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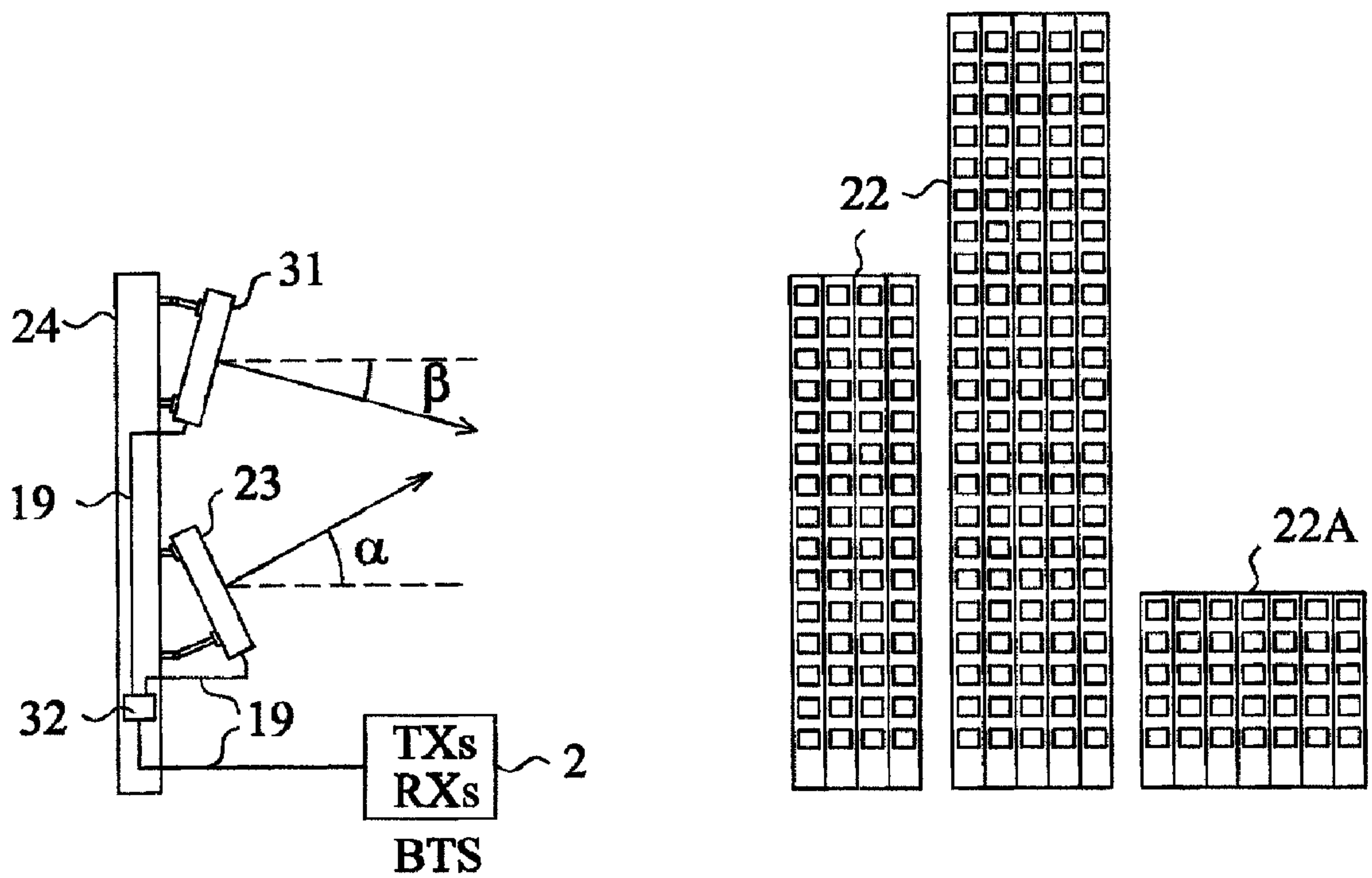


(57) Abrégé/Abstract:

Network, method and base station are disclosed to establish a three-dimensional space coverage cellular telecommunications network for providing cellular signals coverage on the ground and in space above the ground, especially in high-rise buildings, in a cellular telecommunications system. An up-tilt antenna and a down-tilt antenna are coupled to the same base station transceivers, so as to share the base station and frequency spectrum, and to avoid interferences. The down-tilt antenna covers the ground; the up-tilt antenna covers space above the ground, especially the upper floors of high-rise buildings in its cell. The up-tilt antenna and the down-tilt antenna may be integrated into one antenna.

ABSTRACT

Network, method and base station are disclosed to establish a three-dimensional space coverage cellular telecommunications network for providing cellular signals coverage on the ground and in space above the ground, especially in high-rise buildings, in a cellular telecommunications system. An up-tilt antenna and a down-tilt antenna are coupled to the same base station transceivers, so as to share the base station and frequency spectrum, and to avoid interferences. The down-tilt antenna covers the ground; the up-tilt antenna covers space above the ground, especially the upper floors of high-rise buildings in its cell. The up-tilt antenna and the down-tilt antenna may be integrated into one antenna.

A THREE-DIMENSIONAL SPACE COVERAGE CELLULAR NETWORK

Field of The Invention

This invention relates to a three-dimensional (3D) space coverage cellular network in a cellular mobile or fixed wireless communications access system, providing cellular radio frequency (RF) signals coverage on the ground and in space above the ground, especially in high-rise buildings.

Background

Mobile cellular telecommunications 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 (BSs) dispersed across a geographic service area and a plurality of ground-based subscriber radio stations. It comprises at least one communication control channel and a group of communication traffic channels, and provides mobile wireless access communications services for ground-based subscriber radio stations using radio frequencies or frequency spectrums allocated for cellular mobile wireless access communications. Each base station includes a base station transceivers system (BTS), at least one base station antenna and an antenna supporting structure (tower, pole or 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 base station transceivers system includes a plurality of transmitters and a plurality of receivers, both comprising at least one communication control channel and a plurality of communication traffic channels. In each country, exclusive radio frequency bands are assigned to mobile cellular systems. In North America, two frequency bands are assigned to TDMA (time division multiple access), GSM (global system for mobile communications) and CDMA (code division multiple access) cellular systems. One is in 800MHz band with transmission frequency from 824MHz to 849MHz and receiving frequency from 869MHz to 894MHz; another one is in 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 service area is divided into many smaller areas – cells, which are generally represented as hexagons tangent at each other and composing a cellular pattern. Base stations locate proximately at the centre of each cell with antennas mounted on towers (or poles, rooftops etc.), transmitting/receiving RF signals and communicating with mobile and/or fixed subscriber radio stations in their own cells. Radio frequencies are reused among these cells. The advantage of this strategy is the great increase in network capacity with limited radio frequency spectrum. Today, this cellular strategy has been widely used in mobile cellular systems like AMPS (advanced mobile phone system), TDMA, GSM, CDMA and 3G (third generation cellular system) etc., and in fixed wireless communications access systems like WLL (wireless local loop) etc.

FIG.1A illustrates a typical mobile cellular system, which includes at least one mobile switch centre (MSC) 8, a plurality of base station controllers (BSCs) 7A and 7B, and a plurality of base stations 5A, 5B, 5C and 5D (the dashed line circles) dispersed across a geographic service area. Each base station (BS) comprises a BTS, at least one antenna and a tower, and has a coverage area - a cell (sometimes called " ground cell"). Each BTS communicates with mobile subscriber radio stations (MSs) inside its cell by cellular RF signals. BS 5A comprises BTS 2A, antenna 3A and tower 4A; it covers cell 1A and serves MS 6A. BS 5B comprises BTS 2B, antenna 3B and tower 4B; it covers cell 1B and serves MS 6B. BS 5C comprises BTS 2C, antenna 3C and tower 4C; it covers cell 1C and serves MS 6C. BS 5D comprises BTS 2D, antenna 3D and tower 4D; it covers cell 1D and serves MS 6D. MSC 8 interfaces with the Public Switched Telephone Network (PSTN) in one side and connects to the cellular network in the other side through a plurality of BSCs 7A and 7B. Each BSC serves a plurality of BTSs. BSC 7A serves BTSs 2A and 2B; BSC 7B serves BTSs 2C and 2D. MSC 8 controls communications among MSs in its cellular network and between any subscriber 9 (a telephone for example) in PSTN and any MS in its cellular network. MS can move around inside a cell and across cells while keeping communications. Exclusive cellular radio frequency spectrum is granted for the mobile cellular system in its service area.

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. Cluster is a group of cells. Within a cluster of cells, the whole available frequency spectrum is 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 split into multiple sectors with directional sector antennas. Each sector covers 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 CDMA cellular systems, 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 RF signals radiating to the adjacent cells, less interferences will be created to the system. Confining base station RF signals within its own cell is a way to control interferences in the cellular system.

FIG.1B illustrates a typical cellular network structure and the 7/21 frequency reuse plan, which is commonly used in FDMA and TDMA cellular systems to achieve a good balance between cell traffic capacity and frequency interferences. Cellular network 10 comprises a plurality of clusters in a geographical service area. Each cluster 11 comprises seven cells. The available frequency spectrum is divided into seven groups of frequency channels A, B, C, D, E, F and G. Each cell 1 is assigned one group of frequency channels. Each cell 1 may be further divided into three sectors. Each sector 12 is covered by a directional antenna. And each group of frequency channels in a cell can be further divided into three subgroups of frequency channels. For example, frequency channels group C is divided into three subgroups C1, C2 and C3. Each sector is assigned a subgroup of frequency channels. So in 7/21 plan, there are seven cells and maximum twenty one sectors in one cluster, or seven groups of frequency channels (A, B, ... , G) and maximum twenty one subgroups of frequency channels (A1, A2, A3, ... , G1, G2, G3) in one cluster. No frequency channel is reused within a cluster. This frequency arrangement then repeats in each cluster throughout the whole cellular network. BTS is located proximately at the centre of each cell. In this plan, the frequency reuse distance is much larger than the cell radius. It helps to reduce co-channel interferences. The orientation of the sector antenna further reduces co-channel interferences. There are other frequency reuse plans in FDMA and TDMA cellular systems, like 4/12 reuse plan and 9/27 reuse plan etc. In CDMA cellular systems, the same wide spread frequency spectrum is reused in each cells.

Fixed cellular system has the similar system structure, cellular network structure and frequency reuse plan as the mobile cellular system does. Unlike subscriber radio stations moving around in a mobile cellular system, its subscriber radio stations are fixed and they use fixed directional antennas oriented to the base station antennas in their cells. The system includes at least one switch centre, a plurality of base stations and a plurality of fixed subscriber radio stations. It provides wireless communications services for its fixed subscribers to communicate with each other, and to communicate with subscribers in PSTN. Exclusive frequency spectrum is granted for each fixed cellular system in a geographical service area.

Down-tilt beam base station antenna (herein after simply called "down-tilt antenna") is widely used in cellular systems (U.S. patent No. 4,249,181) to reduce interferences. The down-tilt antenna radiates RF signals downward below the horizontal surface from its mounting position, confines its RF signals within its own cell and reduces its RF signals to radiate to the 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 pointed downward to the ground, the space above its mounting height is suffered by sharply reduced RF 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.1D), high in the centre but low at the boundary.

In rural areas where communications traffic is low, cells are designed as large as possible to cover a wider area. Base station antennas generally down-tilt at small angles or they don't tilt at all. In urban areas, where communications 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 the ground. That leaves the upper floors of many high-rise buildings in urban areas, especially in big cities, out of cellular networks 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 cellular communications have been becoming so popular worldwide, cellular signal coverage in high-rise buildings is now a major concern for both cellular service providers and their customers.

FIG.1C illustrates the lobe pattern in elevation of a typical down-tilt base station antenna. It further explains why there is lack of cellular RF signals coverage in the upper floors of high rising buildings. The major lobe 13 of base station antenna is down-tilted β degree below the horizontal surface from its mounting position. While 14 is its first upper side lobe; 15 is its first lower side lobe; and 16 is its back lobe. Notice the null between the major lobe 13 and the first upper side lobe 14 is in the direction just above the horizontal surface and oriented to the upper floors of high-rise buildings in its cell or sector. The null generally is more than 20dB lower in signal strength than the major lobe. There will be another 10 to 30dB loss when cellular RF signals penetrate the walls and windows of high-rise buildings. As a result, cellular RF signals inside the upper floors of high-rise buildings are just too weak to make good quality communications. Inside low-rise buildings or the lower floors of high-rise buildings, where are within the major lobe coverage range of the down-tilt antenna, cellular RF signals are generally strong enough to make good quality communications. (Herein after, a ground cell covered by a down-tilt antenna or antennas is called "downward cell"; a ground sector covered by a down-tilt sector antenna or antennas is called "downward sector").

FIG.1D illustrates the schematic 3D space coverage image of a cellular network. A plurality of downward cells juxtaposes on the earth surface composing a cellular network. The space coverage shape of downward cell 17 looks like a big dome, which is high in its centre but low at its boundary. Obviously, downward cells do not cover spaces above their down-tilt antennas. The coverage height decreases as the distance to their cell centres increases. The coverage near their cell boundaries is worse in both signals strength and coverage height. As described before, almost all ground cells in urban areas are downward cells. Many high-rise buildings stand out of their coverage ranges. That makes inside of the upper floors of these high-rise buildings lack of cellular signals coverage. The design and structure of the existing cellular system and network create this problem. It should be solved in a cost-efficient way.

Description of The Prior Art

A system and method called "distributed antenna system" (DAS) has been used to provide cellular signals indoor coverage in high-rise buildings. It introduces cellular radio signals inside buildings from a microcell base station or a repeater via RF cables and/or fibre cables. Generally, it needs a microcell base station or a repeater, long and complicated radio signals distribution network and many indoor antennas. Radio signals strength is limited to cover small indoor areas around the indoor antennas to avoid interfering to outside cellular signals. Unfortunately, DAS is not a cost-effective solution for high-rise buildings coverage. The microcell base station or repeater and the distribution network are very expensive. Rental of equipment space to host the system in a high-rise building is very expensive as well. It also requires permission from landlord to run its distribution network. The expenses related to system installation, rental of equipment space and system maintenance are prohibitive. To achieve full coverage in all high-rise buildings, you have to run this system floor-by-floor, 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 in high-rise buildings coverage.

FIG.1E is an example of a distributed antenna system in a high-rise building for cellular signals coverage. High-rise building 22 has fifty floors (from F-1 to F-50) and two parking floors (P-1 and P-2). The cellular RF signals from BTS 2 are distributed in the whole building by a plurality of couplers 18 and RF cables 19 to a plurality of indoor antennas 20 floor by floor. Some bi-directional amplifiers (BDAs) 21 are inserted in the middle of the distribution network to boost RF signals and to compensate signal losses along RF cables.

