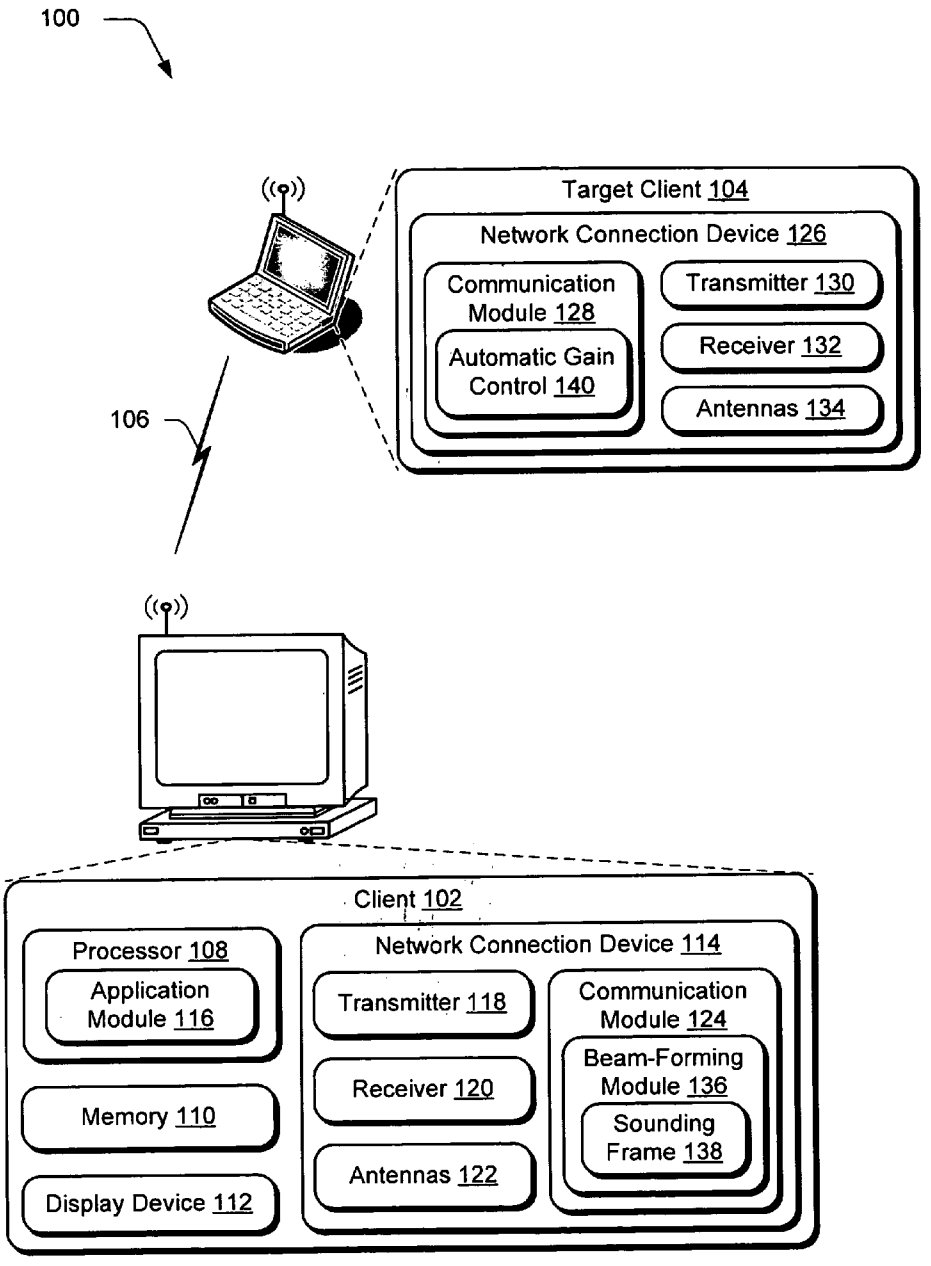
(57) **ABSTRACT**

Embodiments of transmission power normalization are presented herein.



