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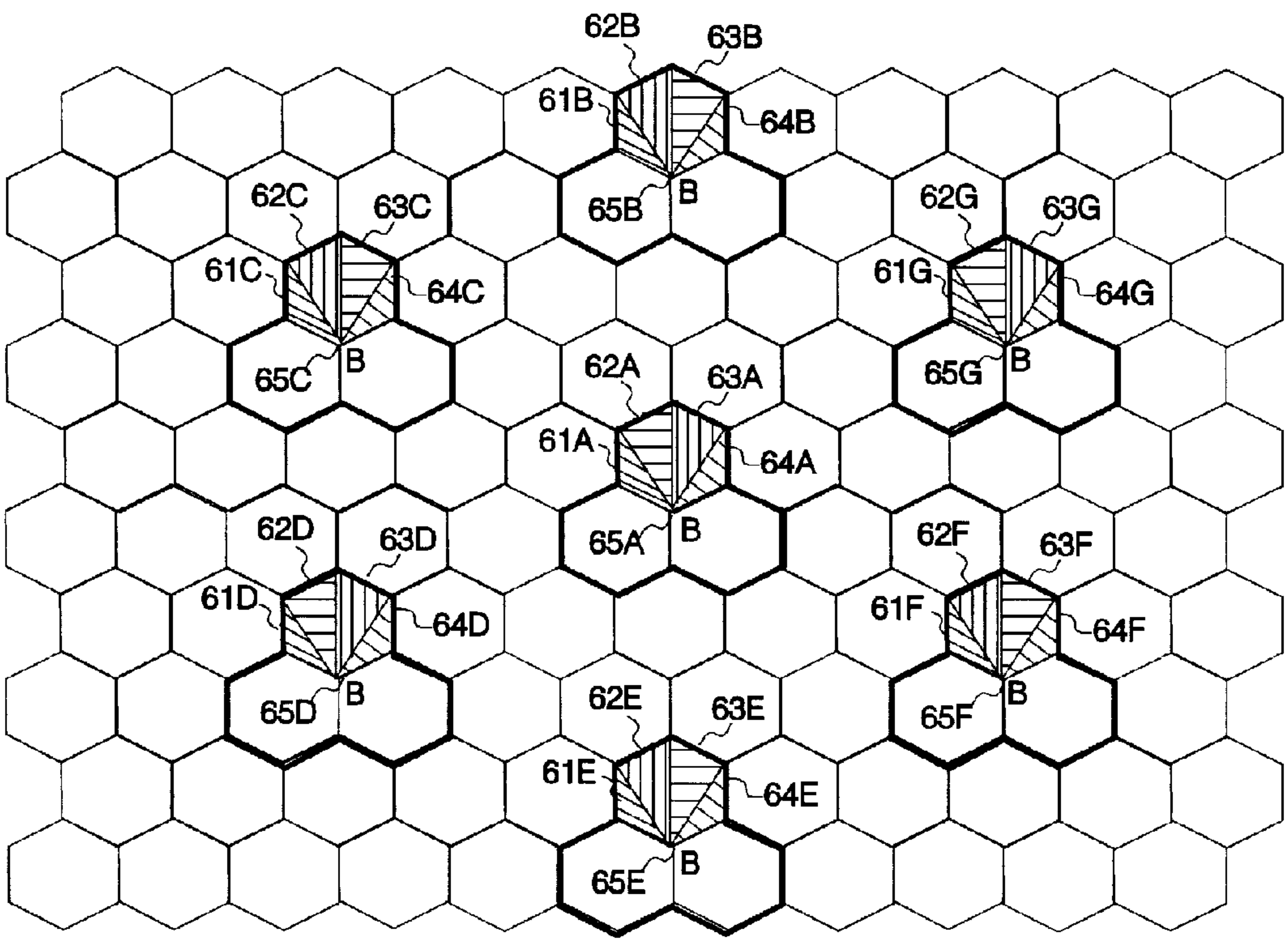

(57) Abrégé/Abstract:

A method of arranging a plurality of directional beams (61-64)in a cellular radio system having a plurality of antennas each communicating over a corresponding respective sector area. Interference between geographically close sectors is reduced by the method resulting in an improvement in carrier to interference ratio performance. Carrier frequencies of inner two beams transmitted by antenna an exchange for inner two beams which are transmitted in substantially the same direction by another antenna. This results in an improved carrier to interference performance for all four beams transmitted by the antennas. The techniques disclosed are applicable to center-excited or corner excited (tri-cellular) systems.