So far, before this invention, there is just no a practical, cost-effective solution for cellular radio signals coverage in high-rise buildings.

Object of The Invention

This invention provides a three-dimensional space coverage cellular network in a cellular telecommunications system, providing cellular RF signals coverage on ground and in space above ground, especially in high-rise buildings. It provides a method to set up the three-dimensional space coverage cellular network in a cost-efficient way and to eliminate frequency interferences meanwhile. It also provides a base station, having three-dimensional space coverage extent. It provides an easy solution for cellular RF signals coverage in high-rise buildings. The cellular network, method and base station of this invention can be implemented in all kinds of cellular telecommunications systems, like AMPS, TDMA, GSM, CDMA, 3G and WLL.

Summary of The Invention

A cellular telecommunications network (simply called “cellular network” herein after) of this invention has the feature that at least one of its base stations has a three-dimensional space coverage extent on ground and in space 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 cellular signals coverage in three-dimensional space in a geographical area, especially in the upper floors of high-rise buildings.

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

A cellular telecommunications network of this invention comprises a plurality of base stations in a geographical area. It provides cellular telecommunications 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 three-dimensional space coverage extent on ground and in space 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. Antenna beam, also called antenna major lobe, is the radiation lobe containing major radiation energy in confined small angle in at least one dimension).

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 telecommunications services 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 the 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 telecommunications 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 the up-tilt antenna. The down-tilt antenna and the up-tilt antenna may be integrally formed into one antenna.

Brief Description of The Drawings

FIG.1A (prior art): A typical mobile cellular telecommunications system.

FIG.1B (prior art): A typical cellular network structure and the 7/21 frequency reuse plan.

FIG.1C (prior art): The lobe pattern in elevation of a typical down-tilt base station antenna.

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

FIG.1E (prior art): A distributed antenna system in a high-rise building for cellular signals indoor coverage.

FIG.2A: The up-tilt base station antenna covers high-rise buildings in its cell.

FIG.2B: The lobe pattern in elevation of a typical up-tilt base station antenna.

FIG.2C: The schematic 3D space coverage image of an upward cellular network.

FIG.3A: Space coverage profile in elevation when upward cells overlay on ground cells in the first way.

FIG.3B: Space coverage profile in elevation when upward cells overlay on ground cells in the second way.

FIG.3C: Space coverage profile in elevation when upward cells overlay on ground cells in the third way.

FIG.3D: Space coverage profile in elevation when upward cells overlay on ground cells in the fourth way.

FIG.4A: An up-tilt antenna and a down-tilt antenna share a base station.

FIG.4B: An upward cell base station co-sites with a ground cell base station.

FIG.5A: Uplink space diversity application in an upward cell base station.

FIG.5B: Uplink space diversity application in the shared base station of an upward cell and a ground cell.

FIG.6A (prior art): The beam pattern and its coverage of a typical sector antenna.

FIG.6B: The beam pattern and its coverage of a narrow beam sector antenna.

FIG.7A: An embodiment of a down-tilt antenna and an up-tilt antenna in an integrated form.

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

Detailed Descriptions

The mobile cellular telecommunications system was developed for mobile telecommunications on the ground. Its cellular network structure was designed for ground coverage. Basically it is a two-dimensional space coverage network. Down tilting of its base stations antennas makes cellular signals coverage even worse in space above the ground. The real world is three-dimensional. The existing cellular network covers the ground and low-rise buildings only. It does not cover the upper floors of many high-rise buildings. It needs to be modified to cover space above the ground, especially the upper floors of high-rise buildings.

This invention solves this problem by providing a three-dimensional space coverage cellular telecommunications network that has a coverage extent on the ground and in space above the ground. Its down-tilt base station antennas cover the ground; its up-tilt base station antennas cover space above the ground. Each of these up-tilt base station antennas couples to a base station and has its major lobe pointing upward to cover space above the ground, especially the upper floors of high-rise buildings in its cell. This significantly increases cellular signals strength in the upper floors of high-rise buildings up to 20 dB and brings dramatic improvement in communication quality for subscribers there. Like the ground being divided into ground cells in a geographical area, space above the ground in the area can also be divided into a plurality of small service spaces – upward cells. An upward cell may be further divided into multiple upward sectors (three upward sectors for example). Each upward cell has at least a base station inside and is covered by an up-tilt antenna (or antennas) coupled to the base station. Each upward sector has a base station inside and is covered by an up-tilt sector antenna (or sector antennas) coupled to the base station. A plurality of upward cells juxtaposing on the earth surface in a cellular telecommunications system composes an upward cellular network. The existing cellular network covers the ground and low-rise buildings already. The upward cells lay on the ground cells to expand its coverage to space above the ground, especially in the upper floors of high-rise buildings.

As shown in FIG.2A, up-tilt antenna 23 couples to BTS 2 of a cellular system with RF cable 19. It is mounted on mast 24. Up-tilt antenna 23 has its major lobe up-tilted α degree (10° for example) above the horizontal surface from its mounting position and pointed to the upper floors of high-rise buildings 22 in its upward cell (or upward sector). So the upper floors of high-rise buildings 22 are in the major lobe coverage of up-tilt antenna 23 now. Compared to the null coverage of a down-tilt base station antenna, cellular signals strength there increases significantly (up to 20dB). Though shown as a sector antenna with its beam up-tilted mechanically, antenna 23 can be an omni-directional antenna. Its beam can be up-tilted mechanically and/or electrically. Instead of mast 24, antenna 23 can be mounted on a tower or rooftop etc.

FIG.2B is the lobe pattern in elevation of a typical up-tilt base station antenna. Its major lobe 25 is up-tilted α degree (10° for example) above the horizontal surface from its mounting position. While 14 is its first upper side lobe; 15 is its first lower side lobe; and 16 is its back lobe. It is preferred to adjust the antenna tilt angle to make the null between major lobe 25 and first lower side lobe 15 occur in the horizontal surface. This will minimize cellular signals' strength in the horizontal surface, so as to minimize interferences.

A base station has its antenna (or antennas) pointing upward. Its coverage space above the ground forms an upward cell (or upward sector if the antenna is a sector antenna). FIG.2A is such an embodiment. As shown in FIG.2C, a plurality of upward cells 26 juxtaposes on the earth surface in a geographical area, composing an upward cellular network. FIG.2C also illustrates the schematic 3D space coverage image of the upward cellular network (within certain elevation height). The coverage space of upward cell 26 has a shape like a large bowl or concave disc, which is low in its centre but high at its boundary. In a similar way as down-tilt antennas and down-tilt sector antennas eliminating interferences among ground cells by beam down-tilting, up-tilt antennas and up-tilt sector antennas can also eliminate interferences among upward cells within certain elevation heights (for example, within the heights of high-rise buildings) by beam up-tilting. For high-rise buildings coverage application, an upward cellular network is set up in a cellular system. Each up-tilt antenna of the upward cellular network is properly adjusted to maximizes its coverage on the high-rise buildings inside its upward cell and minimizes its coverage on the high-rise buildings outside its upward cell simultaneously.

The concept of upward cell, upward sector and upward cellular network of this invention can be implemented in any cellular telecommunications systems to provide cellular signals coverage in space above the ground, especially in the upper floors of high-rise buildings.

FIG.3A to 3D illustrate the space coverage profile in elevation when upward cellular cells overlay on ground cells in different ways.

To expand existing ground cellular network coverage to space above the ground, especially in high-rise buildings, an upward cellular network need to be set up and integrated with the ground cellular network. There are many ways to integrate an upward cellular network with the ground cellular network. From location view, an upward cell can collocate with a ground cell. It can also locate somewhere else (for example, it can locate around the boarder of a ground cell). FIG.3A and 3B show the space coverage profiles of the integrated cellular networks when each upward cell collocates with a ground cell. Their base stations of both cells are proximately collocated. In this configuration, the upward cell may share all or part of the apparatuses of its collocated ground base station, like the equipment room, the power supply, the tower and the carrier etc. As shown in FIG.4A, even the BTS is shared between an upward cell and a ground cell. FIG.3C and FIG.3D show the space coverage profiles of the integrated cellular networks when each upward cell locates around the boarder of ground cells. No matter where the base station of an upward cell is located, its up-tilt antenna can be above, below or in the same elevation height as the base station antenna of a ground cell.

In FIG.3A, a plurality of upward cells 26A, 26B and 26C (the dashed line areas) lays on a plurality of ground cells 17A, 17B and 17C (the continued line areas). Cell centre 27A of upward cell 26A collocates with cell centre 28A of ground cell 17A; cell centre 27B of upward cell 26B collocates with cell centre 28B of ground 17B; cell centre 27C of upward cell 26C collocates with cell centre 28C of ground cell 17C. The collocated two type cells may share base station apparatuses. The up-tilt antenna of the upward cell is in proximately the same height as the down-tilt antenna of its collocated ground cell. This arrangement is cost-effective and easy to implement. The disadvantage is that it creates interspaces 29 not covered by both type cells.

FIG.3B illustrates a similar situation as FIG.3A does except that the up-tilt antenna of the upward cell is substantially below the down-tilt antenna of its collocated ground cell in FIG.3B. This arrangement is also cost-effective and easy to implement. Another advantage is that the interspaces can be eliminated and the overlapped spaces 30 (the hatched areas) covered by both type cells are created.

In FIG.3C, a plurality of upward cells 26A, 26B, 26C and 26D (the dashed line areas) lays on a plurality of ground cells 17A, 17B and 17C (the continued line areas). Upward cell centres 27A, 27B, 27C and 27D locate approximately at the boundaries of the ground cells. Relatively, ground cell centres 28A, 28B and 28C also locate approximately at the boundaries of the upward cells. The up-tilt antennas of upward cells and the antennas of ground cells are approximately in the same elevation height. This arrangement also creates interspaces 29 not covered by both type cells.

FIG.3D illustrates a similar situation as FIG.3C does except that the up-tilt antennas of the upward cells are substantially below the antennas of the ground cells in elevation in FIG.3D. An advantage of this arrangement is it also creates overlapped spaces 30 (the hatched areas) covered by both cell types.

An essence of this invention is that an upward cell and its collocated ground cell share the same base station (shown in FIG.4A as an embodiment). It is also a method that an upward cell and its collocated ground cell share frequency spectrum and eliminate interferences between them.

Cellular frequency is a scarce and precious resource. As limited frequency spectra assigned to each cellular system and the fact that almost all frequency spectra have been fully exploited in the existing ground cellular systems, especially in urban areas, an upward cellular network may need to reuse the cellular frequency spectra of the existing ground cellular network. It creates a new problem: frequency interferences between them. This invention provides an easy solution to this problem, that is the up-tilt antenna of an upward cell and the antenna of its collocated ground cell couple to the same transmitter or transmitters of a base station transceivers system. Both antennas may also couple to the same receiver or receivers of the base station transceivers system. In this way, both antennas share all or part transmitters and receivers of a ground base station. The shared transmitters and receivers comprise at least one communication control channel and a plurality of communication traffic channels of the cellular system. In this way, the cellular frequency spectra of the ground cell are reused in the upward cell, but it doesn't create frequency interferences between them. Actually in this situation, the upward cell becomes the extension of its collocated ground cell in elevation direction. Both cells form one three-dimensional space coverage cell. This solution is also extremely economic. The existing ground cellular system easily expands its coverage to space above the ground, especially in the upper floors of high-rise buildings at minimum cost by addition of up-tilt antennas to its base stations.

FIG.4A is an embodiment of this solution. Up-tilt antenna 23 is added to the base station of a ground cell. Its beam is up-tilted α degree (10° for example) above the horizontal surface from its mounting position and directed to high-rise buildings 22 in the ground cell. The antenna 31 of the ground cell has its beam down-tilted β degree (8° for example) below the horizontal surface from its mounting position and directed to the ground and low-rise building 22A in the ground cell. Both antennas are mounted on mast 24. Through a splitter/combiner 32 (or coupler) and RF cables 19, both antennas couple to the transmitters (TXs) and the receivers (RXs) of BTS 2 of the ground cell. So BTS 2 of the ground cell provide cellular signals coverage on the ground and in space above the ground in its cell through antenna 23 and antenna 31. It forms a three-dimensional space coverage cell. Though mounted substantially below antenna 31 in FIG.4A, up-tilt antenna 23 may be mounted above or at the same height as it. Though both antenna 23 and antenna 31 shown as sector antennas in FIG.4A, either one can be an omni-directional antenna. Though mast 24 shown in FIG.4A, it may be a tower or rooftop etc. Though all transmitters and receivers of BTS 2 are shared by antenna 23 and antenna 31 in FIG.4A, it may be only part of them to be shared by both antennas.

This invention provides another solution to avoid interferences between upward cells and ground cells. That is the base stations of upward cells in a cellular system are assigned dedicated cellular frequencies or frequency spectra. The dedicated cellular frequencies or frequency spectra are exclusive to the upward cells only and they are not used in the ground cells of the cellular system in a geographical area. They may be reused among the upward cells. Their frequency reuse plan may be the same as or different from the frequency reuse plan in the ground cells. For example, the 4/12 frequency reuse plan may be used for these dedicated frequencies or frequency spectra among the upward cells to achieve higher cell traffic capacity with the limited frequency channels, whilst the 7/21 frequency reuse plan may be used among the ground cells. When the dedicated frequencies or frequency spectra are not in the same cellular frequency band of the ground cellular network, a new switch centre may be needed to control the base stations of the upward cells. For example, if the existing cellular system is in 800MHz frequency band, and the dedicated frequencies or frequency spectrum are in 1900Mhz frequency band, then a new cellular system switch centre may need to be added to serve the 1900MHz band base stations of the upward cells.

FIG.2A is also an embodiment when dedicated cellular frequencies or frequency spectrum are used in a base station of an upward cell.

FIG.4B is another embodiment when dedicated cellular frequencies or frequency spectrum are used in the base station of an upward cell, which co-sites with the base station of a ground cell. BTS1 2 of an upward cell uses dedicated frequencies or frequency spectrum. It co-sites with BTS2 2A of a ground cell. Up-tilt antenna 23 couples to BTS1 2 through RF cable 19. Its beam is up-tilted α degree (10° for example) above the horizontal surface from its mounting position and pointed to the upper floors of high-rise buildings 22 in its upward cell. Down-tilt antenna 31 couples to BTS2 2A through RF cable 19. Its beam is down-tilted β degree (8° for example) below the horizontal surface from its mounting position and pointed to the ground and low-rise building 22A in its ground cell. Both antennas are mounted on mast 24. As the cellular frequencies used in BTS1 2 of the upward cell and the cellular frequencies used in BTS2 2A of the ground cell are different from each other, no frequency interferences will occur between the upward cell and the ground cell.