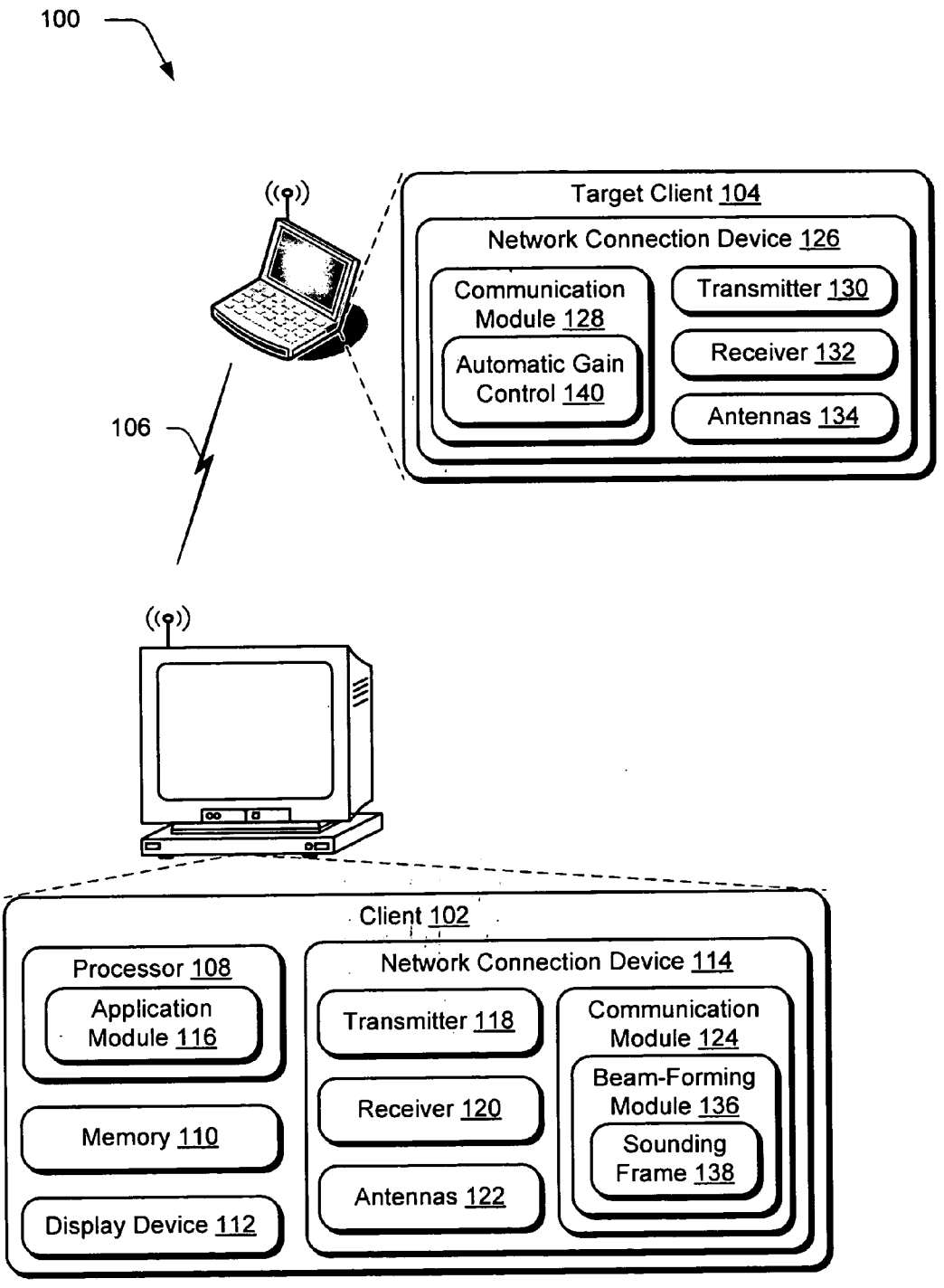

100
Target Client 104
Network Connection Device 126
Communication Module 128
Automatic Gain Control 140
Transmitter 130
Receiver 132
Antennas 134
106
Client 102
Processor 108
Application Module 116
Memory 110
Display Device 112
Network Connection Device 114
Transmitter 118
Receiver 120
Antennas 122
Communication Module 124
Beam-Forming Module 136
Sounding Frame 138

