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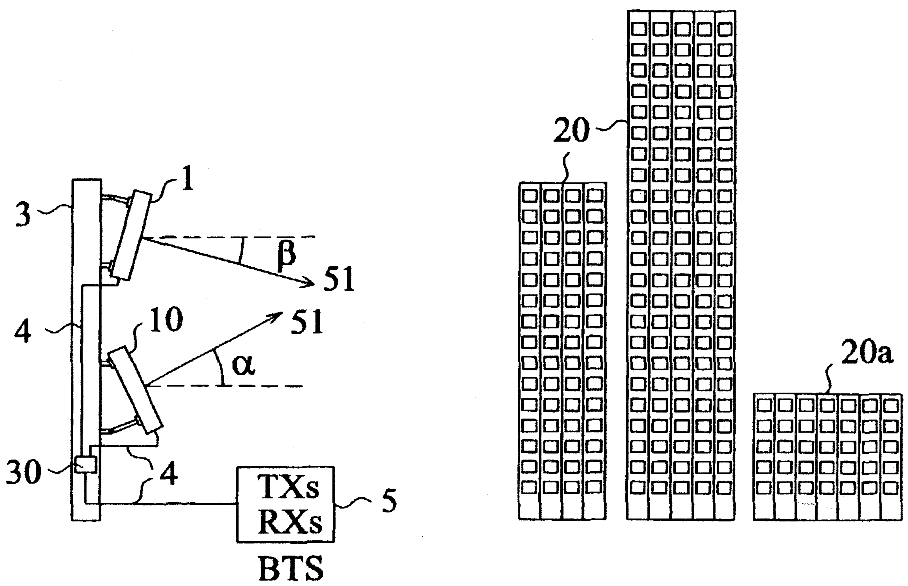
(54) Title: A THREE-DIMENSION COVERAGE CELLULAR NETWORK



(57) Abstract: Network, method, base station and antenna are disclosed to establish three-dimension cellular signal coverage, especially coverage in upper floors of high-rise buildings in city, for a cellular telecommunication system. To expand base station coverage to space above ground, up-tilt antenna and down-tilt antenna are coupled together to share base station transceivers, so as to share cellular frequency spectrum, expand coverage and meanwhile avoid interferences. The down-tilt antenna covers ground; the up-tilt antenna covers space above ground, especially the upper floors of high-rise buildings in its cell. A multibeam multi-tilt base station antenna is invented to replace a down-tilt antenna and an up-tilt antenna to provide three-dimension coverage with single antenna. It has one beam pointing downward to cover ground and one beam pointing upward to cover space above ground in a base station.

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A THREE-DIMENSION COVERAGE CELLULAR NETWORK

Cross-References to Related Applications

This application claims priority to and the benefit of Canada Patent Application Serial No. 2,393,552, filed July 31, 2002, titled "Methods and Antennae for High-Rise Buildings Coverage of Terrestrial Cellular Wireless Communications Systems", the entire disclosure of which is hereby incorporated by reference.

Field of The Invention

This invention relates to cellular signal coverage on ground and above ground for a cellular telecommunication system. It is about network, method, base station and antenna to establish three-dimension cellular signal coverage for a cellular telecommunication system and meanwhile eliminate interferences in a geographical area.

Background

Mobile cellular telecommunication system (simply called "mobile cellular system", or "cellular system"), originally invented by Bell Telephone Laboratories in the 1970s (U.S. patent No. 3,663,762), is generally known to include at least one mobile switch centre (MSC), a plurality of base stations dispersed across a geographic area and a plurality of ground-based subscriber radio stations. It comprises of at least one control channel and a group of traffic channels, and provides mobile wireless access telecommunication services for ground-based subscriber radio stations using radio frequencies or frequency spectra allocated for cellular mobile communications. Each base station includes a base station transceivers system (BTS), at least one base station antenna and an antenna supporting structure (tower, pole and rooftop etc.), and serves a ground area – a ground cell, which is covered by one or a plurality of base station antennas. Each ground cell can be further divided into multiple ground sectors, each of which is covered by one or a plurality of base station sector antennas. Radio frequencies or frequency spectra are reused among the ground cells and sectors. The BTS includes a plurality of transmitters and a plurality of receivers, both comprising at least one control channel and a plurality of traffic channels. Exclusive radio frequency bands are assigned to mobile cellular systems in a geographical area. In North America, two frequency bands are assigned to mobile cellular systems. One is 800MHz band with transmission frequency from 824MHz to 849MHz and receiving frequency from 869MHz to 894MHz; another one is 1900MHz band with transmission frequency from 1850MHz to 1910MHz and receiving frequency from 1930MHz to 1990MHz.