Though the shared base station between an up-tilt antenna and a down-tilt antenna is a much better choice to expand cellular signals coverage to space in high-rise buildings in terms of frequency usage and expenses, there may be still a need for non co-sited upward cells when the base station locations of ground cells don't favour the coverage of high-rise buildings in a cellular system. Actually the upward cell with a shared base station and the upward cell with non co-sited base station can be combined to use in a cellular system to expand its coverage from the ground to space above ground, especially in high-rise buildings. That is in a cellular system, up-tilt antennas are added to base stations of ground cells and share these base stations with their down-tilt antennas; new base stations with up-tilt antennas are added to the cellular system.

Space diversity, especially in uplink direction (from subscriber radio stations to base station), is a common method used in the base stations of a cellular system to overcome multi-path fading and to improve system performance. It can be used in base stations of upward cells for the same purposes.

FIG.5A is an embodiment of up-link space diversity application in an upward cell base station. Up-tilt antenna 23A acts as the main transmitting and receiving antenna. It couples to the main transmitters TXsA and receivers RXsA of BTS 2 through RF cables 19 and duplexer 33. Up-tilt antenna 23B acts as the receiving diversity antenna. It couples to the diversity receivers RXsB of BTS 2 through RF cable 19.

FIG.5B is an embodiment of uplink space diversity application in the shared base station of an upward cell and a ground cell. Up-tilt antenna 23A and down-tilt antenna 31A both act as the main transmitting and receiving antenna of the shared base station. They are coupled together with a splitter/combiner (or coupler) 32 to share the main transmitters TXsA and receivers RXsA of BTS 2 through RF cables 19 and duplexer 33. Up-tilt antenna 23B and down-tilt antenna 31B both act as the receiving diversity antenna of the shared base station. They are coupled together with another splitter/combiner (or coupler) 32 to share the diversity receivers RXsB of BTS 2 through RF cables 19.

The beam pattern of a typical base station sector antenna is wide in azimuth but narrow in elevation. It well suits ground sector coverage. FIG.6A shows the beam pattern and its coverage of a typical base station sector antenna. Antenna 34 comprises a set of radiation elements (dipole for example) 35 arranged in a vertical plane. It creates beam 36 whose azimuth beam-width ϕ (45° for example) is much larger than its elevation beam-width θ (10° for example). Obviously beam 36 cannot cover the whole high-rise building 22 when antenna 34 is close to it, even if antenna 34 is up-tilted. A coordinate XYZ is shown as a reference.

High-rise buildings are not everywhere, but concentrate in small core business areas in a city and intersperse in wide urban areas. There may be only one or a small number of high-rise buildings to be covered in a geographical area. High-rise buildings may be very close to a base station as well. Instead of covering a whole upward cell, base station antenna may focus its coverage on individual high-rise buildings. This will benefit system performance in terms of signal strength and interferences, because antenna radiation focuses in a small space than in a whole upward cell. A narrow beam sector antenna with a beam pattern narrow in azimuth but wide in elevation will serve this coverage purpose well. FIG.6B is an embodiment of this type of sector antenna. Antenna 34A comprises a set of radiation elements (dipoles for example) 35A, which are arranged in a horizontal plane. It creates beam 36A, whose elevation beam-width θ (45° for example) is much bigger than its azimuth beam-width ϕ (10° for example). Antenna 34A is up-tilted α degree (10° for example) for better coverage of high-rise building 22. A coordinate XYZ is shown as a reference. Actually antenna 34A is easy to realize. Just rotating antenna 34 in FIG.6A 90° clockwise around the X-axis, it becomes antenna 34A in FIG.6B. Obviously, antenna 34A is very suitable for individual or a small group of high-rise buildings' coverage in a short distance.

The up-tilt antenna and the down-tilt antenna of a shared base station may be integrated into one antenna. The integrated antenna has two beams in two directions. When it is installed and connected to a base station, its one beam points downward to cover the ground and another beam points upward to cover space above the ground. For example, up-tilt antenna 23 and down-tilt antenna 31 in FIG.4A can be integrated into one antenna. A major advantage of the integrated antenna is mounting space saving.

FIG.7A is an embodiment of the integrated antenna. FIG.7B is its lobe pattern in elevation when it is installed in a base station. Dual-beam dual-tilt antenna 37 comprises two sets of radiation elements 35B (above the dashed line) and 35C (below the dashed line). Both sets of radiation elements are in vertical polarity and operate in the same cellular frequency band (800MHz band for example). 35B comprises at least two radiation elements (six elements are shown) arranged in a vertical plane. It forms major lobe 13 down-tilted β degree (8° for example) below the horizontal surface from its mounting position. 35C comprises at least two radiation elements (six elements are shown) arranged in a vertical plane. It forms major lobe 25 up-tilted α degree (10° for example) above the horizontal surface from its mounting position. The dual-beam dual-tilt antenna 37 may be used to replace the up-tilt antenna and the down-tilt antenna of a shared base station. For example, it may be used to replace up-tilt antenna 23 and down-tilt antenna 31 in FIG.4A.

Although this invention has been described by way of example and with reference to possible embodiments thereof it is to be appreciated that improvements and modifications may be made thereto without departing from the scope or spirit of the present invention.

What is claimed:

1. A cellular telecommunications network for providing cellular wireless communications service in a geographical area, said geographical area divided into a plurality of cells, said network comprising:

   a plurality of base stations, each providing radio signals to subscriber stations in an associated one of said cells;

   at least a first one of said base stations comprising

      a transmitter for generating a first radio signal to be provided within a first one of said cells which is associated with said first base station, and within a frequency range which is reusable in more than one of said cells;

      a first antenna coupled to said transmitter for radiating said first radio signal in a characteristic radiation pattern having its major lobe pointed downward;

      a second antenna coupled to said transmitter for radiating said first radio signal in a characteristic radiation pattern having its major lobe pointed upward;

      so as to radiate said first radio signal within said first cell below said first antenna and above said second antenna, while limiting radiation of said first radio signal into other ones of said cells within which said first radio signal may interfere with radio signals from other ones of said base stations.

2. The network of claim 1 wherein said first base station further comprises a receiver for receiving radio signals generated by subscriber stations in said first cell.

3. The network of claim 2 wherein said receiver is coupled to said first and second antennas so as to receive said radio signals generated by subscriber stations in said first cell through at least one of said first and second antennas.

4. The network of any one of claims 1 to 3, wherein said first and second antennas are substantially collocated.

5. The network of any one of claims 1 to 4, wherein said first antenna is located above said second antenna in altitude.

6. The network of any one of claims 1 to 5, wherein said first and second antennas are integrally formed.

7. The network of anyone of claims 1 to 6, wherein a second one of said base stations comprises:

a second base station transmitter for generating a second base station radio signal to be provided within a second one of said cells which is associated with said second base station, and within a frequency range which is reusable in more than one of said cells;

a second base station antenna coupled to said second base station transmitter for radiating said second base station radio signal in a characteristic radiation pattern having its major lobe pointed upward;

so as to radiate said second base station radio signal within said second cell above said second base station antenna, while limiting radiation of said second base station radio signal into other ones of said cells within which said second base station radio signal may interfere with radio signals from other ones of said base stations.

8. The network of claim 7, wherein said second base station further comprises a receiver for receiving radio signals generated by subscriber stations in said second cell.

9. A method of providing cellular telecommunications service in a geographical area, said geographical area divided into a plurality of cells, comprising:

generating a plurality of radio signals, each to be provided to subscriber stations in an associated one of said cells and having a frequency range which is reusable in more than one of said cells;

providing each one of said signals to its associated cell, wherein a first one of said signals is provided to a first one of said cells which is associated with said first signal by

radiating, from a first antenna, said first signal in a characteristic radiation pattern having its major lobe pointed downward, and

radiating, from a second antenna, said first signal in a characteristic radiation pattern having its major lobe pointed upward, so as to radiate said first signal within said first cell below said first antenna and above said second antenna, while limiting radiation of said first signal into other ones of said cells within which said first signal may interfere with other ones of said signals.

10. The method of claim 9, further comprising receiving at least one radio signal from a subscriber station in said first cell.

11. The method of claim 10 wherein said at least one radio signal is received through at least one of said first and second antennas.

12. The method of any one of claims 9 to 11, wherein said first and second antennas are substantially collocated.

13. The method of any one of claims 9 to 12, wherein said first antenna is above said second antenna in altitude.

14. The method of any one of claims 9 to 13, wherein said first and second antennas are integrally formed.

15. The method of claim 9 to 14, wherein a second one of said signals is provided to a second one of said cells which is associated with said second signal by

radiating, from a second-cell antenna, said second signal in a characteristic radiation pattern having its major lobe pointed upward,

so as to radiate said second signal within said second cell above said second-cell antenna, while limiting radiation of said second signal into other ones of said cells within which said second signal may interfere with other ones of said signals.

16. A base station of a cellular telecommunications network, said network adapted for providing a plurality of cellular radio signals in a geographical area, said geographical area divided into a plurality of cells, said base station comprising:

a transmitter for generating a transmitter radio signal to be provided within a first one of said cells, said transmitter operating at a frequency range which is reusable in more than one of said cells;

a first antenna coupled to said transmitter for radiating said transmitter radio signal in a characteristic radiation pattern having its major lobe pointed downward;

a second antenna coupled to said transmitter for radiating said transmitter radio signal in a characteristic radiation pattern having its major lobe pointed upward;

so as to radiate said transmitter radio signal within said first cell below said first antenna and above said second antenna, while limiting radiation of said transmitter radio signal into other ones of said cells within which said transmitter radio signal may interfere with other ones of said plurality of radio signals.

17. The base station of claim 16, further comprising a receiver for receiving radio signals generated by subscriber stations in said first cell.

18. The base station of claim 17, wherein said receiver is coupled to said first and second antennas so as to receive said radio signals generated by subscriber stations in said first cell through at least one of said first and second antennas.