Fig. 1

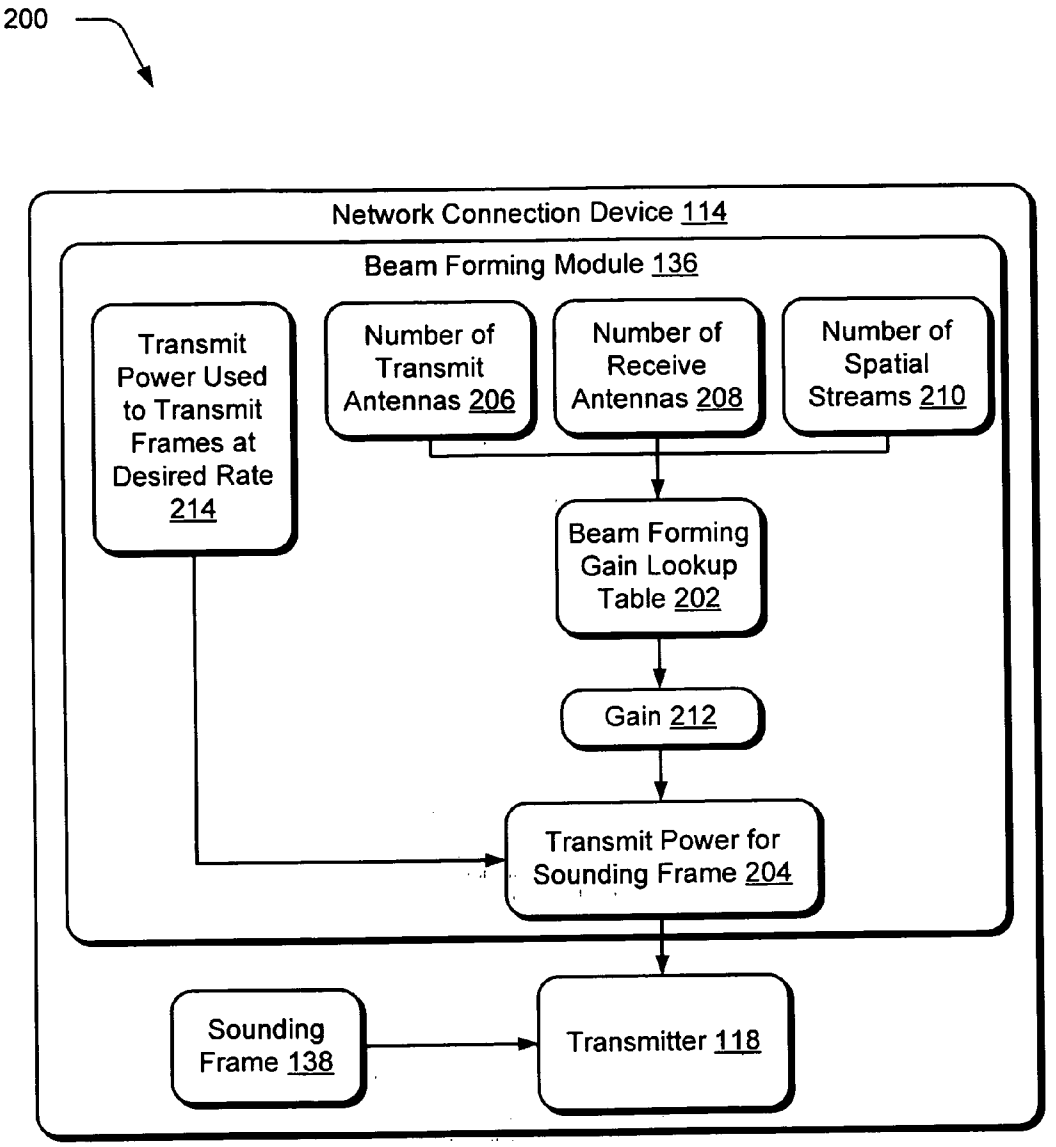

200
Network Connection Device 114
Beam Forming Module 136
Transmit Power Used to Transmit Frames at Desired Rate 214
Number of Transmit Antennas 206
Number of Receive Antennas 208
Number of Spatial Streams 210
Beam Forming Gain Lookup Table 202
Gain 212
Transmit Power for Sounding Frame 204
Sounding Frame 138
Transmitter 118