Cellular system is based on two basic concepts: cells and frequency reuse. A geographical area is divided into many smaller service areas – cells, which are generally represented as hexagons tangent at each other and composing a cellular pattern. Base stations locate proximately at the centres of each cell with antennas mounted on towers (or poles, rooftops etc.), transmitting/receiving radio signals and communicating with subscriber radio stations in their own cells. Radio frequencies are reused among these cells. The advantage of this strategy is great increase in network capacity with limited frequency spectra. Today, this cellular strategy has been widely used in various mobile cellular systems, like AMPS (advanced mobile phone system) system, TDMA (time division multiple access) system, GSM (global system for mobile communications) system, CDMA (code division multiple access) system and 3G (third generation cellular system). (A cell is the geographical area or space covered by a base station or a subsystem of the base station corresponding to a specific logical identification on the radio path. A cell is also considered as the coverage extent of a base station or a subsystem of the base station. Mobile stations in a cell may be reached by the corresponding radio equipment of the base station).

Radio frequencies reuse among cells can cause interferences. In FDMA (frequency division multiple access) cellular systems (like AMPS) and TDMA cellular systems (like GSM), radio frequencies reuse causes co-channel interferences. In order to minimize co-channel interferences, cellular network structure is designed to increase the distances of co-channel interfering sources to subscriber radio stations. Cells are organized in clusters. A cluster is a group of cells. Within a cluster of cells, the whole available frequency spectra can be exploited. A portion of the total number of frequency channels is allocated to each cell, while adjacent cells within the same cluster are assigned different groups of frequency channels. There is no radio frequency reuse within a cluster. The frequency channels arrangement in a cluster then repeats in all clusters of a cellular network. In this structure, frequency reuse distance is much larger than the cell's radius, helping to reduce co-channel interferences. A cell can further be split into multiple sectors with directional sector antennas. Each sector covers a part area of the cell. Each sector is assigned a portion of the total frequency channels of the cell. The orientation of sector antenna further reduces co-channel interferences. In a CDMA cellular system, all cells use the same spread spectrum in a wide frequency range. The interferences come from increased on-going communications within the cell and from the adjacent cells, which contribute as noise floor to the system. Less signals radiating to the adjacent cells, less interferences will be created to the system. Containing base station radio signals within its own cell is a way to control interferences in the cellular system.

As shown in FIG.1A and 1B, the down-tilt beam base station antenna (simply called "down-tilt antenna") is a method widely used in mobile cellular systems (U.S. patent No. 4,249,181). The down-tilt antenna radiates signal downward, contains its signal within its own cell and limits its signal radiating to its adjacent cells, so as to reduce interferences in a cellular system. Whilst helping to reduce interferences, down-tilt antenna comes at a price. As its beam points downward to the ground, space above the down-tilt antenna is suffered by sharply reduced radio signals, especially near the boundary of its cell. The space coverage pattern of a cell when using the down-tilt antenna is just like a big dome (as shown in FIG.1C and FIG.1D), high in the centre but low at the boundary. Radio signal outside cells coverage extents is not strong enough for communications. (Herein after, a cell covered by down-tilt antennas or by antennas without beam tilting is called "ground cell"; a sector covered by down-tilt sector antennas or by sector antennas without beam tilting is called "ground sector", a cellular network composed of ground cells and ground sectors is called "ground cellular network". Word "ground" is to emphasis their coverage target).