Abstract

MEANS OF INCREASING CAPACITY IN CELLULAR RADIO (MOBILE & FIXED) SYSTEMS

A method of arranging a plurality of directional beams (61-64)in a cellular radio system having a plurality of antennas each communicating over a corresponding respective sector area. Interference between geographically close sectors is reduced by the method resulting in an improvement in carrier to interference ratio performance. Carrier frequencies of inner two beams transmitted by antenna an exchange for inner two beams which are transmitted in substantially the same direction by another antenna. This results in an improved carrier to interference performance for all four beams transmitted by the antennas. The techniques disclosed are applicable to center-excited or corner excited (tri-cellular) systems.

Fig. 6

MEANS OF INCREASING CAPACITY IN CELLULAR RADIO (MOBILE AND FIXED) SYSTEMS

Field of the Invention

The present invention relates to a method of operating an antenna arrangement in a cellular communications system and more particularly to a method of assigning frequencies to multi-beam directional antennas.

Background to the Invention

In conventional cellular radio systems, geographical areas are divided up into a plurality of adjoining cells, in which mobile stations within a cell communicate with a base transceiver station. In general, each mobile (or set of mobiles sharing a multiplexed channel) communicating with a base station in a cell uses a different carrier frequency to other mobiles in the cell, to avoid interfering with the other mobiles. Thus the number of mobiles which can be served in a cell is limited by the number of available carrier frequencies. There is increased capacity demand for use of cellular radio systems, however the frequency band within which cellular radio systems operate is limited in width, and so to provide increased capacity in the system available carrier frequencies are re-used from cell to cell.

The re-use of frequencies in a locality is restricted by co-frequency interference between different cells which re-use the same or close frequencies and which are geographically close to each other. To obtain maximum capacity in a system comprising a plurality of cell areas, cellular radio system designers aim to re-use as many different carrier frequencies of the set of available carrier frequencies as possible in each cell. However there are limits on the re-usage of carrier frequencies in a cell due to other potentially interfering signals, particularly from:

(1) interference between a carrier frequency in a first cell and an identical frequency re-used in neighboring cells and (2) interference between a carrier frequency used in a first cell and adjacent carrier frequencies used in neighboring cells.

The minimum physical distance between geographic cells which re-use a same carrier frequency or an adjacent carrier frequency is limited by the required quality of signals received at the carrier frequency. One metric used to describe the quality of the signal is referred to in the art as the carrier to interference ratio (C/I ratio). The C/I ratio is a ratio of signal strength of a received desired carrier frequency to a signal strength of received interfering carrier frequencies and noise. A number of physical factors can affect the C/I performance in cellular systems, including reflections from buildings, geography, antenna radiation patterns, mobile station transmitting power, and mobile station locations within a cell. In general, calculating the distances between cells which re-use an interfering carrier frequency is a complex problem, however a general approach to the calculations may be found in Mobile Cellular Telecommunications Systems by William Chien-Yeh Lee published by McGraw Hill Book Company, New York 1989.

Taking as an example a Digital Amps TDMA (time division and multiple access) system having available 12.5 MHZ of frequency spectrum, for example in the 850 MHZ band, individual carrier frequencies are spaced apart from each other centered at spacings of every 30 KHz, giving a total of 416 carrier frequencies available across the network as a whole. The 416 carrier frequencies are partitioned so that individual carrier frequencies are re-used from cell to cell.

Taking as an example a base station re-use factor n of 7 (n=7), for center-excited cells each cell is allocated 416÷7=59 carrier frequencies per cell.

However, with a base station re-use factor of n=4, this give 416÷4=104 carrier frequencies per cell, resulting in a higher capacity than for an n=7 re-use factor. At a base station re-use factor of n=4 cells which re-use a same carrier frequency (the frequency re-use cells) are closer to each other than at a base station re-use factor n=7, resulting in more interference, and a lower C/I ratio in the base station re-use factor n=4 case than in the base station re-use factor n=7 case. To implement the lower base station re-use factor (n=4) frequency, re-use cells must be closer together than with a higher base station re-use n=7. However, the distance between the re-use cells must be great enough so that the carrier to interference ratio is high enough to allow the cellular radio telecommunications apparatus to distinguish signals at each re-used carrier frequency in one cell from the interfering frequencies present in other cells across the network. The C/I performance is a limiting factor in implementation of a lower base station re-use factor.

SUMMARY OF THE INVENTION

An object of the present invention is to provide improved carrier to interference ratio for a plurality of beams which re-use frequencies from beam to beam, and to provide an acceptably low level of interference overall, thereby allowing greater re-use of frequencies and providing a capacity gain for a cellular radio communication system.