Fig. 2

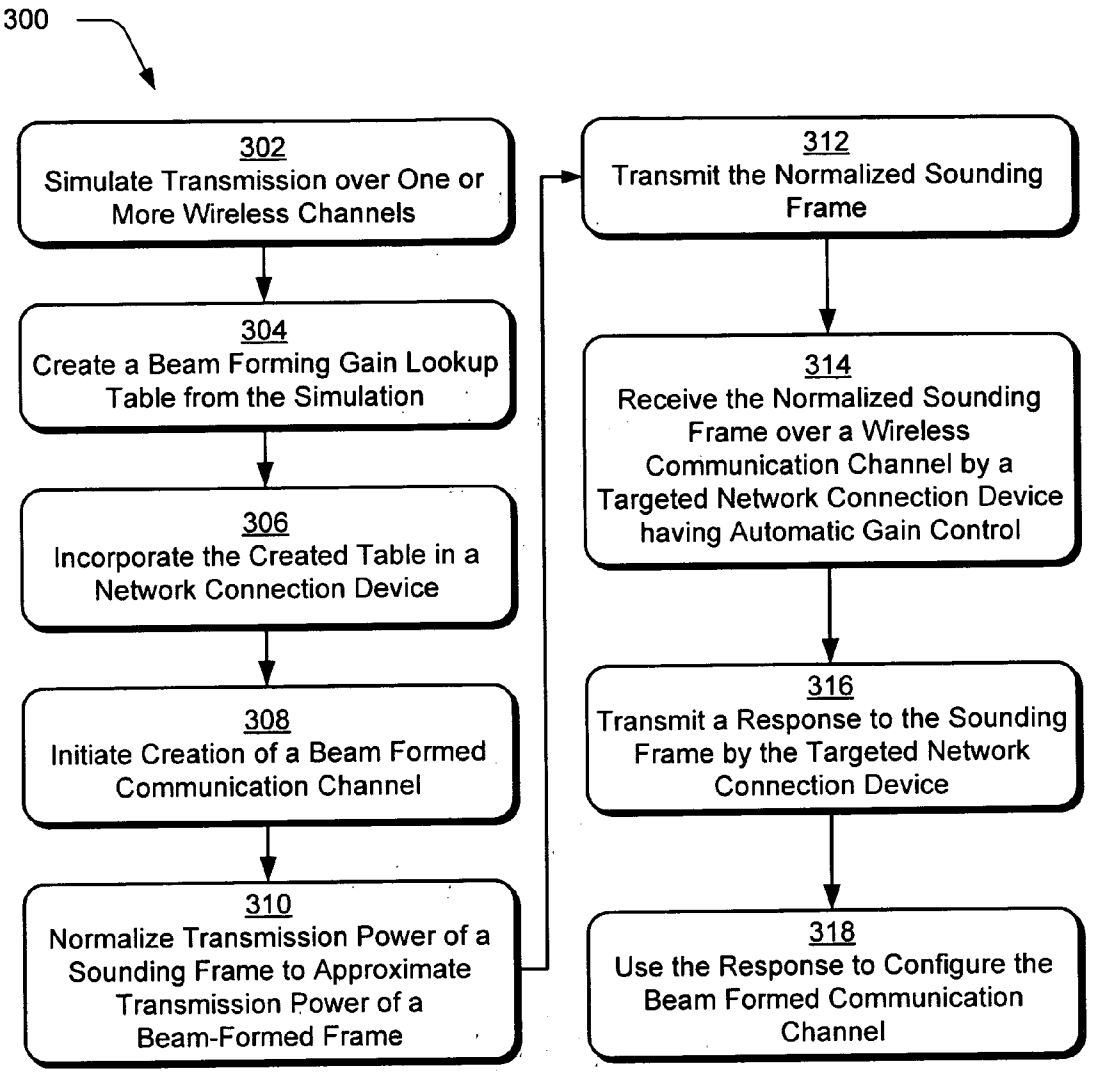

300
302
Simulate Transmission over One or More Wireless Channels
304
Create a Beam Forming Gain Lookup Table from the Simulation
306
Incorporate the Created Table in a Network Connection Device
308
Initiate Creation of a Beam Formed Communication Channel
310
Normalize Transmission Power of a Sounding Frame to Approximate Transmission Power of a Beam-Formed Frame
312
Transmit the Normalized Sounding Frame
314
Receive the Normalized Sounding Frame over a Wireless Communication Channel by a Targeted Network Connection Device having Automatic Gain Control
316
Transmit a Response to the Sounding Frame by the Targeted Network Connection Device
318
Use the Response to Configure the Beam Formed Communication Channel