Mobile cellular system was developed to provide mobile telecommunications on ground. Its network structure and system design were based on mobility and ground coverage. Traditionally, a mobile cellular network treats its coverage area as a surface and covers ground only. It is basically a two-dimensional coverage network. The world is three-dimensional. There are many high-rise buildings in urban areas, especially in large cities. Limited heights and down tilting of base station antennas make the upper floors of many high-rise buildings out of the coverage range of a mobile cellular network. Though as technology improves, subscriber radio station like mobile phone and BTS are made more and more sensitive to enable them to pick up weaker signal, it has been proved that cellular signal inside the upper floors of many high-rise buildings is too weak to make good quality communications. There are two major additional signal losses besides free space loss, happening between a base station and a mobile phone inside an upper floor of a high-rise building in its cell. One major additional signal loss is penetration loss of the wall and/or window of the high-rise building. It contributes about 20dB loss on average. Another major additional signal loss is due to the down tilting of its base station antenna. The upper floors of many high-rise building are not in the major lobe coverage range of the down-tilt antenna. Instead, they are in the null zone of the down-tilt antenna. Generally, the gain of a cellular base station antenna is 20dB less in its null zone than in its major lobe. It contributes another 20dB loss on average. Cellular signal inside the upper floors of most high-rise buildings is about 40dB lower on average, compared with cellular signal on ground in the same location. That's why we have difficulty to make cellular phone calls on the upper floors of many high-rise buildings. Whist inside the lower floors of high-rise buildings or inside low-rise buildings, which are under major lobes coverage range of down-tilt antennas, cellular signals suffer only 20dB on average the penetration loss besides free space loss. Cellular signals there are much stronger than inside the upper floors of most high-rise buildings in the same area. You can make good quality cellular phone calls there in most situations. 20dB makes a significant difference in radio communications, especially in weak radio signal environments like indoors. The existing mobile cellular network needs to be modified to solve the coverage problem in the upper floors of high-rise buildings. (Antenna major lobe is the lobe of the antenna radiation pattern, which containing the maximum radiation energy. Sometimes it is also called "main lobe" or "beam").

In rural areas, where telecommunication traffics are low, cells are designed as large as possible to cover a wider area. Base station antennas generally down-tilt small angles or don't tilt at all. In urban areas, where telecommunication traffics are high, cells are designed much smaller than in rural areas. Most base station antennas down-tilt relatively larger angles than in rural areas to contain their radiations within small cells and to avoid interferences. As concerns of interferences, cell size, aesthetics, cost and location availability, base station antennas are generally mounted on rooftops in heights from 20 meters to 40 meters above ground. That leaves the upper floors of many high-rise buildings in urban areas, especially in big cities, out of mobile cellular network coverage range in space. The reality is the absence of or weak cellular signal coverage in the upper floors of many high-rise buildings. People work and live there. As mobile phone becomes so popular worldwide, mobile cellular signal coverage in high-rise building is now a major concern for both service providers and their customers.

A system and method called "distributed antenna system" (DAS) has been used to provide mobile cellular signal indoor coverage in high-rise buildings. It introduces cellular radio signal inside buildings from a microcell base station or a repeater via RF (radio frequency) cables and/or fibres. Generally, it needs a microcell base station or a repeater, a long and complicated radio signal distribution network and many indoor antennas. Radio signal strength is limited to cover small areas around the indoor antennas. Unfortunately, the DAS system is not a cost-effective solution for high-rise building coverage. The microcell base station or repeater and the distribution network are very expensive. Rentals of equipment rooms to host the microcell base station or repeater and the distribution network in high-rise buildings are very expensive as well. It also requires permission from landlords to run the distribution network. The installation expenses are prohibitive. To achieve full coverage in all buildings, you have to run this system floor-by-floor and building-by-building at extraordinary expenses. The paid traffics in the coverage areas of the DAS system are limited. In most situations, revenue generated from the DAS system simply cannot compensate its investment. That's why it is not commonly implemented.

There is a need of a more practical, cost-effective solution for cellular signal coverage in upper floors of high-rise buildings for a cellular system.

