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Application-Based Beam Selection for Uplink-Downlink Imbalance

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APPLICATION-BASED BEAM SELECTION FOR UPLINK-DOWNLINK IMBALANCE

Abstract

Form factor limitations and power constraints in user equipment such as a millimeter wave user equipment lead to link imbalances between uplink beams generated by the user equipment and downlink beams generated by network base stations. For example, the number of antenna elements in a user equipment is typically lower than the number of antenna elements in a base station, which results in an uplink beam range that is smaller than a downlink beam range. The user equipment can therefore detect the base station and nevertheless be unable to establish an uplink connection to the base station, *e.g.*, via a random-access channel (RACH). The effects of the link imbalance are reduced or eliminated by selectively activating different antenna elements at the user equipment and selectively orienting the user equipment based on its antenna configuration relative to the network base station.

Background

Wireless communication systems include a network of cells (also referred to as base stations) that provide wireless connectivity to user equipment within the network. In some cases, the base stations and the user equipment implement beamforming by coordinating the operation of multiple antennas or antenna arrays during transmission or reception of signals. For example, directional signal transmission or reception is performed by combining elements in an antenna array in such a way that signals at particular angles experience constructive interference while others experience destructive interference, thereby enhancing the signal strength or receptivity within beams around the beamforming angle. Techniques for adapting transmission power levels in wireless communication systems are disclosed in U.S. Patent Publication No. 20110136478, entitled “Self-optimizing networks for fixed wireless access.”

Imbalances can arise between the downlink (*e.g.*, the beam formed by the base station to transmit signals towards the user equipment) and the uplink (*e.g.*, the beam formed by the user equipment to transmit signals towards the base station). For example, form factor limitations and power constraints in a millimeter wave user equipment typically limit the number of antenna elements in the user equipment to fewer elements than can be implemented in a typical network base station. Consequently, the range of the downlink beam generated by the base station is larger than the range of the uplink beam generated by the user equipment. The user equipment can therefore detect the presence of the base station but may be unable to form an uplink connection due to the link imbalance. The user equipment can compensate (at least partially) for a link imbalance by increasing its transmission power. For example, techniques for managing uplink/downlink power imbalances are disclosed in U.S. Patent Publication No. 10045244, entitled "Enhanced Connection Performance in UL/DL Imbalance Scenarios." However, power constraints at the user equipment limit the transmission power to remain below a maximum transmission power, which may be insufficient to overcome the link imbalance.

FIG. 1 illustrates a link imbalance that forms between a millimeter wave user equipment and a network base station.

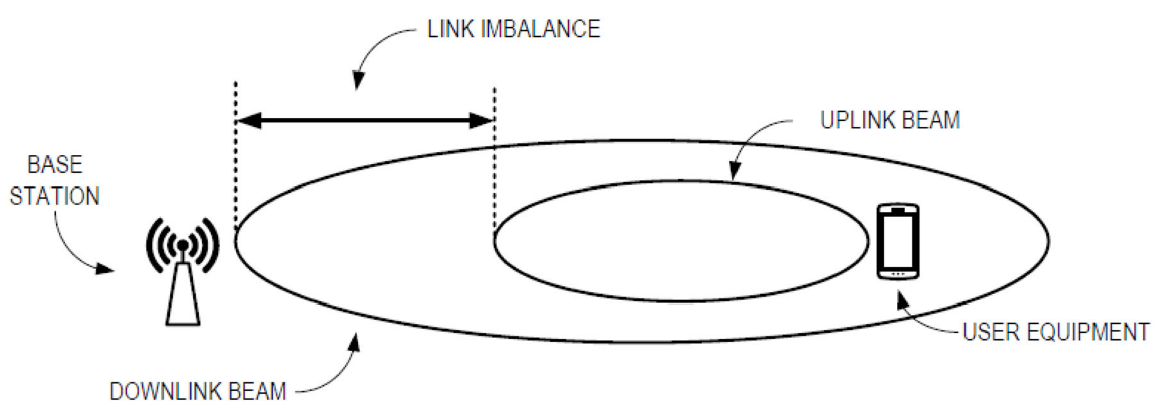

FIG. 1

Description

Link imbalances between base stations and user equipment that have different levels of antenna gain, *e.g.*, due to different numbers of antennas implemented in the devices, are reduced or eliminated by selectively activating different antenna elements at the user equipment and selectively orienting the user equipment based on its antenna configuration relative to the base station.