Fig. 3

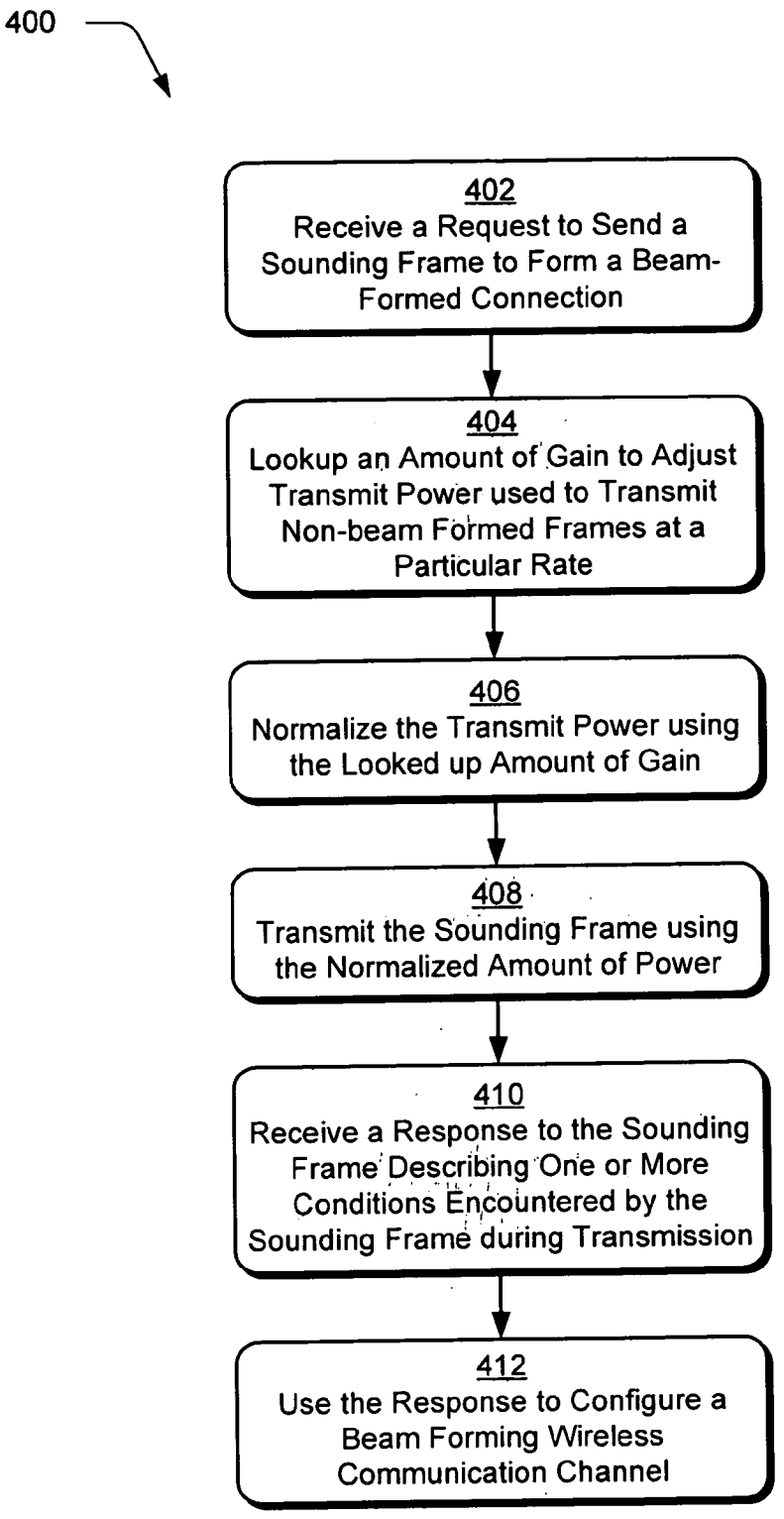

400
402
Receive a Request to Send a Sounding Frame to Form a Beam-Formed Connection
404
Lookup an Amount of Gain to Adjust Transmit Power used to Transmit Non-beam Formed Frames at a Particular Rate
406
Normalize the Transmit Power using the Looked up Amount of Gain
408
Transmit the Sounding Frame using the Normalized Amount of Power
410
Receive a Response to the Sounding Frame Describing One or More Conditions Encountered by the Sounding Frame during Transmission
412
Use the Response to Configure a Beam Forming Wireless Communication Channel

Fig. 4

TRANSMISSION POWER NORMALIZATION

BACKGROUND

[0001] The desire by users to interact with devices that provide wireless communication is ever increasing. For example, rather than use a wired connection that limits the mobility of a device having the connection, users may utilize a wireless phone, a laptop computer, a desktop computer, and so on to access a network, such as to surf the Internet, communicate with other wireless devices, and so on. To address this ever increasing desire and the corresponding increasing prevalence of devices configured to provide wireless communication, techniques have been developed to expand wireless functionality, such as to increase bandwidth, range and so on of a wireless channel used to communicate.

[0002] One such technique is referred to as "beam forming", in which, transmissions performed by a device are focused toward a target device. Traditional techniques that were used to form a beam formed connection, however, did not address automatic gain control functionality that may be employed by the target device. Therefore, a device attempting to form a beam-formed communication channel with the target device may not obtain an accurate "view" of the communication medium used to communicate between the devices, which may adversely affect the beam-formed communication channel that is formed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The detailed description is described with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different instances in the description and the figures may indicate similar or identical items.

[0004] FIG. **1** is an illustration of an environment in an exemplary implementation that is operable to employ transmission power normalization techniques that address automatic gain control that may be employed by a target client.

[0005] FIG. **2** is an illustration of a system in an exemplary implementation showing a beam-forming module of FIG. **1** in greater detail.

[0006] FIG. **3** is a flow diagram depicting a procedure in an exemplary implementation in which a table is created through a simulation that is useable to determine an amount of gain to be applied to adjust transmission power of a sounding frame. The sounding frame is used, at least in part, to form a beam-formed wireless channel.

[0007] FIG. **4** is a flow diagram depicting a procedure in an exemplary implementation in which a beam forming gain lookup table is used to normalize transmission power for a sounding frame used to form a beam-formed communication channel.

DETAILED DESCRIPTION

[0008] In the following discussion, an exemplary environment is first described that is operable to perform techniques to normalize transmission power. Exemplary procedures are then described that may be employed in the exemplary environment, as well as in other environments.

[0009] Exemplary Environment

[0010] FIG. **1** is an illustration of an environment **100** in an exemplary implementation that is operable to employ transmission power normalization techniques that address automatic gain control that may be employed by a target client. The illustrated environment **100** includes a client **102** communicatively coupled to a target client **104** over a wireless channel **106**.