Summary

A cellular telecommunication network (simply called “cellular network) of this invention has the feature that at least one of its base stations has a 3D (three-dimensional) space coverage extent on ground and above ground, while eliminating interferences by sharing the transmitters and receivers of the base station between its down-tilt antenna and up-tilt antenna and by beam down-tilting and up-tilting of its base station antennas. It may further have another feature that at least another one of its base stations has coverage extent in a space above ground, while eliminating interferences by beam up-tilting of its base station antenna. So the cellular network of this invention provides a cost-efficient solution for 3D space coverage in a geographical area, especially coverage of the upper floors of high-rise buildings in city.

This invention also provides method and base station to set up the cellular telecommunication network with the features described above.

A cellular telecommunication network of this invention comprises a plurality of base stations in a geographical area. It provides cellular telecommunication services in the geographical area. The geographical area is divided into a plurality of cells. Each base station provides radio signals to subscriber stations in its cell. At least one base station of the cellular network has a 3D space coverage extent on ground and above ground in its cell. The base station comprises a transmitter, a down-tilt antenna and an up-tilt antenna. The transmitter generates a radio signal to be provided within the cell of the base station, and within a frequency range that is reusable in more than one of the cells of the cellular network. The down-tilt antenna is coupled to the transmitter for radiating the radio signal in a characteristic radiation pattern having its major lobe pointed downward. The up-tilt antenna is coupled to the transmitter for radiating the radio signal in a characteristic radiation pattern having its major lobe pointed upward, so as to radiate the radio signal within the cell of the base station below the down-tilt antenna and above the up-tilt antenna, while limiting radiation of the radio signal into other cells of the cellular network within which the radio signal may interfere with radio signals from other base stations of the cellular network. The base station further comprises a receiver for receiving radio signals generated by subscriber stations in its cell. The receiver may be coupled to both the up-tilt antenna and the down-tilt antenna, so as to receive the radio signals generated by subscriber stations in the cell of the base station through at least one of the two antennas. Both antennas may be substantially collocated. The down-tilt antenna may be located above the up-tilt antenna in altitude. The two antennas may be integrally formed into one antenna. (Radio signal, or sometimes simply called “signal”, is detectable radio energy that carry information generated by a transmitter or by a subscriber radio station. Antenna radiation pattern is the variation of the field intensity of the antenna as an angular function with respect to the axis.)

The cellular network of this invention may further comprise at least another one of its base stations, which has coverage extent in a space above ground. The base station comprises a transmitter and an up-tilt antenna. The transmitter generates a radio signal to be provided within the cell of the base station, and within a frequency range that is reusable in more than one of the cells of the cellular network. The up-tilt antenna is coupled to the transmitter for radiating the radio signal in a characteristic radiation pattern having its major lobe pointed upward, so as to radiate the radio signal within the cell of the base station above the up-tilt antenna, while limiting radiation of the radio signal into other cells of the cellular network within which the radio signal may interfere with radio signals from other base stations of the cellular network. The base station further comprises a receiver for receiving radio signals generated by subscriber stations in its cell.

A method of this invention, for providing cellular telecommunication service in a geographical area where is divided into a plurality of cells, comprises the flowing process: generating a plurality of radio signals in a frequency range which is reusable in more than one of the cells, wherein each radio signal is to be provided to subscriber stations in its cell; providing each radio signals to its cell. Wherein one of the radio signals is provided to its cell by radiating it from a down-tilt antenna in a characteristic radiation pattern having its major lobe pointed downward, and by radiating it from an up-tilt antenna in a characteristic radiation pattern having its major lobe pointed upward. So the radio signal is radiated within its cell below the down-tilt antenna and above the up-tilt antenna, while being limited its radiation into other cells within which it may interfere with other radio signals. The method further comprises the process of receiving at least one radio signal from a subscriber station in the cell. The radio signal from the subscriber station may be received through at least one of the down-tilt antenna and up-tilt antenna. Both antennas may be substantially collocated. The down-tilt antenna may be above the up-tilt antenna in altitude. The down-tilt antenna and the up-tilt antenna may be integrally formed into one antenna.

The method of this invention may further comprise the following process: providing another radio signal to its cell by radiating it in a characteristic radiation pattern having its major lobe pointed upward from an up-tilt antenna of the cell, so as to radiate it within its cell above the up-tilt antenna, while limiting its radiation into other cells within which it may interfere with other radio signals.