According to one aspect of the present invention there is provided in a cellular radio communications system having a plurality of base stations each for communicating over at least one corresponding tri-cellular region using a plurality of directional beams, the tri-cellular region having three corner excited cells, a method of configuring the plurality of directional beams comprising: arranging each of the base stations at the center of the corresponding at least one tri-cellular region; arranging the plurality of beams across each of the cells such that a pair of beams which reuse a like carrier frequency as each other are disaligned with respect to each other; selecting at least one of the beams reusing the like carrier frequency; and restricting usage of the like carrier frequency on the at least one selected beam.

Preferably the step of the method according to claim 1, wherein said step of arranging the plurality of beams comprises: at a first of the base stations, forming a first set of beams in a first tri-cellular region; at a second of the base stations, forming a second set of beams in a second tri-cellular region; wherein at least one beam of the first set is directed in a substantially same direction to and reuses a first carrier frequency as at least one beam of the second set; and at least one remaining beam of the first set reuses a second carrier frequency as at least one remaining beam of the second set, the remaining beam of the first set being disaligned away from the remaining beam of the second set.

According to a second aspect of the present invention there is provided a cellular radio system comprising a plurality of base stations each for communicating over at least one corresponding tri-cellular region using a plurality of directional beams, the at least one tri-cellular region having three corner excited cells, the base stations being arranged at the center of the corresponding at least one tri-cellular region, and the plurality of base stations operating to: arrange the plurality of beams across each of the cells such that a pair of beams which reuse a like carrier frequency as each other are disaligned with respect to each other; select at least one of the beams reusing the like carrier frequency; and restrict usage of the like carrier frequency on the at least one selected beam.

The use of a plurality of directional beams in a single cell of a tri-cellular arrangement may enable improved carrier to interference ratio, and allow tighter frequency re-use in a cellular radio system. Preferably each of the set of beams comprises four directional beams. Preferably each of the set of directional beams comprises two inner beams and two outer beams.

Another broad aspect of the invention provides a cellular radio communications system comprising: a plurality of base stations each for communicating over at least one corresponding tri-cellular region using a corresponding plurality of directional beams, the tri-cellular region having three corner excited cells; a common pool of carrier frequencies for the directional beams such that like carrier frequencies are reused as between different ones of the base stations, wherein usage of at least one of the like carrier frequencies is restricted and wherein beams from different ones of the base stations having the like carrier frequencies are disaligned with respect to each other.

Preferably the beams of the first set extend along directions diverging within an angle of 60° from a main direction of the first cell; the beams of the second set extend along directions diverging within an angle of 60°

from a main direction of the second cell; and the main directions of the first and second cells being substantially coincident with each other.

According to a fourth aspect of the present invention there is provided a method for improving the carrier to interference ratio of a cellular radio communications system, comprising: arranging a plurality of base stations each for communicating over a corresponding tri-cellular region through the use of a plurality of directional beams, the tri-cellular region having three corner excited cells; arranging the plurality of beams across each of the cells such that a pair of beams which reuse a like carrier frequency are disaligned with each other; selecting at least one of the beams reusing a like carrier frequency; and restricting usage of the like carrier frequency on the at least one selected beam.

Preferably the first set of base stations are arranged substantially along a first line and the second set of base stations are arranged substantially along a second line. Preferably the first line is substantially parallel to the second line.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention and to show how the same may be carried into effect, there will now be described by way of example only, specific embodiments, methods and processes according to the present invention with reference to the accompanying drawings in which:

Fig. 1 illustrates an arrangement of center excited tri-sectorized hexagonal cells in which each sector is served by a plurality of directional beams;

Fig. 2 illustrates a prior art tri-cellular arrangement wherein each of three sectors of tri-cellular area are served by a separate beam;

Fig. 3 illustrates beam coverage of one sector of a tri-cellular area of the prior art arrangement of Fig. 2, showing a -3dB contour and a -10dB contour, illustrating coverage of the cell from a beam originating at a corner of the sector;

Fig. 4 illustrates a directional beam layout having a frequency re-use between cells for edge excited sectors with four beams per sector in a tri-cellular arrangement;

Fig. 5 illustrates a carrier to noise and interference ratio graph corresponding to the layout in Fig. 4;

Fig. 6 illustrates a directional beam layout for edge excited sectors having frequency re-use between sectors with four beams per sector in a tri-cellular arrangement according to a specific method of the invention herein; and

Fig. 7 illustrates a carrier to noise and interference ratio graph corresponding to the layout in Fig. 6.