[0011] The client **102** and the target client **104** may be configured in a variety of ways for network **106** access. For example, one or more of the clients **102**, **104** may be configured as a computing device, such as a desktop computer, a mobile station, an entertainment appliance, a wireless phone, a personal digital assistant (PDA), and so forth. The client **102** and the target client **104**, in portions of the following discussion, may also relate to a person and/or entity that operate the clients. In other words, the clients **102**, **104** may describe logical clients that include users, software, and/or devices.

[0012] The client **102**, as illustrated, includes a processor **108**, memory **110** (e.g., dynamic random access memory), a display device **112** and a network connection device **114**. The processor **108** is further illustrated as executing an application module **116**, which is storable in memory **110**. The application module **116**, for instance, may be configured to provide data to be transmitted by the network connection device **114**, to be displayed by the display device **112**, and so on.

[0013] Processors are not limited by the materials from which they are formed or the processing mechanisms employed therein. For example, processors may be comprised of semiconductor(s) and/or transistors (e.g., electronic integrated circuits (ICs)). In such a context, processor-executable instructions may be electronically-executable instructions. Additionally, although a single memory **110** is shown, a wide variety of types and combinations of memory may be employed, such as random access memory (RAM), hard disk memory, removable medium memory, and other types of computer-readable media.

[0014] The network connection device **114** includes a transmitter **118**, a receiver **120**, antennas **122** and a communication module **124**. The antennas **122**, for instance, may be used to support multiple input/multiple output (MIMO) communication. For example, the antennas **122** may be used to increase transmission power (e.g., which may be related to a square of the number of antennas), increase reception power (e.g., which may be expressed as a linear function of the number of antennas), and so on. A variety of other instances are also contemplated, further discussion of which may be found below.

[0015] The communication module **124** is representative of functionality that is employable by the client **102**, and more particularly the network connection device **114** in the illustrated example, to manage wireless communication, such as with the target client **104** over the wireless channel **106**. The communication module **124**, for instance, may employ functionality to negotiate the wireless channel **106** with a network connection device **126** of the target client **104** that also includes a communication module **128**, a transmitter **130**, a receiver **132** and antennas **134**. For example, the communication module **124** of the network connect device **114** may communicate with the communication module **128** of the network connection device **126** of the target client **104** to negotiate protocols that are to be used to form and communicate over the wireless channel **106**. A variety of techniques may be used to form the wireless channel **106**.

[0016] One such technique is referred to as "beam forming". The communication module **124**, for instance, may incorporate a beam forming module **136** which is representative of functionality to form a beam-formed communication channel between the client **102** and the target client **104**. When the wireless channel **106** is beam-formed, transmissions performed by the client **102** are focused toward the target client **104**, with transmissions to other directions being minimized.

[0017] In order to form the beam-formed communication channel **106**, for instance, the beam-forming module **136** forms a sounding frame **138** to be transmitted to the target client **104**. The target client **104** receives the sounding frame **138** and transmits a response that describes how the sounding frame **138** "looks" to the target client **104**. Therefore, the client **102** may determine from the response one or more conditions of the communication medium between the client **102** and the target client **104** and how those conditions affect transmission of frames between the clients.

[0018] The target client **104**, however, may incorporate automatic gain control **140** to equalize frames received by the receiver **132** for subsequent demodulation. Thus, the automatic gain control **140** may influence the "view" of the wireless channel **106** between the client **102** and the target client **104**. For example, a beam-formed frame transmitted from client **102** to the target client **104** may cause the automatic gain control **140** to be set at a certain level, i.e., a certain amount of gain.

[0019] Traditional techniques that were used to form a beam formed connection, however, did not address automatic gain control. For instance, a traditional sounding frame that was transmitted using traditional techniques generally had an amount of transmission power that was lower than the transmission power used to transmit a beam-formed frame. Therefore, gain set by the automatic gain control **140** for the traditional sounding frame may be different than how gain is to be set when receiving a beam-formed frame. This difference in gain may therefore result in an inaccurate view of wireless channel **106** by the beam-forming module **136**, which may result in degradation in beam forming performance.

[0020] The beam-forming module **136**, therefore, may incorporate one or more techniques to normalize transmission power of the sounding frame **138** to approximate that of a beam-formed frame and/or to normalize transmission power of the beam-formed frame to that of the sounding frame **138**. In this way, the beam-forming module **136** may obtain an accurate view of a wireless medium between the clients **102**, **104** and configure the beam-formed communication channel **106** accordingly. A variety of techniques may be employed to normalize transmission power of a sounding frame **138**, further discussion of which may be found in relation to the following figures.

[0021] Generally, any of the functions described herein can be implemented using software, firmware, hardware (e.g., fixed logic circuitry), manual processing, or a combination of these implementations. The terms "module," "functionality," and "logic" as used herein generally represent software, firmware, hardware, or a combination thereof. In the case of a software implementation, for instance, the module, functionality, or logic represents program code that performs specified tasks when executed on a processor (e.g., CPU or CPUs). The program code can be stored in one or more computer readable memory devices, e.g., memory **110**. The features of the techniques described below are platform-independent, meaning that the techniques may be implemented on a variety of commercial computing platforms having a variety of processors.