The user equipment includes multiple antenna modules that are deployed at different locations around its boundaries. Some of the antenna modules have a higher gain than others, *e.g.*, due to a higher number of antenna elements. The antenna modules that have smaller gains have larger coverage and the antenna modules that have larger gains have smaller coverage areas. An application processor implemented in the user equipment controls the antenna modules. For example, the application processor can selectively enable or disable the antenna modules. The application processor (or platform) also modifies the orientation of the user equipment or the antenna modules within the user equipment. For example, the application processor can issue commands to motors or sensors implemented in the user equipment that rotate or tilt the user equipment, thereby modifying the orientation of the user equipment and its antenna modules relative to a network base station. The algorithm is applied to non-handheld or stationary scenarios. For example, the application processor can modify the orientation of a device left on a desk, customer premises equipment (CPE), and other devices.

FIG. 2 illustrates a user equipment that includes multiple antenna modules (labeled 1 and 2) deployed at different locations within the user equipment.

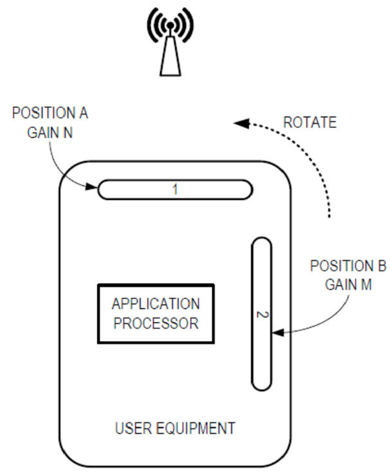

FIG. 2

The user equipment detects a link imbalance while the user equipment is using one of the antenna modules, *e.g.*, antenna module 1 in position A shown in FIG. 2. The antenna module 1 has a gain of N that is less than a gain M of the antenna module 2 that is initially in position B. The user equipment measures a Reference Signal Received Power (RSRP) on the downlink and compares the RSRP to a cell selection threshold. The user equipment also determines whether it fails a random access channel (RACH) attempt on antenna module 1. If the RSRP measured by the user equipment meets or exceeds the cell selection threshold but the RACH fails, the user equipment is in a link imbalance state.

The application processor in the user equipment modifies a configuration of the antenna modules in response to the user equipment being in the link imbalance state. The application processor disables a lower gain antenna module and enables a higher gain antenna module. For example, the application processor shown in FIG. 2 can disable the antenna module 1 (in Position A) and enable antenna module 2 in position B. The application processor then modifies an orientation of the user equipment. For example, the application processor shown in FIG. 2 can rotate the user equipment so that antenna module 2 is at position A.

Selecting appropriate antenna modules and re-orienting the user equipment has a number of advantages. The user equipment selects the best antenna module to serve the base station, which is particularly useful in the millimeter wave user equipment. The technique also uses the platform capabilities of sensors and motors to auto-correct the device orientation and position to point to the best possible signal. For example, the vibration feature of the user equipment can be used to move or reposition the user equipment. This approach is also applicable to scenarios where the device is not hand-held and/or non-mobile. Using the best antenna module will result in the enhancements to the following key performance indicators (KPIs):

a. Higher dwell time in 5G

b. Power saving because the user equipment always chooses the best antenna module to serve at a lower transmit power.

Furthermore, user experience is enhanced because the link with the network base station is more robust in both downlink and uplink directions