Detailed Description of the Best Mode for Carrying Out the Invention

There will now be described by way of example the best mode contemplated by the inventors for carrying out the invention. In the following description numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent however, to one skilled in the art, that the present invention may be practiced without using these specific details. In other instances, well known methods and structures have not been described in detail so as not to unnecessarily obscure the present invention.

In this specification, the term sector is used to denote an azimuth angular range of view from a base station of nominally 120° or less over which the radio base station produces beam coverage. A sector may typically subtend an angle of view (azimuth angle) of nominally 120° in an arrangement of three sectors per base station as illustrated in Figs. 1 and 6 herein. In an arrangement of six sectors per base station (a hex-sectored arrangement), each sector may subtend a nominal angle of 60° from a base station. In a conventional tri-sectored center-excited hexagonal cell arrangement a sector may comprise a nominal quadrilateral area, which is edge or corner excited. Three such sectors form a nominally hexagonal cell. In a conventional tri-cellular arrangement, a sector comprises a nominally hexagonal area excited from one edge or corner. Three such sectors surround a base station to provide a tri-cellular area. In each case, the sector is edge excited and extends radially outwards from the base station.

A capacity increase over a prior art center-excited tri-sectorized cellular arrangement having three 120° sectors each served by a separate 120° azimuth beam can be achieved by the use of a plurality of directional beams in each sector, as shown in Fig. 1 herein.

Referring to Fig. 1 there is shown an example of a geographical area served by a cellular radio network covering a plurality of nominally hexagonal center excited cells each cell divided into three 120° sectors, each sector served by four directional beams. First, second and third hexagonal cells 100, 101, 102 respectively re-use a common set of frequencies, and are spaced apart from each other by intermediate cells 103 - 105 which use different frequencies to the first to third cells and which are non-interfering with the common frequencies used in the first to third cells. Each of the first second and third cells is tri-sectorized into three 120° sectors, wherein four directional beams per sector are provided.

Using a plurality of directional beams it is possible to increase the capacity of a cellular radio system by reducing interference from neighboring beams which re-use common frequencies. Using the example of a base station re-use factor n=7, where each cell is allocated 416÷7=59 carrier frequencies per cell, where the cell is tri-sectored, each sector having four directional beams, 19 carrier frequencies can be allocated to each set of four beams 106-109 in a sector as shown in Fig. 1. Most of these frequencies can be allocated to traffic, but some are reserved for control purposes.

A base station re-use factor of n=4, gives 416÷4=104 carrier frequencies per cell. In a tri-sectored hexagonal cell, each sector having a multibeam arrangement of four beams per sector, 34 carrier frequencies can be allocated per sector, ie across four directional beams, in a 120° sector. Improvement in the C/I ratio obtained by the use of directional beams within a sector enables the implementation of a lower base station re-use factor n than would otherwise be available with a tri-sectorized center excited cell arrangement.

Considering now a conventional tri-cellular arrangement (otherwise known as edge excited or corner excited cells) as shown in Fig. 2 herein, a base station serves three nominally hexagonal sectors comprising a tri-cellular region, from a position at a center of the tri-cellular region where the three sectors meet each other. Conventionally, network planners use nominally hexagonal areas which are loosely termed "cells" to plan terrestrial cellular network coverage. Hence the arrangement of three nominally hexagonal edge-excited sectors surrounding a base station has become known as a tri-cellular arrangement. In this specification terminology used for each edge-excited area surrounding a base station is maintained as a sector, in accordance with the description hereinabove irrespective of whether the edge excited area is nominally hexagonal or quadrilateral or any other shape. The tri-cellular arrangement has an inherent advantage in terms of C/I performance compared to an equivalent conventional center excited tri-sectorized hexagonal cell of comparable area, due to the narrower beam which can be used in each sector of the tri-cellular arrangement as compared to each sector of the known center excited tri-sectorized center excited arrangement .