[0022] FIG. **2** is an illustration of a system **200** in an exemplary implementation showing the beam forming module **136** of the network connection device **114** of the client **102** of FIG. **1** in greater detail. The system **200** of FIG. **2** includes a beam forming gain lookup table **202** that is used to calculate transmission power for a sounding frame **204** to be used by the transmitter **118**.

[0023] The beam forming module **136**, for instance, may receive inputs that describe a number of transmit antennas **106**, number of receive antennas **208** and a number of spatial streams **210** to be used in a beam formed wireless connection. The number of spatial streams, for instance, may describe an instance in which multiple antennas are used to transmit a single stream. These inputs may then be used as a lookup in the beam forming gain lookup table **202** to arrive at a gain **212** to be added to transmit power used to transmit frames at a desired rate **214**. The gain **212** and the transmit power used to transmit frames at a desired rate **214** may then be used to arrive at the transmit power for the sounding frame **204**. The beam forming gain lookup table **202** may be formed in a variety of ways, such as through simulation, further discussion of which may be found in relation to the following exemplary procedures.

[0024] Although this implementation, described use of the beam forming gain lookup table **202** to normalize the transmission power of the sounding frame **204** to that of a beam-formed frame, this technique may also be applied to normalize the beam-formed frame to the sounding frame. In this way, the same amount of automatic gain may be encountered by the sounding packet as well as the beam-formed frames.

[0025] Exemplary Procedures

[0026] The following discussion describes transmission power normalization techniques that may be implemented utilizing the previously described systems and devices. Aspects of each of the procedures may be implemented in hardware, firmware, or software, or a combination thereof. The procedures are shown as a set of blocks that specify operations performed by one or more devices and are not necessarily limited to the orders shown for performing the operations by the respective blocks. In portions of the following discussion, reference will be made to the environment **100** of FIG. **1** and the system **200** of FIG. **2**.

[0027] FIG. **3** depicts a procedure **300** in an exemplary implementation in which a table is created through a simulation that is useable to determine an amount of gain to be applied to adjust transmission power of a sounding frame. Transmission over one or more wireless channels is simulated (block **302**). For example, the affects of a wireless medium on a variety of different configurations of a network connection device may be simulated, such as based on a number of transmitting antennas, streams and/or receiving antennas, further discussion of which may be found in relation to FIG. **4**.

[0028] A beam forming gain lookup table is created from the simulation (block **304**). The table, for instance, may be configured as a three-dimensional lookup table that accepts, as inputs, the different configurations that were simulated for a network connection device. The created table may then be

incorporated within a network connection device (block **306**), such as stored in memory, formed in hardware, and so on.

[0029] The network connection device, having the table, may then initiate creation of a beam formed communication channel (block **308**). For example, the network connection device may form a sounding frame. The network connection device may then normalize transmission power of the sounding frame to approximate transmission power of a beam-formed frame (block **310**) and then transmit the normalized sounding frame (block **312**).

[0030] The network connection device, for instance, may make a determination that beam formed frames are to be transmitted having certain characteristics (e.g., by a number of antennas using a particular transmission power) and configure transmission of the sounding frame to mimic those characteristics.

[0031] The normalized sounding frame may be received over a wireless communication channel by a targeted network connection device having automatic gain control (block **314**). The targeted network connection device, for instance, may set gain by the automatic gain control to an amount that approximates gain that would be used upon reception of a beam-formed frame. Additionally, the sounding frame may cause the targeted network connection device to transmit a response to the sounding frame (block **316**) The response, for instance, may describe how the sounding frame "appears" to the targeted network connection device, when received, such as due to interference caused by the wireless medium.

[0032] The response may then be used to configure the beam formed communication channel (block **318**), such as by giving an "understanding" to the network connection device that transmitted the sounding frame as to how the communication channel and the wireless medium between the network connection device affects transmission of frames. Further, this understanding takes into account a likely setting of the automatic gain control when receiving beam formed frames, and therefore accurate knowledge of the channel is used to perform beam forming calculations. Normalization of the transmission power of the sounding frame may be performed in a variety of ways, an example of which may be found in the following procedure.

[0033] FIG. **4** depicts a procedure in an exemplary implementation in which a beam forming gain lookup table is used to normalize transmission power for a sounding frame used to form a beam-formed communication channel. A request is received to send a sounding frame to form a beam-formed connection (block **402**).

[0034] A lookup is performed to determine an amount of gain to adjust transmit power used to transmit non-beam formed frames at a particular rate (block **404**). The lookup, for instance, may use a number of transmit antennas **206**, number of receive antennas **208** and a number of spatial streams **210** to be used in the beam-formed connection as a lookup in the beam forming gain lookup table **202**. An output of the lookup is the gain **212** that is applied to transmit power used to transmit frames at a desired rate **214** in a non-beam formed connection, i.e., used to transmit a "conventional" frame. The gain **212** may then be used to normalize the transmit power (block **406**).