19. The base station of any one of claims 16 to 18, wherein said first and second antennas are integrally formed.

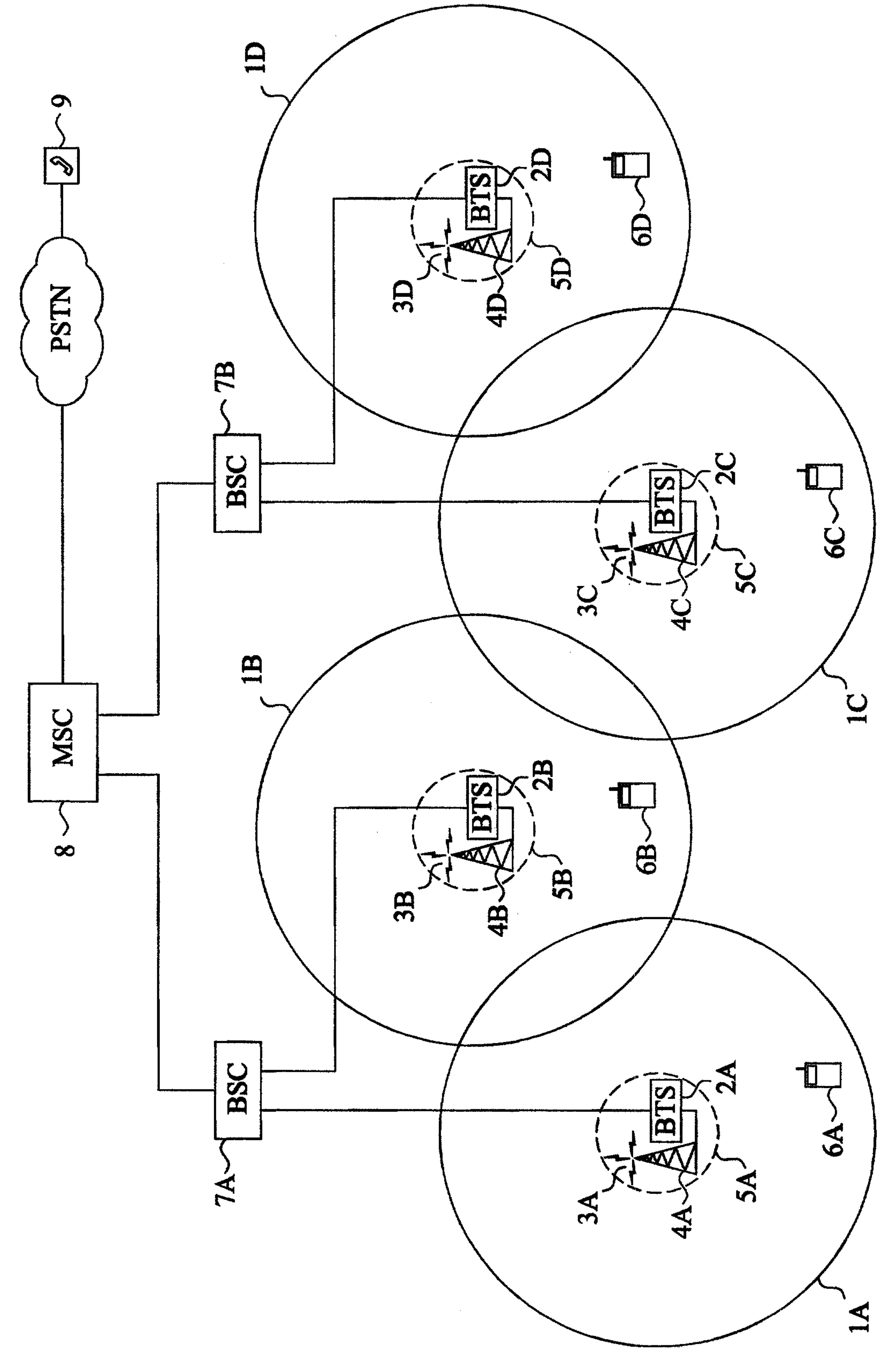

MSC
8
PSTN
9
BSC
7A
BSC
7B
BTS
BTS
BTS
BTS
1A
1B
1C
1D
2A
2B
2C
2D
3A
3B
3C
3D
4A
4B
4C
4D
5A
5B
5C
5D
6A
6B
6C
6D

FIG. 1A

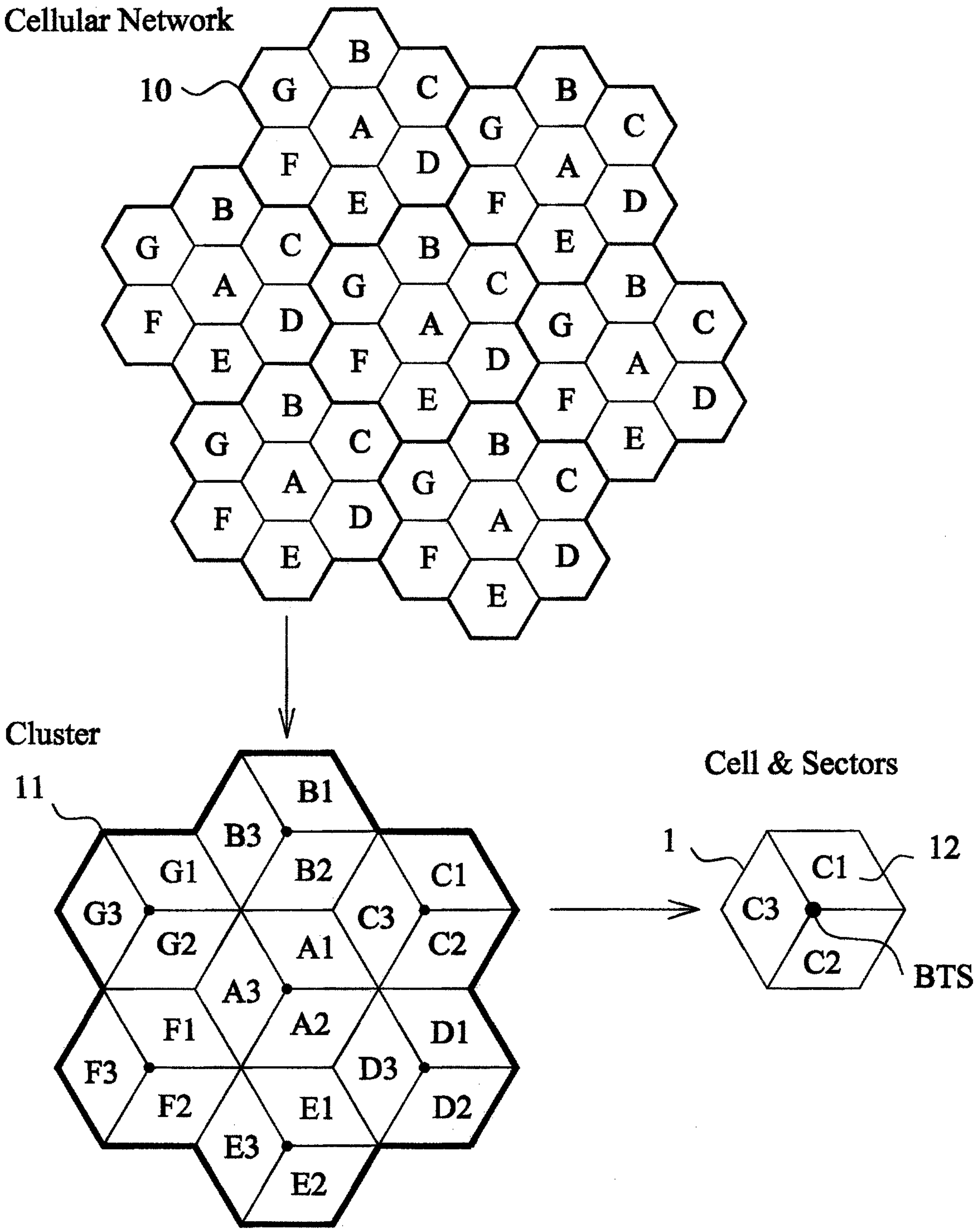

Cellular Network
10
B
G
C
B
A
G
C
F
D
A
E
F
D
B
G
E
C
B
A
G
C
B
F
D
A
G
C
E
F
D
A
B
E
F
D
G
C
B
E
A
G
C
F
D
A
E
F
D
E
Cluster
11
B1
B3
G1
B2
C1
G3
C3
G2
A1
C2
A3
F1
A2
D1
F3
D3
F2
E1
D2
E3
E2
Cell & Sectors
1
12
C1
C3
C2
BTS