Referring to Fig. 3 herein, one sector of a three sector tri-cellular arrangement is illustrated in which one hexagonal sector 300 is covered by a beam having a coverage pattern having a 60° angular beamwidth 301 at -3 dB gain. Such a beamwidth may give adequate performance for coverage of a 120° angle azimuth 302 at the corner of the sector where the base station is situated, as the coverage pattern of the beam falls away in power in such a way that at a -10 dB contour 303 of the beam, nearest corners 304, 305 of the nominally hexagonal sector which are adjacent to the corner occupied by the base station are relatively close to the base station compared to oppositely facing corners 306, 307 and are within the -10 dB contour of the beam with the result that acceptable power levels are available for communicating with mobile stations at the nearest corners 304, 305. Thus, the known tri-cellular arrangement has an inherent advantage over the known center excited tri-sectorized hexagonal cell arrangement in terms of the narrower beam which can be used to cover an equivalent area. The reduced power received on the downlink by mobile stations located at the nearest corners to the base station corner is compensated by the fact that these corners are closer to the base station corner than other parts of the tri-cellular sector. Typically a -3 dB azimuth beamwidth of 60° to 70° is acceptable for coverage of the tri-cellular sector.

Referring to Fig. 4 of the accompanying drawings there is illustrated a cellular radio system serving a geographical area divided into a plurality of adjoining hexagonal edge-excited sectors 40 of substantially equal area to each other in a tri-cellular configuration in which a plurality of base stations B are each surrounded by a corresponding respective set of three hexagonal sectors, which they serve. Each base station has one or more directional beam antennas 45. Each base station supports coverage of its three surrounding sectors comprising a tri-cellular region. Tri-cellular regions are shown enclosed by a thickened line in Fig. 4.

A plurality of frequency re-use base stations B which use a common set of frequencies are arranged in a plurality of substantially straight lines which are approximately parallel to each other, the base stations of a line being spaced approximately equidistantly from each other along the line. Base stations of one line are positioned off-set to base stations of a neighboring line. Each tri-cellular area comprises three nominally hexagonal sector areas. Each sector area is served by a plurality of substantially radially extending beams extending outwardly from the base station and covering the area of the sector. The plurality of beams extend either side of a main length of the sector, the main length extending between a corner of the hexagonal sector at which the base station is situated, and a furthermost corner of the sector opposite the corner at which the base station is located. Each beam is of relatively narrow beamwidth, typically of the order 45° to 50° azimuth at the -3dB gain contour.

For ease of description, hereinafter a method corresponding to one sector of a tri-cellular region, the tri-cellular regions supported by two base stations which are spaced apart from each other and re-use a common set of carrier frequencies will be described. It will be understood that coverage of all sectors in the cellular radio system requires duplication of the method described hereinafter. In Fig. 4 a first set of directional beams has been labeled 41A, 42A, 43A and 44A for one of the sectors covered by first frequency re-use base station 45A and a second set of directional beams has been labeled 41B, 42B, 43B and 44B for one of the sectors covered by second frequency re-use base station 45B. When referring to Fig. 4 herein, a beam referred to by a number 41 shall represent beam 41A, 41B or any other beam of equivalent re-used carrier frequency and substantially similar direction transmitted by any other frequency re-use base station 45 in Fig. 4. Likewise beams referred to by a number 42, 43 or 44 shall represent beams of identical re-used carrier frequency and substantially similar direction of any frequency re-use base station 45 in Fig. 4. All other sectors in Fig. 4 have a corresponding pattern of four beams 41 to 44 which use other frequencies but these are not illustrated for clarity.

In the arrangement of beams shown in Fig. 4, outer beam 41A supported by first base station 45A re-uses the same carrier frequency as outer beam 41B supported by second base station 45B. Likewise all inner beams 42, have the same carrier frequency as each other, and similarly inner beams 43 re-use another same carrier frequency, and outer beams 44 re-use a further same carrier frequency, as between the first and second base stations 45A, 45B in Fig. 4.

The sector served by first base station 45A containing first set of directional beams 41A-44A uses a same set of frequencies as second set of beams 41B-

44B of second base station 45B serving the second tri-cellular area. Similarly, other surrounding frequency re-use base stations 45C, 45D, 45E, 45F, 45G, each serving a corresponding respective tri-cellular area, re-use the same frequencies as first base station 45A, allocating those re-use frequencies to corresponding respective third to seventh beam sets 41C-41G, 42C-42G, 43C-43G, 44C-44G as shown in Fig. 4. Each frequency re-use sector contains a set of directional beams 41-44. In each case, the directional beams extend radially about the corresponding respective base station, and either side of a main length of the corresponding respective sector served by the beam set. Each sector containing a beam set re-using a same set of frequencies has a main length extending in a same direction to each other sector re-using the same frequency set. Each beam of first beam set 41A-44A extends in a respective general direction which is the same as a corresponding respective beam 41B -44B of a corresponding sector comprising second tri-cellular area supported by second first tier re-use base station 45B.