A base station of a cellular telecommunication network of this invention comprises a transmitter, a down-tilt antenna and an up-tilt antenna. The cellular network is adapted to providing a plurality of cellular radio signals in a geographical area where is divided into a plurality of cells. The transmitter generates a radio signal to be provided within the cell of the base station. It operates at a frequency range that is reusable in more than one of the cells. The down-tilt antenna is coupled to the transmitter for radiating the radio signal in a characteristic radiation pattern having its major lobe pointed downward. The up-tilt antenna is coupled to the transmitter for radiating the radio signal in a characteristic radiation pattern having its major lobe pointed upward. So the radio signal is radiated within the cell of the base station below the down-tilt antenna and above the up-tilt antenna, while being limited its radiation into other cells within which it may interfere with other radio signals of the cellular network. The base station further comprises a receiver for receiving radio signals generated by subscriber stations in its cell. The receiver may be coupled to the down-tilt antenna and the up-tilt antenna, so as to receive the radio signals generated by subscriber stations in the cell of the base station through at least one of the down-tilt antenna and up-tilt antenna. The down-tilt antenna and the up-tilt antenna may be integrally formed into one antenna.

This invention further provides a multi-beam multi-tilt base station antenna, which has at least two beams in two different directions. It may be used in a cellular base station to replace a down-tilt antenna and an up-tilt antenna for providing 3D space coverage with single antenna. When it is used in a cellular base station, one of its beams points downward to cover ground, another one of its beams points upward to cover space above ground. (Antenna beam, also called antenna major lobe, is the radiation lobe containing major radiation energy in confined small angle in at least one dimension).

Brief Description of The Drawings

FIG.1A (prior art): A typical base station of a mobile cellular system and its coverage.

FIG.1B (prior art): The lobe pattern in elevation of the down-tilt sector antenna in FIG.1A.

FIG.1C (prior art): The schematic 3D coverage shape of a typical ground cell of a mobile cellular system.

FIG.1D (prior art): The schematic 3D coverage shape of a ground mobile cellular network.

FIG.2A: Up-tilt sector antenna covers the upper floors of high-rise buildings.

FIG.2B: Up-tilt omni-directional antenna covers the upper floors of high-rise buildings.

FIG.2C: Up-tilt transmitting and receiving sector antennas cover the upper floors of high-rise buildings.

FIG.2D: The lobe pattern in elevation of the up-tilt sector antenna in FIG.2A.

FIG.2E: The schematic 3D coverage shape of an upward cell of this invention.

FIG.2F: The schematic 3D coverage shape of an upward cell and sectors of this invention.

FIG.2G: The schematic 3D coverage shape of an upward cellular network of this invention.

FIG.3A: The space coverage profile in elevation with an upward cellular network overlaying on a ground cellular network in first way.

FIG.3B: The space coverage profile in elevation with an upward cellular network overlaying on a ground cellular network in second way.

FIG.3C: The space coverage profile in elevation with an upward cellular network overlaying on a ground cellular network in third way.

FIG.3D: The space coverage profile in elevation with an upward cellular network overlaying on a ground cellular network in fourth way.

FIG.4A: An embodiment of the method and the shared base station of this invention for eliminating interference between an upward cell and a ground cell.

FIG.4B: An embodiment of the method and the shared base station transmitters and receivers of this invention for eliminating interference between an upward cell and a ground cell.

FIG.4C: An embodiment of the method for eliminating interference between an upward cell and a ground cell by using dedicated frequencies or frequency spectra in an upward cellular network.

FIG.5A: A system structure embodiment of an upward cellular network of this invention.

FIG.5B: A system integration embodiment of an upward cellular network and a ground cellular network.

FIG.5C: A system integration embodiment of an upward cellular network and a ground cellular network.

FIG.5D: A system integration embodiment of an upward cellular network and a ground cellular network.

FIG.6A (prior art): A typical base station sector antenna, its beam pattern and coverage

FIG.6B: An embodiment of the method for high-rise building coverage with a narrow beam antenna.