FIG.1B

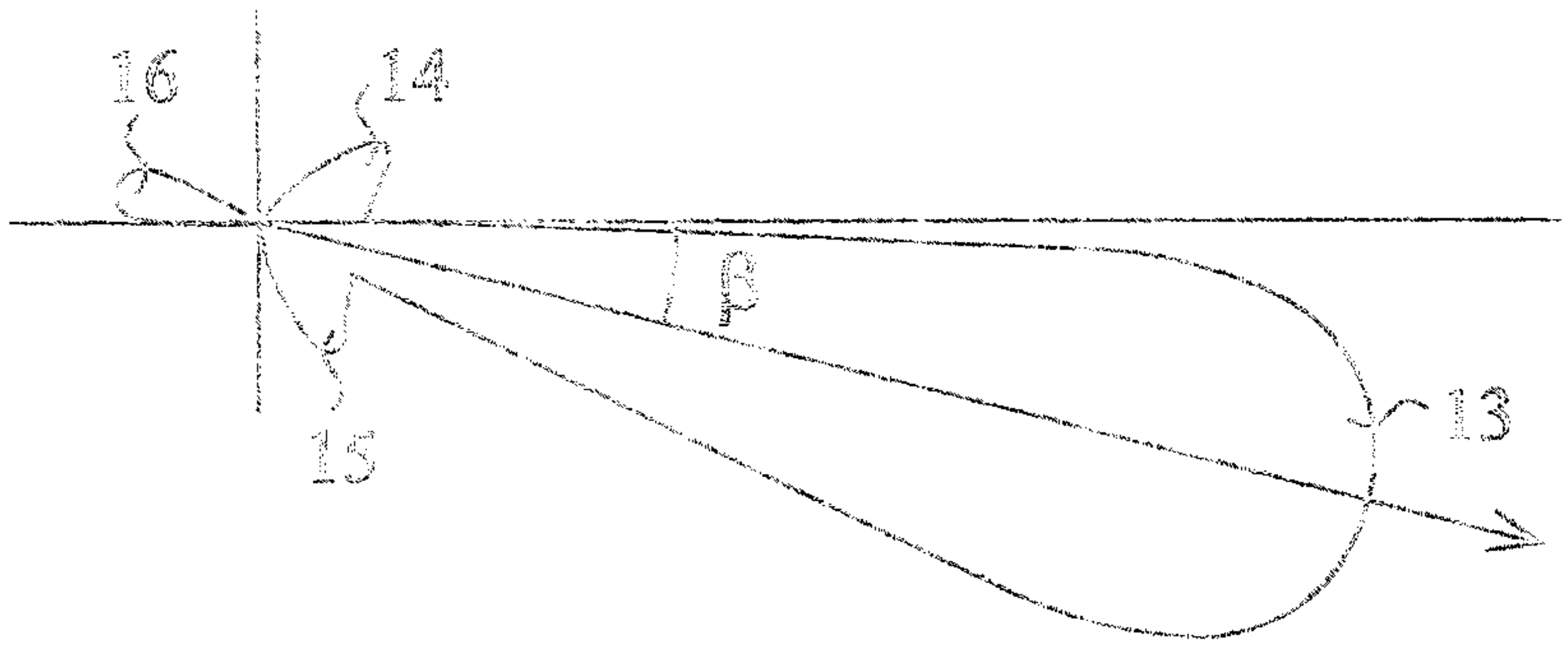


FIG. 1C

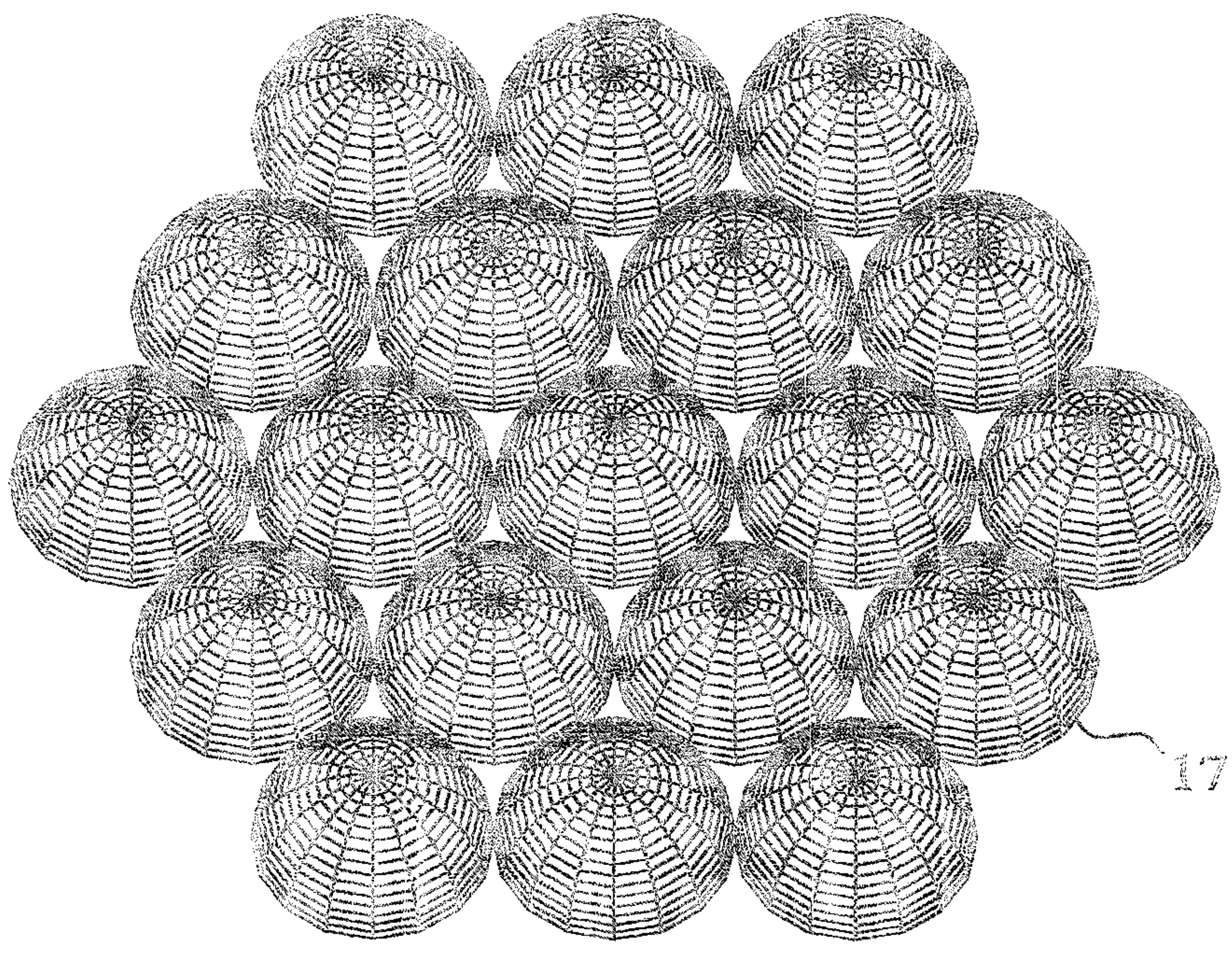


FIG.1D

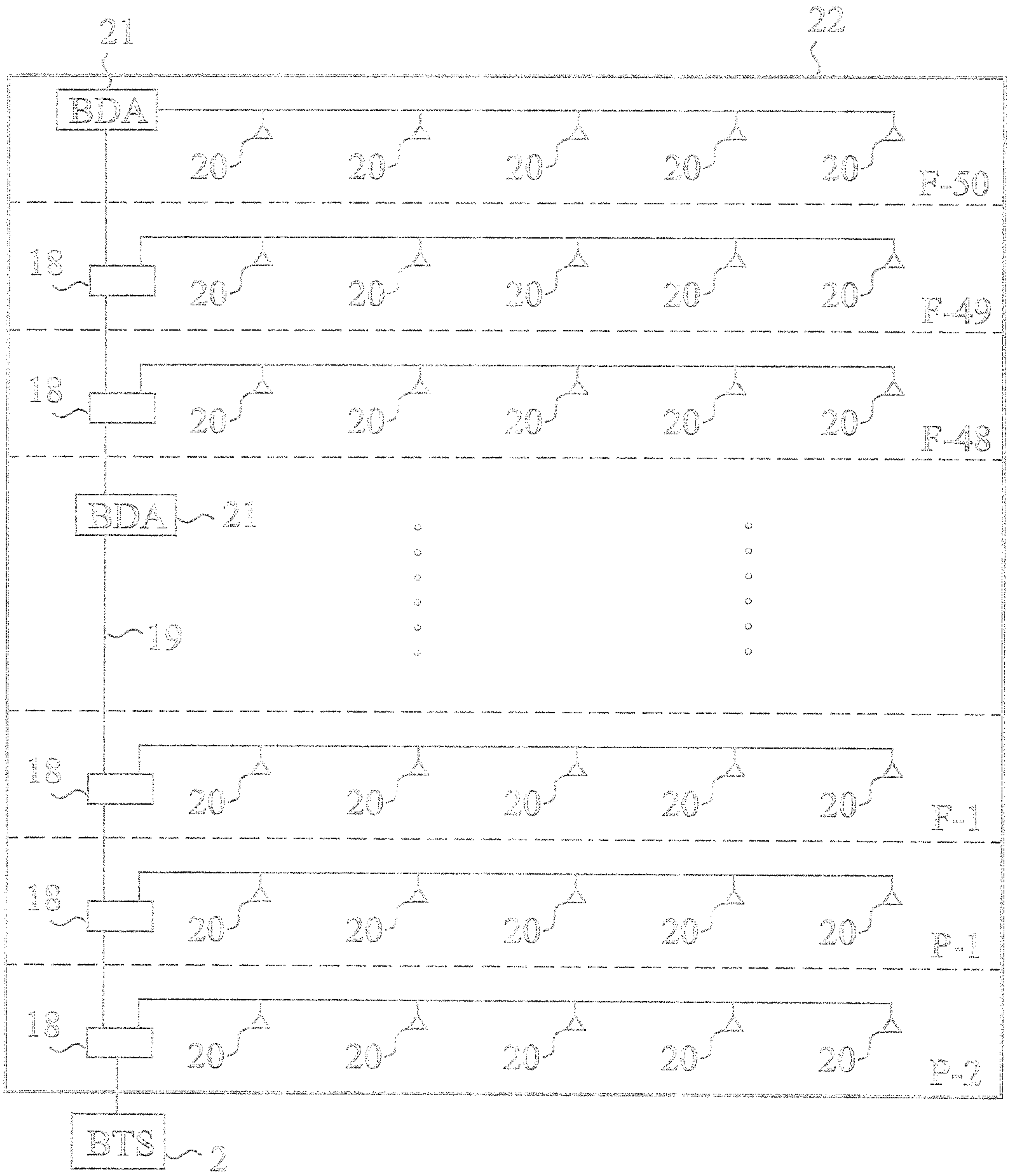


FIG.1E

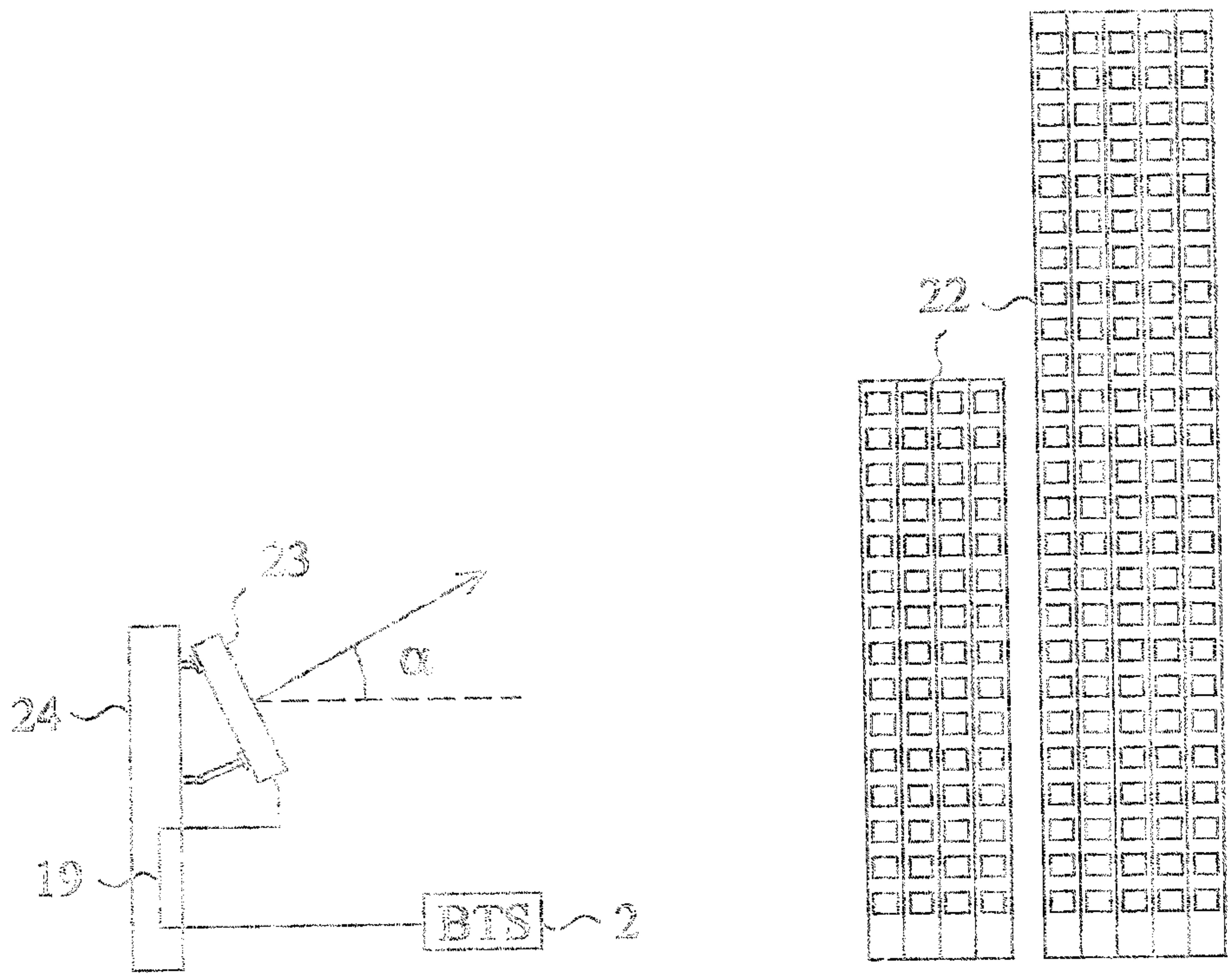


FIG.2A

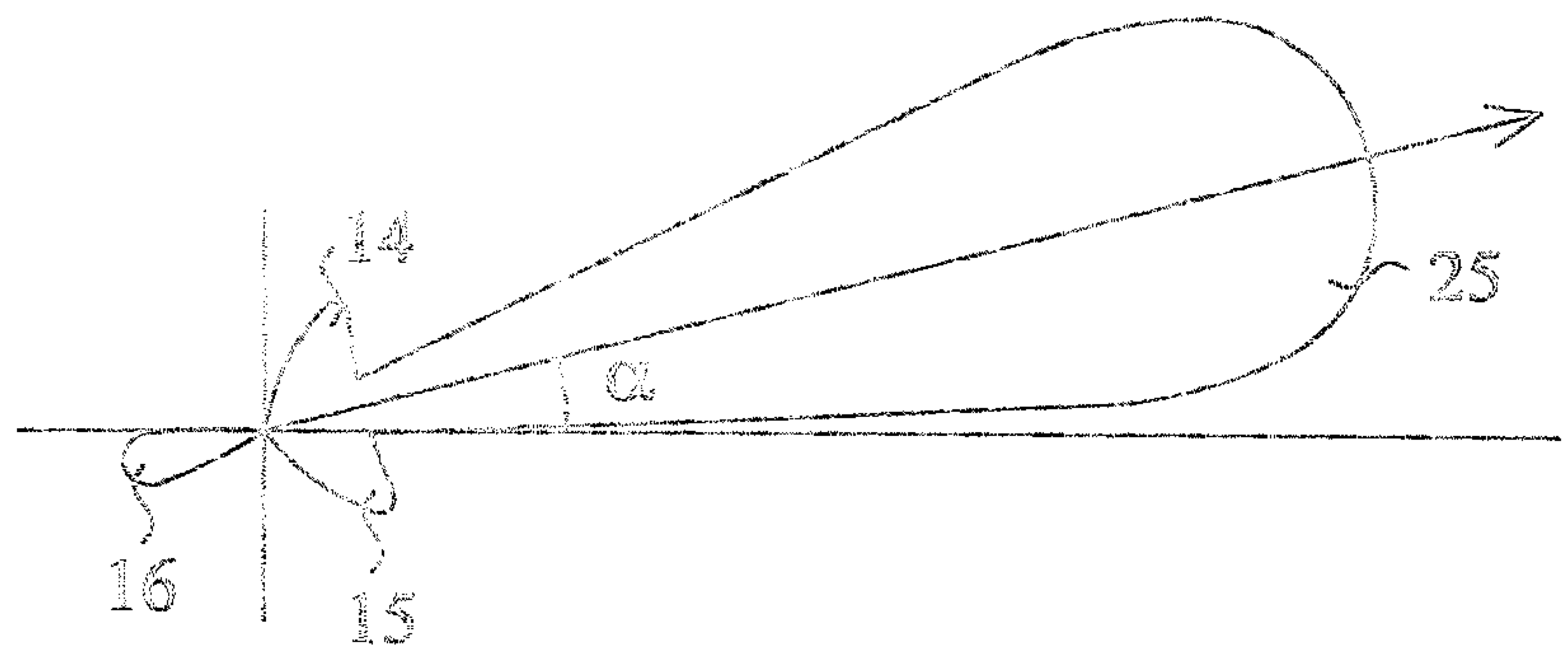


FIG.2B

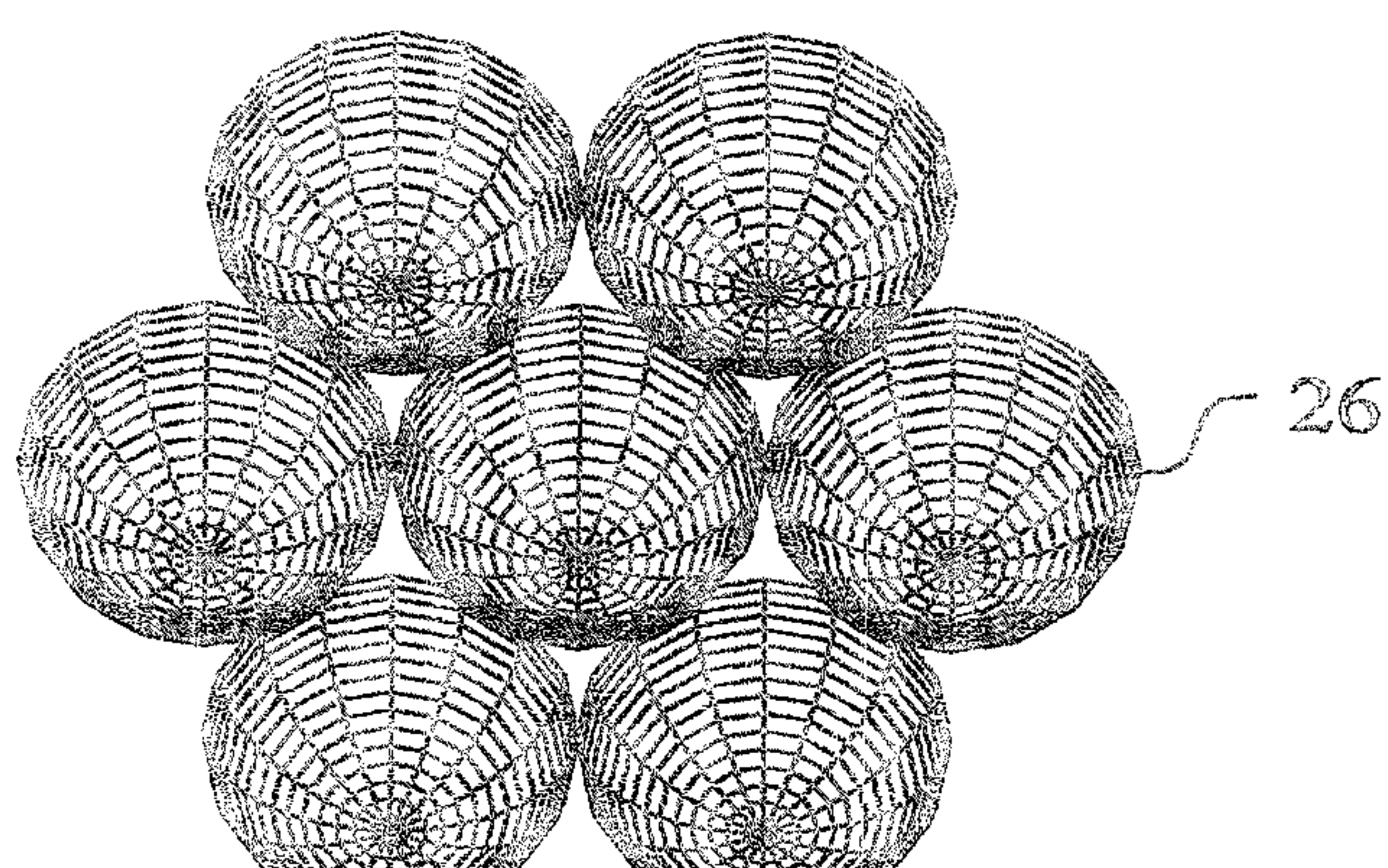


FIG.2C

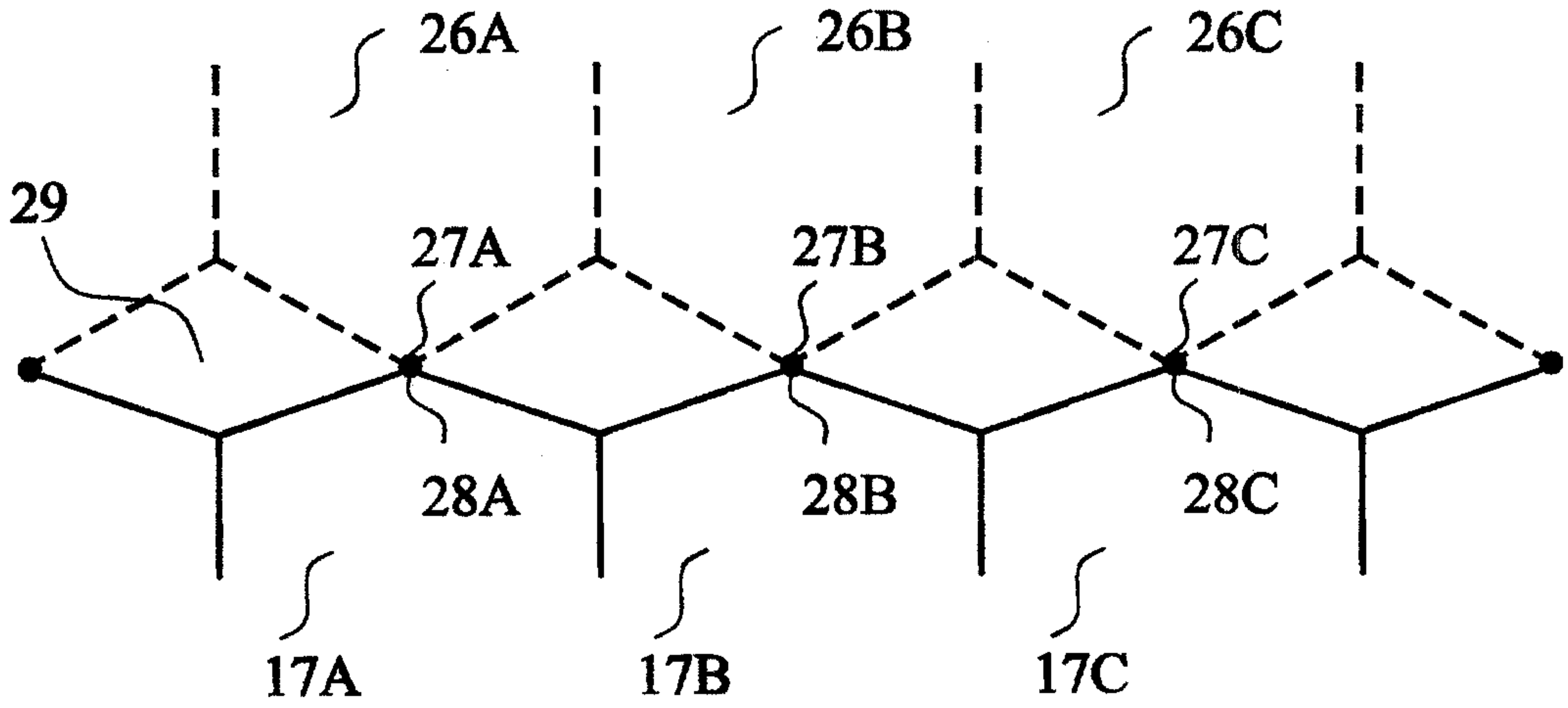