[0035] The sounding frame is transmitted using the normalized amount of power (block **408**). A response to the sounding frame is received that describes one or more conditions encountered by the sounding frame during transmission (block **410**). The response, for instance, may be a re-transmittal of the sounding frame such that the communication module **124** of the client **102** may determine "what happened" to the sounding frame during transmission through the wireless medium. The communication module may then use the response to configure a beam-forming wireless communication channel (block **412**), such as to address the conditions of the sounding frame encountered by adjusting transmission power, error correction techniques, protocol used, and so on.

[0036] As previously described, it should be readily apparent that the techniques of the procedures **300**, **400** of FIGS. **3** and **4** may also be applied to normalize transmission power of a beam-formed frame to approximate that of the sounding frame. For example, the beam forming gain lookup table may be used to normalize the transmission power of the beam-formed frames to approximate that used by the sounding frame. In another example, tables may be used to normalize both types of frames. A variety of other examples are also contemplated.

CONCLUSION

[0037] Although the invention has been described in language specific to structural features and/or methodological acts, it is to be understood that the invention defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as exemplary forms of implementing the claimed invention.

What is claimed is:

1. An apparatus comprising:

a transmitter; and

a communication module to normalize transmission power of the transmitter to transmit one or more sounding frames to approximate that of a beam formed frame, wherein the one or more sounding frames are to form a beam-formed connection.

2. An apparatus as described in claim **1**, wherein the transmission power of the sounding frame approximates that of the beam formed frame such that a network connection device having active gain control that receives the sounding frame does not adjust gain from that used upon reception of the beam formed frame.

3. An apparatus as described in claim **1**, wherein the transmission power is normalized based at least in part on a number of transmit antennas to be used by the beam-formed connection.

4. An apparatus as described in claim **1**, wherein the transmission power is normalized based at least in part on a number of spatial streams to be used by the beam-formed connection.

5. An apparatus as described in claim **1**, wherein the transmission power is normalized based at least in part a number of receive antennas to be used by the beam-formed connection.

6. An apparatus as described in claim **1**, wherein the transmission power is normalized through calculation of gain to be applied to transmission power useable by the transmitter to transmit frames at a predetermined rate of non-beam formed frames.

7. An apparatus as described in claim **1**, wherein the communication module is further configured to cause the transmitter to transmit the one or more sounding frames and

receive a response to the frame that is usable to form the beam-formed wireless connection, wherein the response describes one or more conditions of a wireless medium encountered by the one or more sounding frames when transmitted.

8. A method comprising:

forming a frame to initiate a beam-formed wireless connection; and

setting transmission power to be used to transmit the frame to approximate transmission power used to transmit a beam-formed frame.

9. A method as described in claim **8**, wherein:

the frame is configured as a sounding frame; and

the setting is based at least in part on a number of transmit antennas, a number of spatial streams, and a number of receive antennas to be used in a beam-formed connection.

10. A method as described in claim **8**, wherein the setting including applying an amount of gain to an amount of transmission power used to transmit frames at a predetermined rate without beam forming.

11. A method as described in claim **8**, further comprising:

transmitting the frame to be received by a network connection device; and

receiving a response to the frame that is usable to form the beam-formed wireless connection.

12. A method as described in claim **11**, wherein the received response describes one or more conditions of a wireless medium encountered by the frame when transmitted.

13. A method as described in claim **11**, further comprising forming the beam-formed wireless connection based at least in part on the received response.

14. One or more computer-readable media comprising executable instruction that, when executed, direct a client to query a table to determine an amount of gain to apply to a sounding frame to form a beam-formed wireless connection.

15. One or more computer-readable media as described in claim **14**, wherein the query is based on a number of transmit antennas, a number of spatial streams and a number of receive antennas to be used by the beam-formed wireless connection.

16. One or more computer-readable media as described in claim **14**, wherein the amount of transmission power is normalized to approximate an amount of transmission power to be used to transmit a beam-formed frame.

17. A system comprising:

a processor;

dynamic random access memory memory configured to maintain one or more application modules that are executable on the processor; and

a network connection device having a module to adjust transmission power of a transmitter such that beam-formed frames used in a beam-formed wireless connection have transmission power that approximates that of a sounding frame used to form the beam-formed connection.

18. A system as described in claim **17**, wherein the beam-formed wireless connection is configured to transmit data related to execution of the one or more application modules.

19. A system as described in claim **17**, wherein the adjustment is to be determined based on table lookup using a number of transmit antennas, number of spatial streams and number of receive antennas.

20. A system as described in claim **19**, wherein the adjustment in the table is based on a simulation.

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