The plurality of frequency re-use base stations 45 are arranged in such a way that for each sector of the tri-cellular area supported by the corresponding respective re-use base station 45, beams 41, 44 at an outer edge of each individual sector of the tri-cellular area extend along a line of sight pointing midway between corresponding respective outermost frequency beams 41, 44 of neighboring first tier re-use base stations. For example, outer beam 41A extends along the line of sight pointing to an area midway between corresponding respective outer beams 41B, 41C re-using a same frequency as 41A. Because beams 41A-C are directional, the likelihood of interference between these frequency re-use beams is reduced.

Referring to Fig. 5 herein, there is illustrated carrier to interference ratio graphs corresponding to four beams of one sector of the layout shown in Fig. 4. Graph line 51 shows a plot of carrier to interference level in decibels on a vertical axis, against beam width on a horizontal axis for outer beam 41 in Fig. 4 over beamwidths in the range 20° to 50°. Likewise graph lines 52, 53 and 54 in Fig. 5 correspond to inner beams 42, 43 and outer beam 44 in Fig. 4 respectively.

As can be seen from graph lines 51 and 54 in Fig. 5 the outer two beams 41 and 44 of a sector in Fig. 4 have a relatively higher carrier to interference performance compared to inner beams 42, 43. Innermost beams 42A, 43A of the first base station 45A extend in a direction which points towards the corresponding respective inner beams 42B, 43B of adjacent first tier re-use sector of first tier re-use base station, second base station 45B. Areas covered by inner beams 42B, 43B receive interference from corresponding inner beams of adjacent first tier frequency re-use base station 42A, 43B respectively. The beams 42B and 43B in Fig. 4 experience reduced carrier to interference performance due to the interference which results from beams 42A and 43A transmitted by antenna 45A having the same carrier frequencies and being directed in substantially the same direction.

Fig. 6 herein illustrates a directional beam layout in a sector of a tri-cellular radio system with identical apparatus components to those shown in Fig. 4 but employing a specific method of arranging frequency re-use beams which is subject of the present invention. For ease of description hereinafter a method corresponding to one sector of a tri-cellular region supported by a base station will be described. It will be understood that coverage of all three sectors supported by a base station requires duplication of the method described hereinafter. For this section of the description a beam referred to by a number 61 shall represent first outer beam 61A, 61B or any other beam of substantially similar direction supported by any base station in Fig. 6 which re-uses a common set of carrier frequencies. Likewise beams referred to by a number 62, 63 shall represent inner beams of substantially similar direction supported by any frequency re-use base station 65 in Fig. 6 and beams referred to by number 64 shall represent second outer beams of any frequency re-use base station 65. First outer beam 61 has a same carrier frequency for all base stations 65 in Fig.

6. Second outer beam 64 also has a same carrier frequency for all base stations 65 in Fig. 6. However the carrier frequencies of inner two beams 62 and 63 have been exchanged for each other as between first and second base stations 65A and 65B so that inner beam 62A of first frequency re-use sector served by first base station 65A sector has the same carrier frequency as opposite inner beam 63B of second frequency re-use sector of the second first tier frequency re-use base station 65B, and inner beam 63A of the first frequency re-use sector has the same carrier frequency as opposite inner beam 62B of the second frequency re-use sector. The pattern of alternating the carrier frequencies of the two inner beams transmitted by base stations 65A and 65B is repeated throughout the layout of frequency re-use base stations so that the inner two beams of all adjacent base stations have alternated carrier frequencies in order to minimize overall interference.

In the arrangement of Fig. 6 herein, first base station 65A communicates with first sector area served by first set of beams 61A-64A and second frequency re-use base station 65B communicates with second sector area served by second set of frequency re-use beams 61B-64B. Outer beams 61A, 64A of the first beam set are directed in a same direction as corresponding respective outer beams 61, 64 of the plurality of other beam sets (second to seventh beam sets 61-64 corresponding to second to seventh frequency re-use base stations 65B-65G). Because of the layout of the base stations, arranged substantially along straight lines parallel to each other where frequency re-use base stations are spaced substantially equidistantly from each other along each line, the outer beams 61, 64 of a sector of a tri-cellular area extend along a line of sight which points towards an area between nearest adjacent corresponding respective frequency re-use beams 61, 64 of adjacent frequency re-use base stations, and interference between outer frequency re-use beams 61, 64 of adjacent frequency re-use sectors is relatively low.