26A
26B
26C
29
27A
27B
27C
28A
28B
28C
17A
17B
17C

FIG.3A

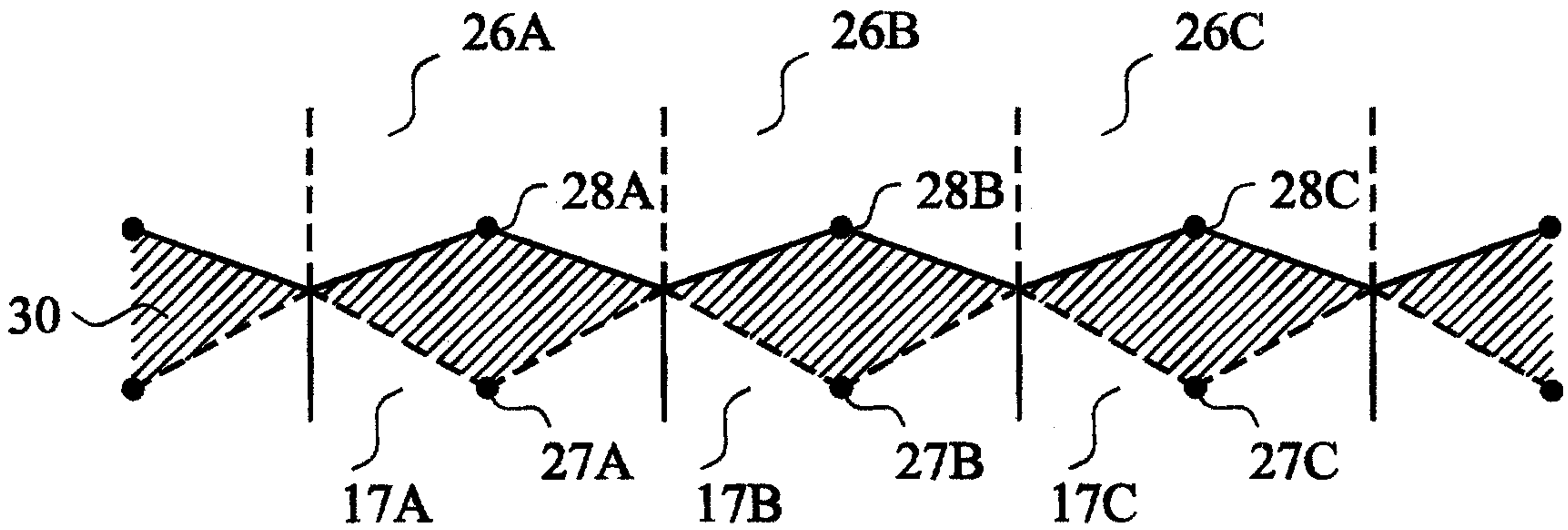

26A
26B
26C
28A
28B
28C
30
17A
27A
17B
27B
17C
27C

FIG.3B

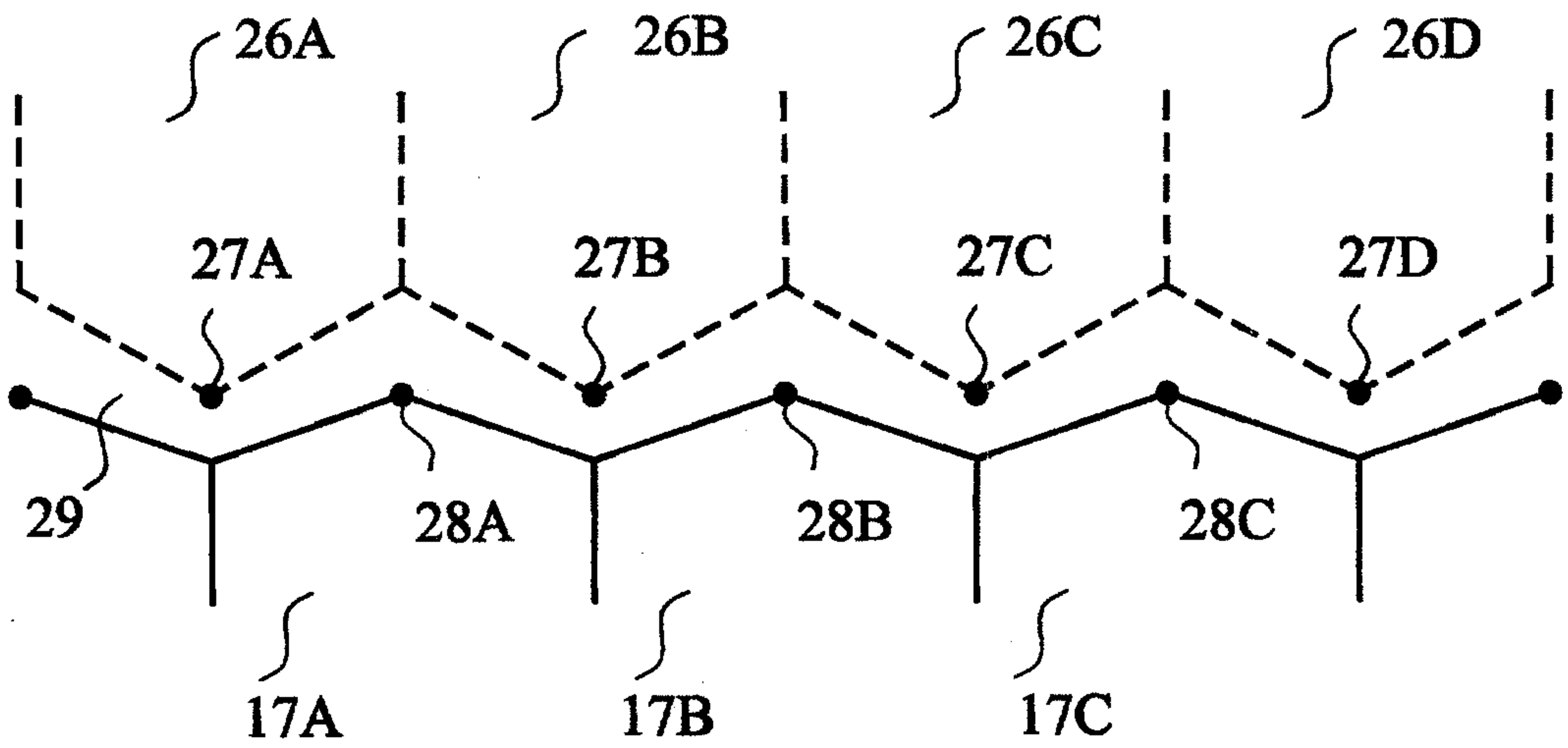

26A
26B
26C
26D
27A
27B
27C
27D
29
28A
28B
28C
17A
17B
17C

FIG.3C

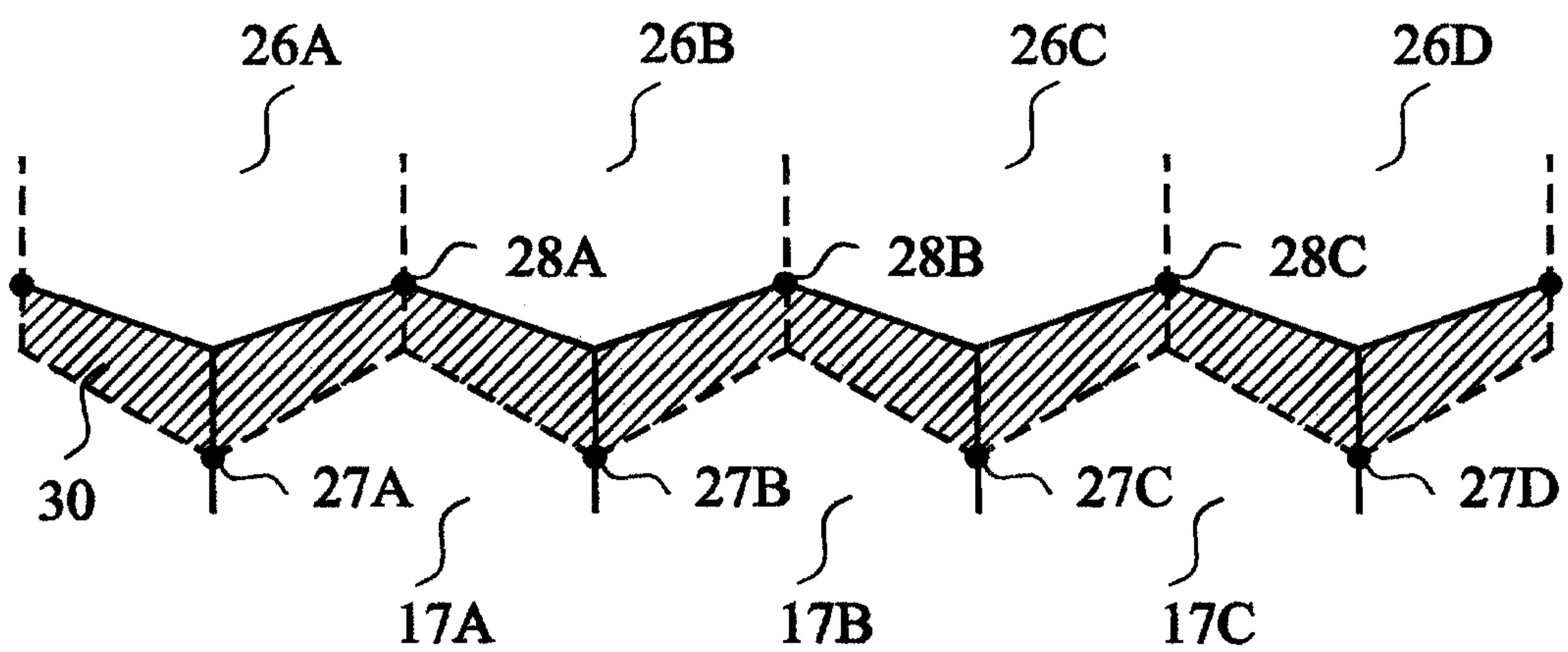

26A
26B
26C
26D
28A
28B
28C
30
27A