FIG.7A: An embodiment of the multi-beam multi-tilt antenna of this invention in single band.

FIG.7B: The lobe pattern in elevation of the antenna in FIG.7A.

FIG.7C: An embodiment of the multi-beam multi-tilt antenna of this invention in dual bands.

FIG.7D: The lobe pattern in elevation of the antenna in FIG.7C.

FIG.7E: An embodiment of mechanical beam tilting means of the multi-beam multi-tilt antenna.

FIG.7F: An embodiment of electrical beam tilting means of the multi-beam multi-tilt antenna.

Detailed Descriptions

FIG.1A to FIG.1D describe prior art and its problem.

FIG.1A is an embodiment of a typical base station of a mobile cellular system and its coverage. Down-tilt sector antenna 1 connects to BTS 5 with RF cable 4. It is mounted on mast 3. Its beam is down-tilted β degree below the horizontal plane from its mounting position. Its beam covers ground, low-rise building 20a and the lower floors of high-rise buildings 20 in its ground sector. Its beam does not cover the upper floors of high-rise buildings 20. Antenna 1 acts as both transmitting and receiving antennas. Arrow 51 is beam (or major lobe) axis. (A sector antenna has a radiation pattern that is directional in both azimuth and elevation. Beam or major lobe axis is the maximum radiation power direction of the beam or major lobe).

FIG.1B is an embodiment of the lobe pattern in elevation of the down-tilt sector antenna 1 in FIG.1A in both transmitting and receiving directions. Because there is reciprocity between the transmitting and receiving characteristics, an antenna has the same lobe pattern in both transmitting and receiving directions. Major lobe 6 of sector antenna 1 is down-tilted β degree below a horizontal plane. (The major lobe direction is its maximum power radiation direction). While 7 is its first upper side lobe; 8 is its first lower side lobe; 9 is its backside lobe. Arrow 51 is major lobe axis. Notice the null between major lobe 6 and first upper side lobe 7 is just around the horizontal plane. It is the space area where are the upper floors of many high-rise buildings. Generally, cellular signal strength in this null zone is 20dB lower than the maximum signal strength of the major lobe. So down-tilting of base station antennas in a cellular system makes cellular signal in the upper floors of most high-rise buildings 20dB lower in strength on average than cellular signal in the lower floors of high-rise buildings or in low-rise buildings in the same area. A coordinate XY is shown as a reference (axis X represents horizontal direction and axis Y represents elevation direction).

FIG.1C is an embodiment of the schematic 3D coverage shape of a typical ground cell of a mobile cellular system. The area and space covered by down-tilt omni-directional antenna 2, form ground cell 11. It may have a shape like a big dome that is high in centre and low around boarder. While 13 is the boarder of ground cell 11. Antenna 2 connects to BTS 5 and is mounted at a height h1 above ground. Ground cell 11 does not cover space higher than h1. Its coverage height decreases as the distance from its cell centre increases. Because of reciprocity between the transmitting and receiving characteristics of an antenna, ground cell 11 has proximately the same coverage shape and range in both transmitting and receiving directions. (An omni-directional antenna has a radiation pattern that is non-directional in azimuth. Its vertical radiation pattern may be of any shape).

FIG.1D is an embodiment of the schematic 3D coverage shape of a ground mobile cellular network in both transmitting and receiving directions. A plurality of ground cells juxtapose on the earth's surface composing a ground mobile cellular network. These ground cells cover only the space under their down-tilt base station antennas. The coverage near their cell boundaries is worse in both signal strength and coverage height. As described before, a ground mobile cellular network doesn't cover the upper floors of many high-rise buildings. It is a problem to be solved. The intention of this invention is to solve this problem in a cost-efficient manner. The ground mobile cellular network has proximately the same coverage shape and range in both transmitting and receiving directions.

FIG.2A to 2G illustrate the first basic concept of this invention: Base station antenna has its major lobe point upward to cover the upper floors of high-rise buildings to increase cellular signal strength there; space above ground in a geographical area is divided into a plurality of small service spaces -- upward cells; each upward cell is covered by one or a plurality of upward major lobes of base station antennae in both transmitting and receiving directions; a plurality of upward cells composes an upward cellular network and covers space above ground in the geographical area. Whereby, an upward cellular network provides cellular signal coverage in space above ground, especially in upper floors of most high-rise buildings, in the geographical area for a mobile cellular system.