First frequency re-use inner beams 62, of each frequency re-use sector along a line of base stations, for example a first line comprising fourth base station 65D, first base station 65A and seventh base station 65G are all directed in a same direction and use a same frequency. However, corresponding first frequency re-use inner beams of an adjacent parallel line of frequency re-use base stations, for example comprising second base station 65B and third base station 65C use a different frequency ie the frequency used by second inner beams 63 of the frequency re-use base stations along the first line comprising fourth base stations 65D, first base station 65A and seventh base station 65G. In the tri-cellular areas corresponding to the base stations along the second line, the frequencies of the inner two beams 62, 63 are reversed as compared to the corresponding respective beams of tri-cellular areas served by base stations along adjacent parallel first line of base stations comprising fourth, first and seventh base stations 65D, 65A, 65G.

In other words, examining the relationship between frequency re-use at first base station 65A and second base station 65B, first base station 65A communicates with a first sector area of a tri-cellular area using a first set of beams, second frequency re-use base station 65B communicates with second sector of second tri-cellular area using a second set of beams, at least one beam of the first set being directed in a substantially same direction as a corresponding beam of the second set, and at least one remaining beam of the first set which re-uses a second same frequency as a beam of the second set, being directed away from that beam. Outer beams 61A, 64A of the first set of beams have a same direction as corresponding respective outer beams 61B, 64B of the second set of beams, corresponding respective beams of each set pointing in the same direction as each other and using the same frequency as each other. Inner beams 62A, 63A of first beam set and inner beams 62B, 63B of second beam set re-use the same two frequencies as each other, however first inner beam 62A of the first set having a common re-used carrier frequency with second, opposite inner beam 63B of the second set are directed in different directions to each other, and second, opposite inner beam 63A of the first set having a same common carrier frequency as first inner beam 62B of the second set also are directed in different directions to each other.

The first set of beams 61A - 64A extending from the first base station 65A are arranged in a first pattern, extending radially from the first base station, whereas the second set of beams 61B-64B extend in a second pattern substantially radially outwardly from the second base station 64B, the first and second sets of beams re-using a common set of carrier frequencies, the carrier frequencies being assigned to the first set of beams 61A, 64A in a different order as compared with their assignment to the second set of beams 61B-64B.

Fig. 7 herein illustrates carrier to interference ratio graphs corresponding to four beams transmitted by a base station 65 in the beam layout shown in Fig. 6. Graph line 71 shows a carrier to interference level in decibels on a vertical axis plotted against beam width for beam 61 in Fig. 6 over beamwidths in the range 20° to 50°. Likewise graph lines 72, 73 and 74 correspond to beams 62, 63 and 64 in Fig. 6 respectively.

As can be seen from graph lines 71 and 72 in Fig. 7 outer two beams 61 and 64 in Fig. 6 achieve a relatively higher carrier to interference performance for beamwidths in the range 20° to 50°. An improvement in carrier frequency to interference performance resulting from alternating the re-used carrier frequencies between inner beams 62 and 63 in Fig. 4 is seen for both inner beams represented by graph lines 72 and 73, as compared to the arrangement of Fig. 4 herein. For graph line 72 (representing beam 62 in Fig. 6) the carrier to interference performance is improved significantly. For graph line 73 (representing beam 63 in Fig. 6) the carrier to interference performance is also improved.

CLAIMS:

1. In a cellular radio communications system having a plurality of base stations each for communicating over at least one corresponding tri-cellular region using a plurality of directional beams, the tri-cellular region having three corner excited cells, a method of configuring the plurality of directional beams comprising:

arranging each of the base stations at the center of the corresponding at least one tri-cellular region:

arranging the plurality of beams across each of the cells such that a pair of beams which reuse a like carrier frequency as each other are disaligned with respect to each other;

selecting at least one of the beams reusing the like carrier frequency; and

restricting usage of the like carrier frequency on the at least one selected beam.

2. The method according to claim 1, wherein said step of arranging the plurality of beams comprises:

at a first of the base stations, forming a first set of beams in a first tri-cellular region;

at a second of the base stations, forming a second set of beams in a second tri-cellular region;

wherein at least one beam of the first set is directed in a substantially same direction to and reuses a first carrier frequency as at least one beam of the second set; and at least one remaining beam of the first set reuses a second carrier frequency as at least one remaining beam of the second set, the remaining beam of the first set being disaligned away from the remaining beam of the second set.

3. The method according to claim 2, wherein said beam forming steps each comprise forming four beams.

4. The method according to claim 1, wherein said step of restricting usage comprises restricting a proportion of time during which the like carrier frequency is available for transmission on the at least one selected beam.