27B
27C
27D
17A
17B
17C

FIG.3D

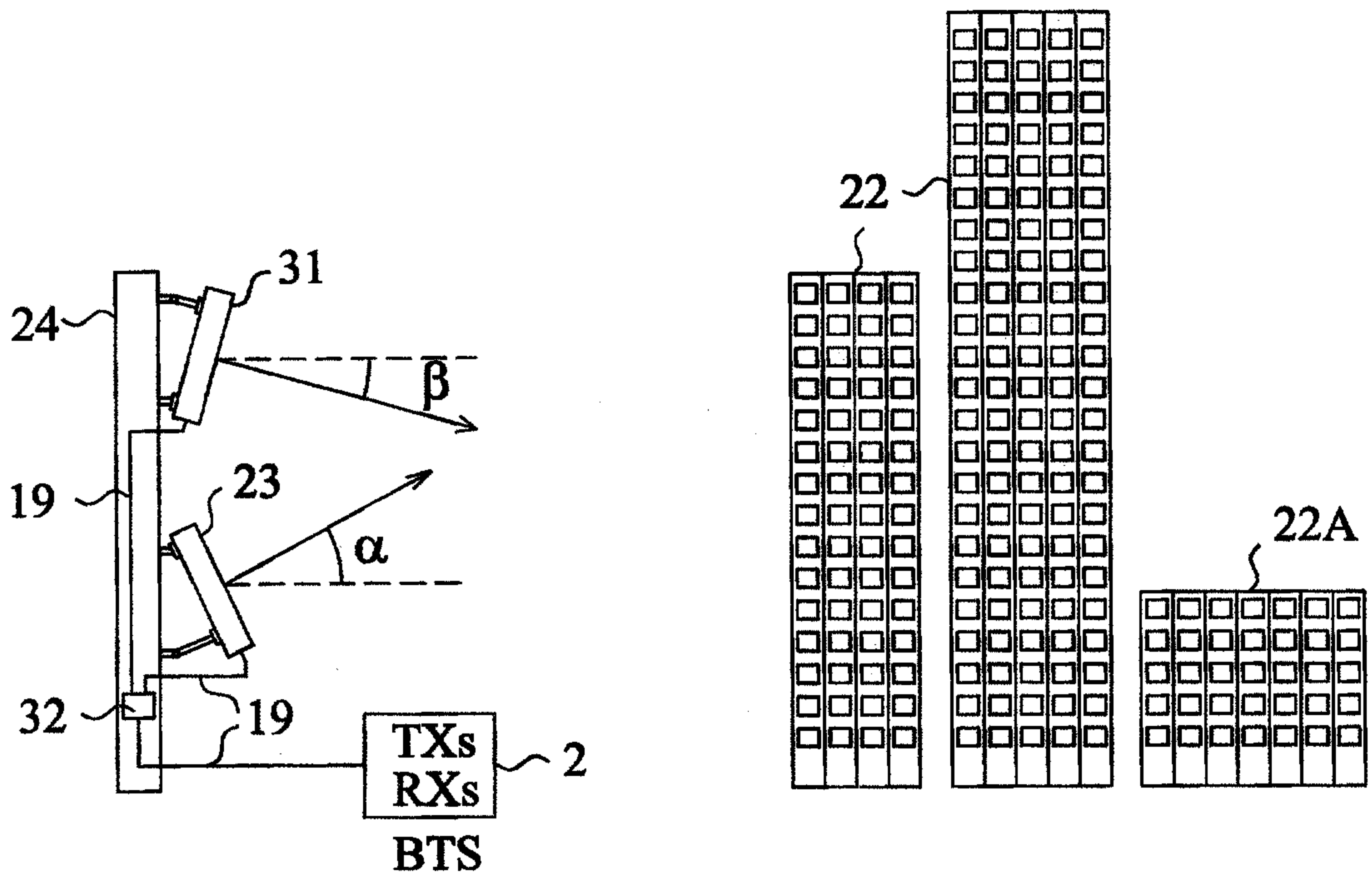

31
24
β
19
23
α
32
19
TXs
RXs
2
BTS
22
22A

FIG.4A

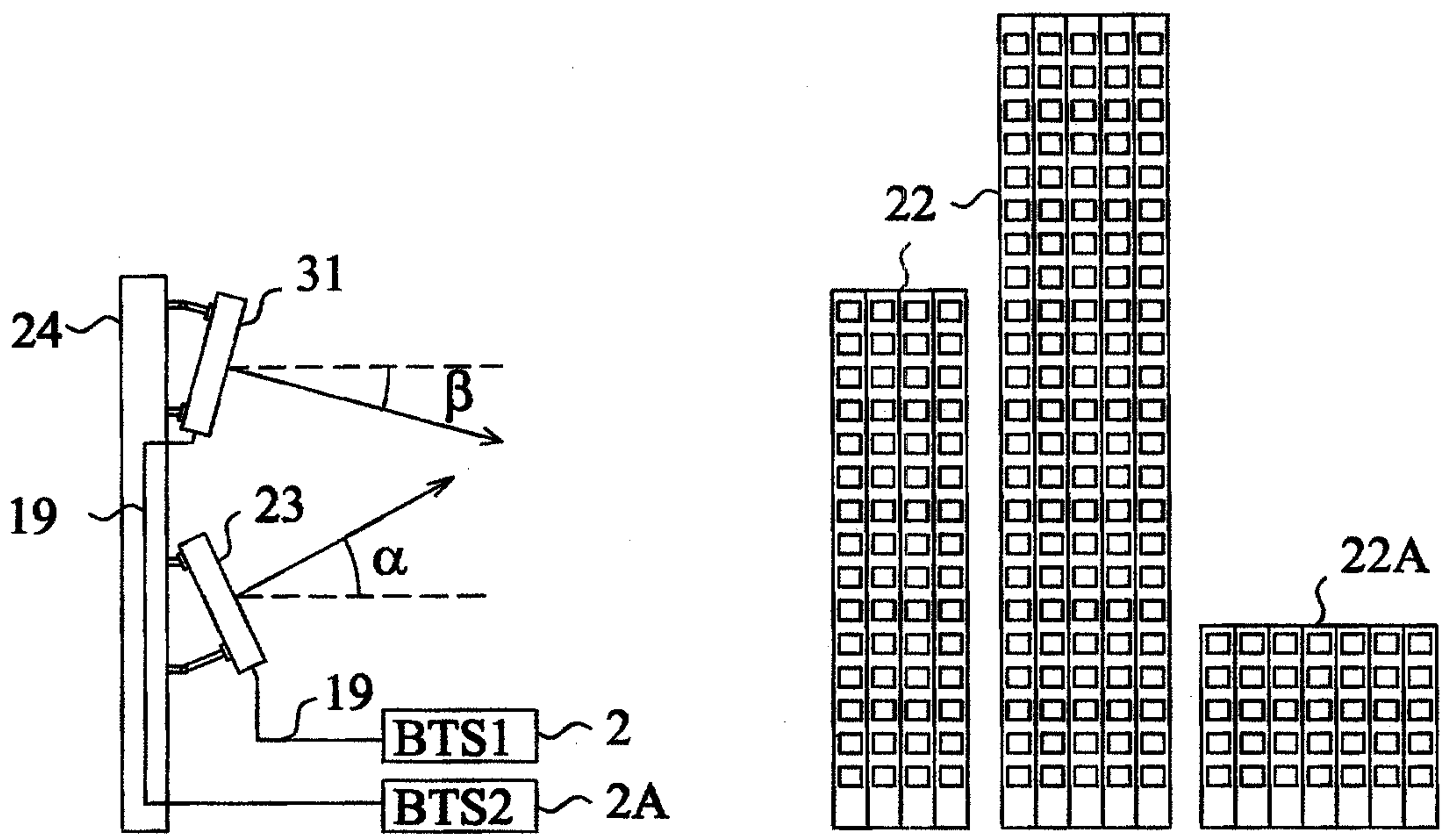

31
24
β
19
23
α
19
BTS1
2
BTS2
2A
22
22A

FIG.4B

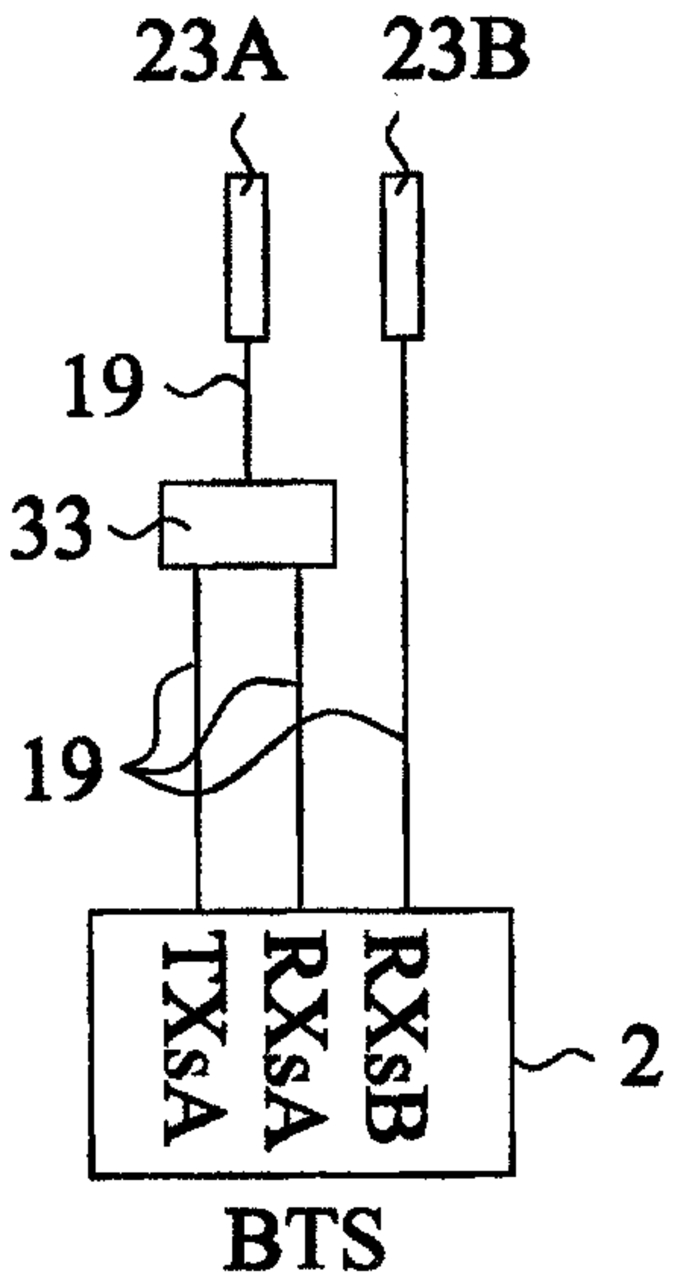

23A
23B
19
33
19
TXsA
RXsA
RXsB
2
BTS

FIG.5A

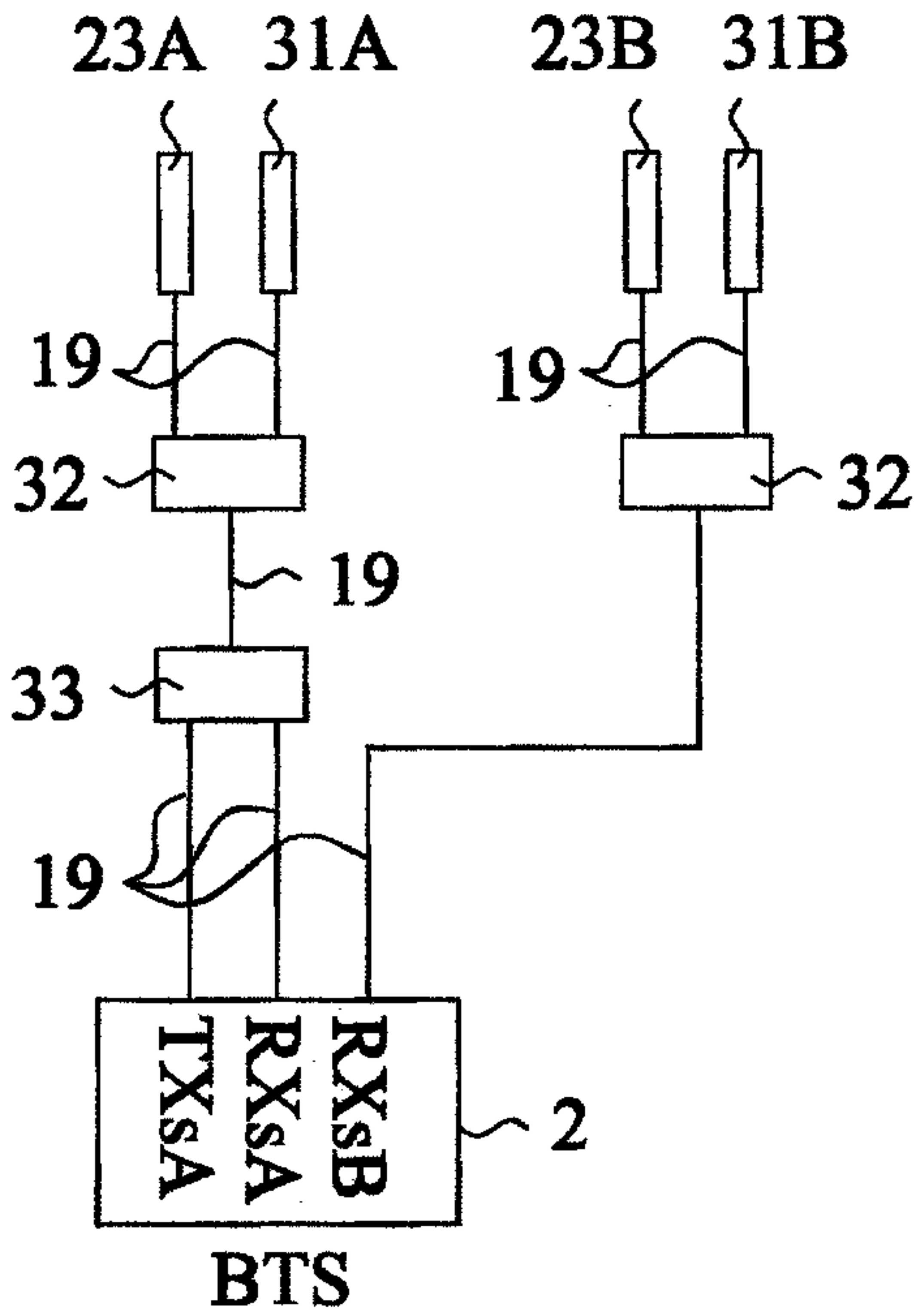

23A