FIG.4A to 4C illustrate the second basic concept of this invention: An up-tilt antenna and a down-tilt antenna are coupled together and then connect to base station transceivers. That is they share base station transceivers, so as to share cellular frequencies or frequency spectrum and avoid interference. They may share the whole BTS or part of it of a base station. The up-tilt antenna covers space above ground, or upward cell; the down-tilt antenna covers ground, or ground cell. Because both antennas share the same radio signal source, no interference will happen between the upward cell and the ground cell. This interference elimination technique and the interference elimination technique of beam down-tilting and beam up-tilting can be combined to use to eliminate interferences in the whole cellular network.

A base station of a mobile cellular system comprises at least a BTS, at least one transmitting antenna and at least one receiving antenna. Each BTS comprises at least one transmitter and at least one receiver. The transmitting antenna is coupled to the transmitters and transmits the radio signals generated by the transmitters into its cell; the receiving antenna is coupled to the receivers and receives the radio signals generated by subscriber stations in its cell. Both have proximately the same radiation characteristic pattern. They are mounted on an antenna supporting structure. The transmitters generate cellular radio signal to be provided in its cell within a frequency range that is reusable in more than one of the cells of the mobile cellular network. The radio signal generated by the transmitters radiates from the transmitting antenna in a radiation characteristic pattern having its major lobe point upward above the transmitting antenna in its cell. The receivers receive radio signals generated by the subscriber stations in its cell through the receiving antenna. A base station is often used as both transmitting and receiving antennas.

As its has been discussed before, cellular signal strength will increase up to 20dB on average in the upper floors of high-rise buildings if a base station antenna is up-tilted to have its major lobe cover there. Because of reciprocity between the transmitting and receiving characteristics of the antenna, the strength of received radio signals generated from the subscriber stations (mobile phones, for example) there and received by the base station antenna will increase up to 20dB on average as well in the base station receivers, if the base station antenna is used as both transmitting and receiving antennas. It will significantly change cellular telecommunication conditions there. One up-tilted base station antenna can cover the upper floors of many high-rise buildings in its cell. It is a cost-efficient coverage solution and easy to be implemented. (Herein after, a beam up-tilted base station antenna simply called "up-tilt antenna"; a beam up-tilted base station sector antenna simply called "up-tilt sector antenna").

The radio communication process between a base station and a subscriber station in a mobile cellular system is a well-known art. It is not the scope of this invention. In most situations, antenna is used as both transmitting and receiving antennas in cellular base stations. It has the same gain and direction selection in transmitting and in receiving. It will reject radio signal from a subscriber station outside its coverage range. For example, an up-tilt antenna will reject radio signal from a subscriber station on the ground in its cell. The up-tilt antenna can be used as a way to eliminate interferences among cells in a mobile cellular network, just the same way as the down-tilt antenna does. Separate transmitting and receiving antennas may be used in a base station for certain reason. They may have different characteristics in order to balance the differences between downlink (from base station to subscriber station) and uplink (from subscriber station to base station). In no matter what situations, It is preferred that a base station has same coverage shape and extent in both transmitting and receiving directions in a mobile cellular network.

Space above ground is treated as three-dimensional in coverage in this invention. Besides the ground cells and ground sectors, concepts of upward cell and upward sector are introduced in this invention. An upward cell is a predefined space above ground and covered by one or a plurality of major lobes pointing upward from one or a plurality of base station antennas. An upward cell can be divided into multiple upward sectors (three upward sectors, for example). An upward sector is a predefined space above ground within an upward cell and covered by one or a plurality of major lobes pointing upward from one or a plurality of base station sector antennas. Each upward cell comprises at least a BTS and at least one antenna (transmitting and receiving). The antenna is coupled to the BTS and mounted on an antenna supporting structure. Each upward sector comprises a BTS and at least one sector antenna (transmitting