31A
23B
31B
19
19
32
32
19
33
19
TXsA
RXsA
RXsB
2
BTS

FIG.5B

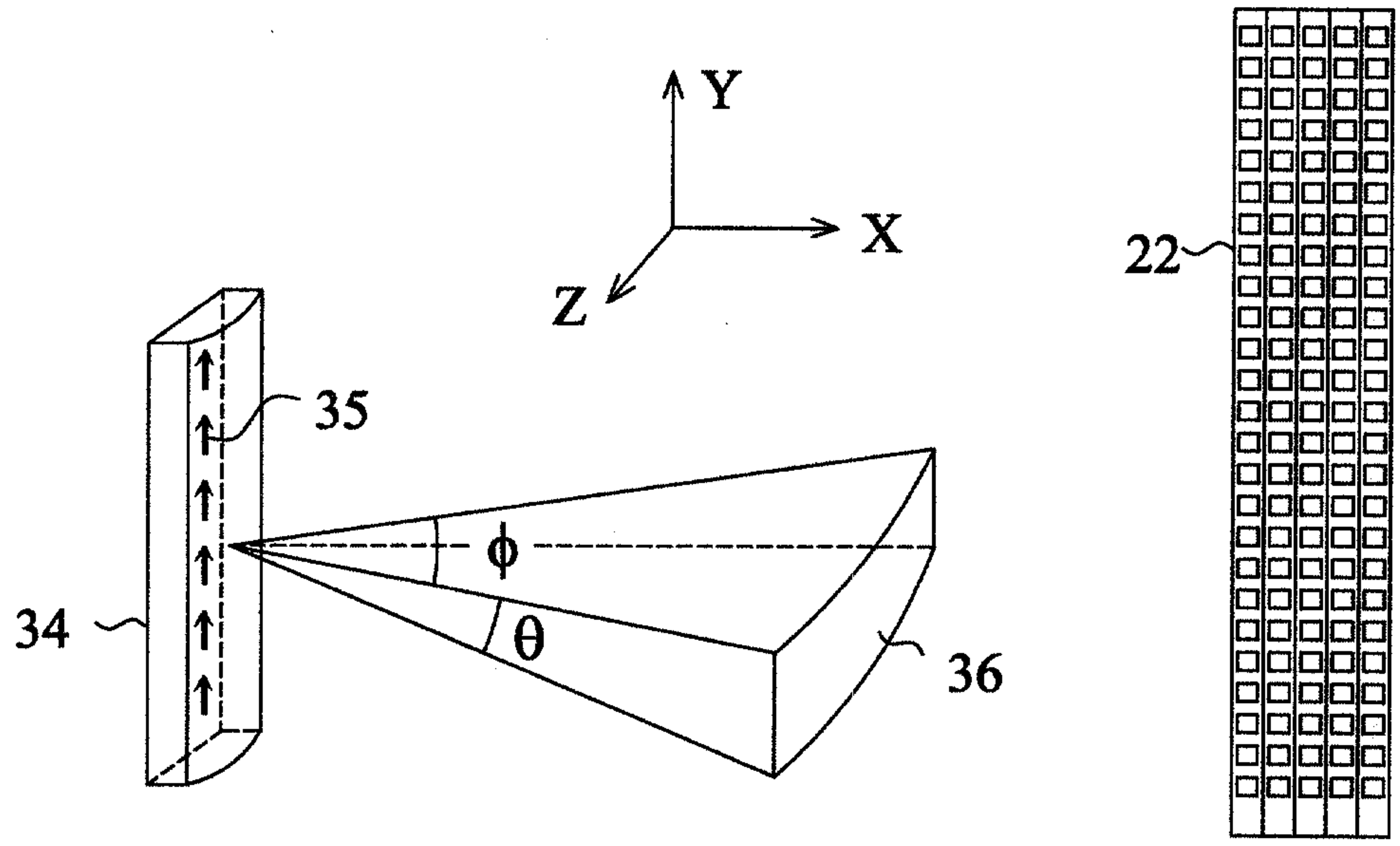


FIG.6A

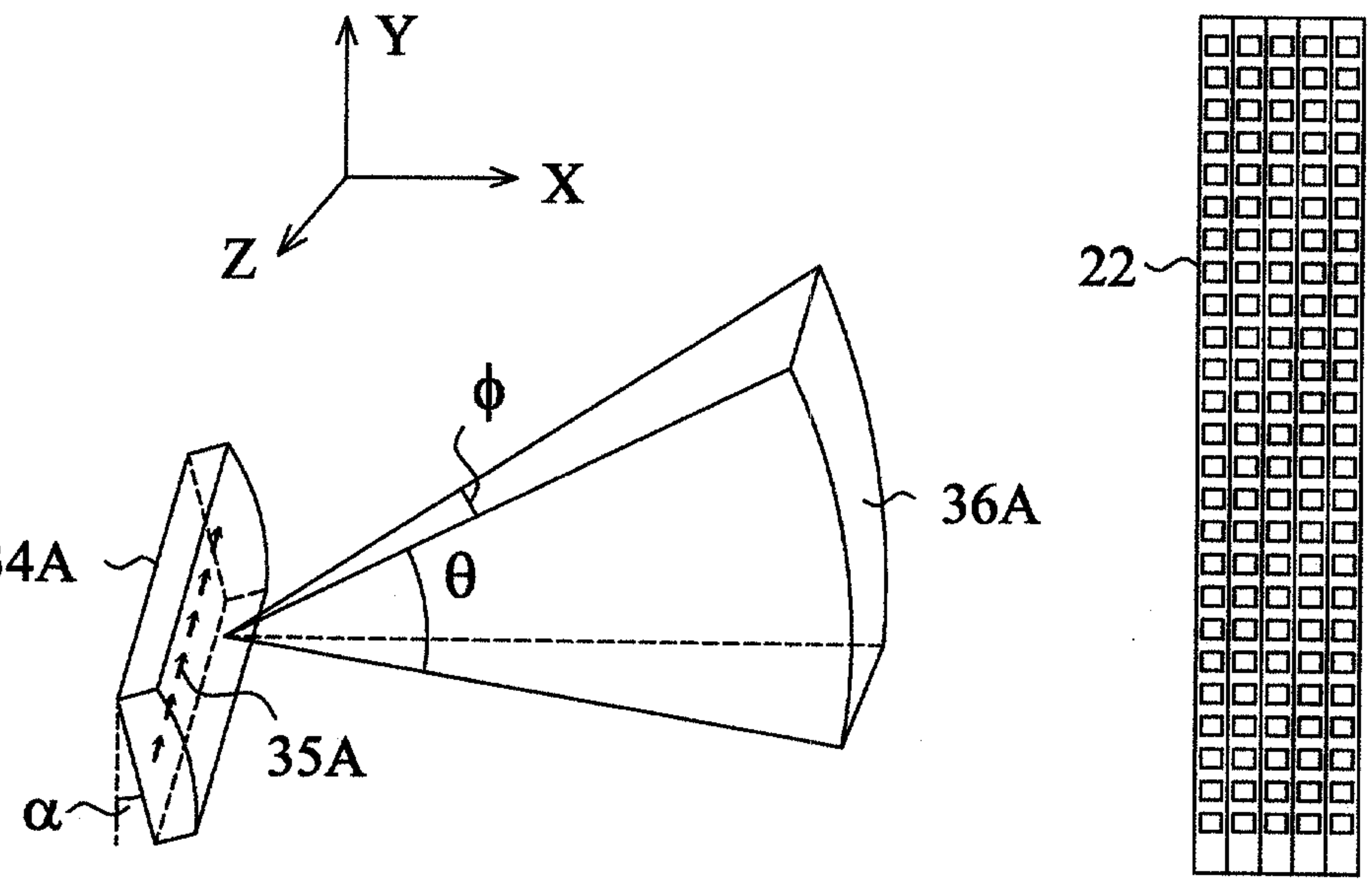


FIG.6B

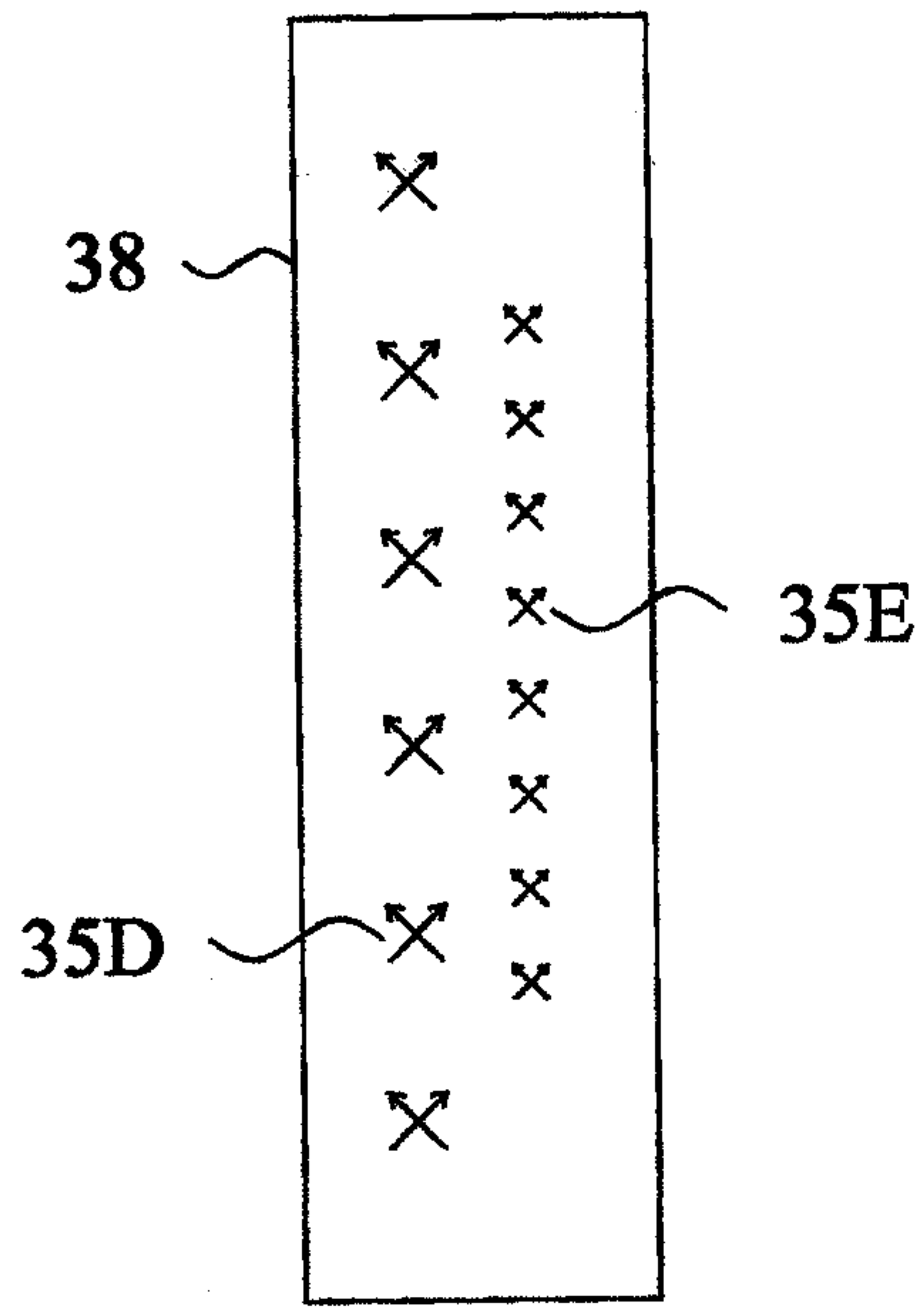


FIG.7C

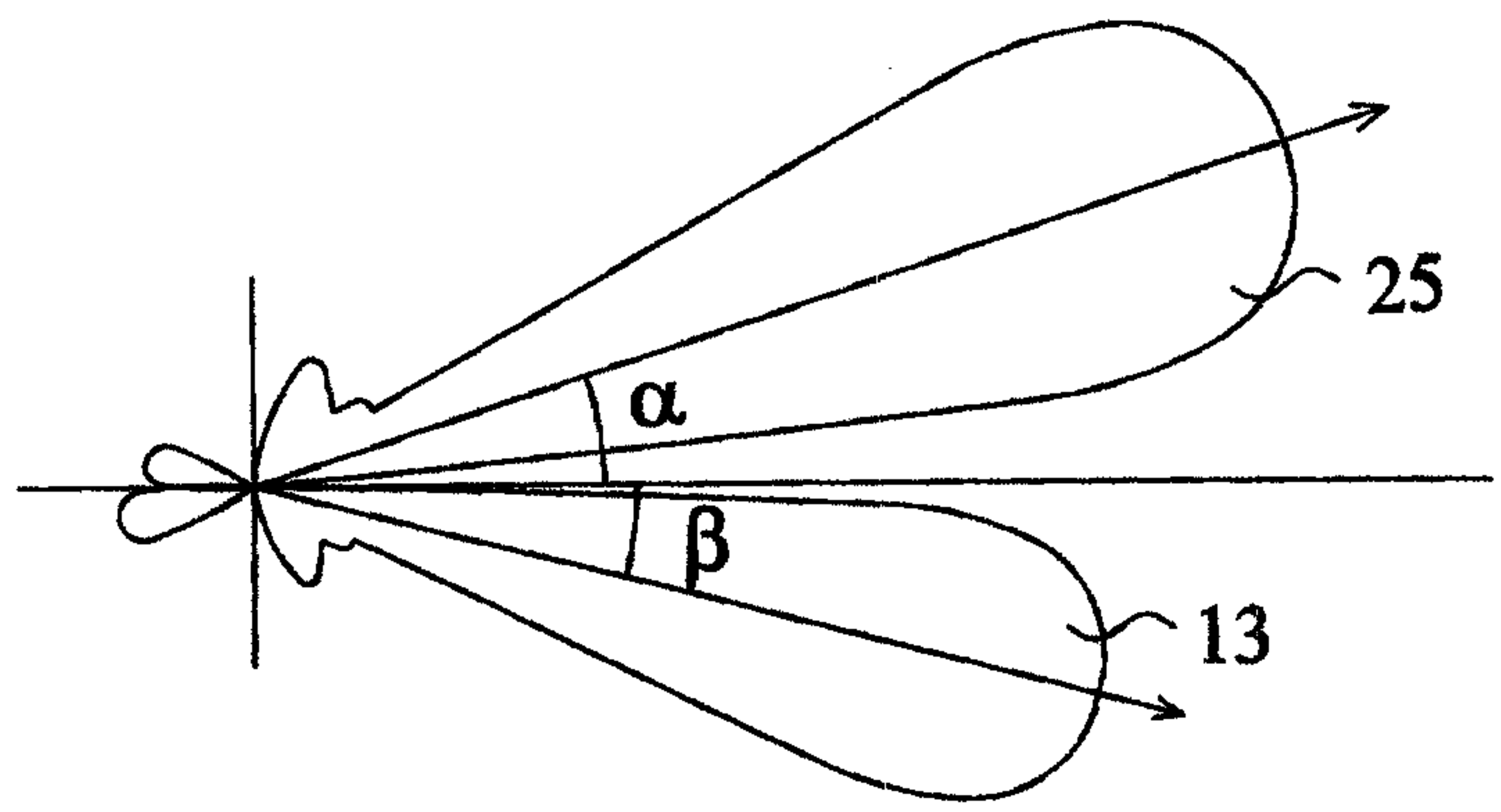
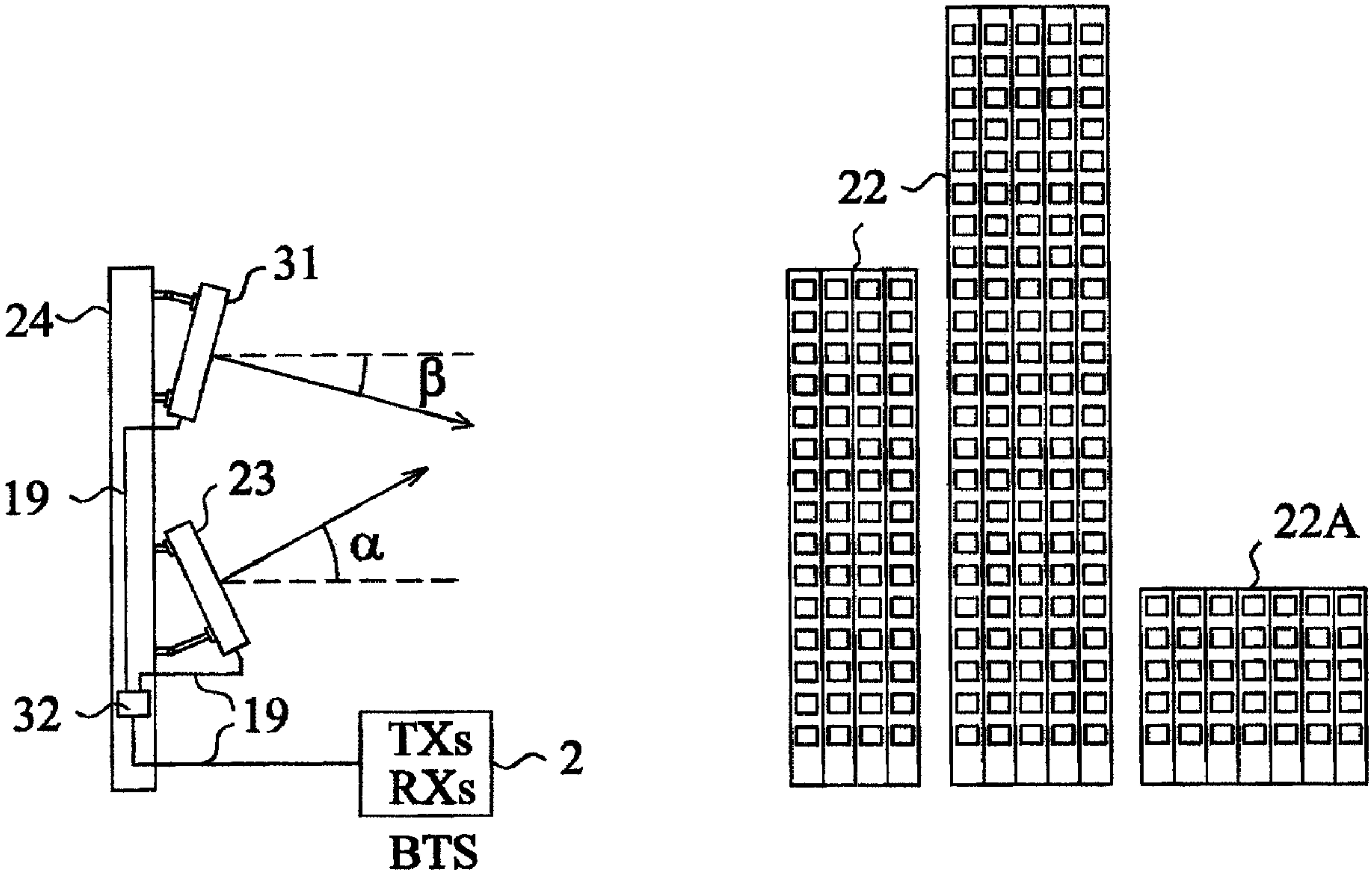


FIG.7D


31
24
β
19
23
α
32
19
TXs
RXs
2
BTS
22
22
22A