5. The method according to claim 1, further comprising:

forming a first beam of the pair of beams at a first of the base stations; and

forming a second beam of the pair of beams at a second of the base stations;

wherein the first and second base stations comprise first tier frequency reuse base stations.

6. The method according to claim 1, further comprising:

using a first inner beam within a first of the cells;

using a first outer beam within the first of the cells;

using a second inner beam within a second of the cells;

using a second outer beam within the second of the cells; and

restricting usage of at least one of the inner beams.

7. The method according to claim 1, wherein the step of selecting the at least one beam comprises selecting a beam that causes the highest amount of interference with the like carrier frequency.

8. A cellular radio system comprising a plurality of base stations each for communicating over at least one corresponding tri-cellular region using a plurality of directional beams, the at least one tri-cellular region having three corner excited cells, the base stations being arranged at the center of the corresponding at least one tri-cellular region, and the plurality of base stations operating to:

arrange the plurality of beams across each of the cells such that a pair of beams which reuse a like carrier frequency as each other are disaligned with respect to each other;

select at least one of the beams reusing the like carrier frequency; and

restrict usage of the like carrier frequency on the at least one selected beam.

9. In a cellular radio communications system having a plurality of base stations each for communicating over at least one corresponding tri-cellular region using a plurality of directional beams, the tri-cellular region having three corner excited cells, a method of configuring the directional beams comprising:

arranging each of the base stations at the center of the corresponding at least one tri-cellular region;

arranging the plurality of beams across each of the cells such that individual ones of the beams that reuse a like carrier frequency as each other are disaligned with respect to each other; and restricting usage of the like carrier frequency on selected ones of the plurality of beams.

10. The method according to claim 9, wherein said restricting step comprises selecting a plurality of beams causing a significant level of like carrier frequency interference.

11. The method according to claim 9, wherein said step of arranging the plurality of beams across each of the cells comprises arranging a first beam operating at the like carrier frequency so as to reduce the amount of overlap between first beam and any reuse beams operating at the like carrier frequency.

12. A cellular radio communications system comprising:

a plurality of base stations each for communicating over at least one corresponding tri-cellular region using a corresponding plurality of directional beams, the tri-cellular region having three corner excited cells;

a common pool of carrier frequencies for the directional beams such that like carrier frequencies are reused as between different ones of the base stations, wherein usage of at least one of the like carrier frequencies is restricted and wherein beams from different ones of the base stations having the like carrier frequencies are disaligned with respect to each other.

13. The cellular radio communications system according to claim 11, wherein the usage restriction of at least one of the like carrier frequencies comprises a temporal restriction of transmission of said at least one of the like carrier frequencies.

14. A method for improving the carrier to interference ratio of a cellular radio communications system, comprising:

arranging a plurality of base stations each for communicating over a corresponding tri-cellular region through the use of a plurality of directional beams, the tri-cellular region having three corner excited cells;

arranging the plurality of beams across each of the cells such that a pair of beams which reuse a like carrier frequency are disaligned with each other;

selecting at least one of the beams reusing a like carrier frequency; and

restricting usage of the like carrier frequency on the at least one selected beam.

15. The method according to claim 14, wherein said step of arranging the plurality of beams comprises:

at a first of the base stations, forming a first set of beams in a first tri-cellular region;

at a second of the base stations, forming a second set of beams in a second tri-cellular region;

wherein at least one beam of the first set is directed in a substantially same direction to and reuses a first carrier frequency as at least one beam of the second set; and at least one remaining beam of the first set reuses a second carrier frequency as at least one remaining beam of the second set, the remaining beam of the first set being disaligned away from the remaining beam of the second set.

16. The method according to claim 15, wherein said beam forming steps each comprise forming four beams.

17. The method according to claim 14, wherein said step of restricting usage comprises restricting a proportion of time during which the like carrier frequency is available for transmission on the at least one selected beam.

18. The method according to claim 14, further comprising:

forming a first beam of the pair of beams at a first of the base stations; and

forming a second beam of the pair of beams at a second of the base stations;

wherein the first and second base stations comprise first tier frequency reuse base stations.

19. The method according to claim 14, further comprising:

using a first inner beam within a first of the cells;

using a first outer beam within the first of the cells;

using a second inner beam within a second of the cells;

using a second outer beam within the second of the cells; and

restricting usage of at least one of the inner beams.

20. The method according to claim 14, wherein the step of selecting the at least one beam comprises selecting a beam that causes the highest amount of interference with the like carrier frequency.

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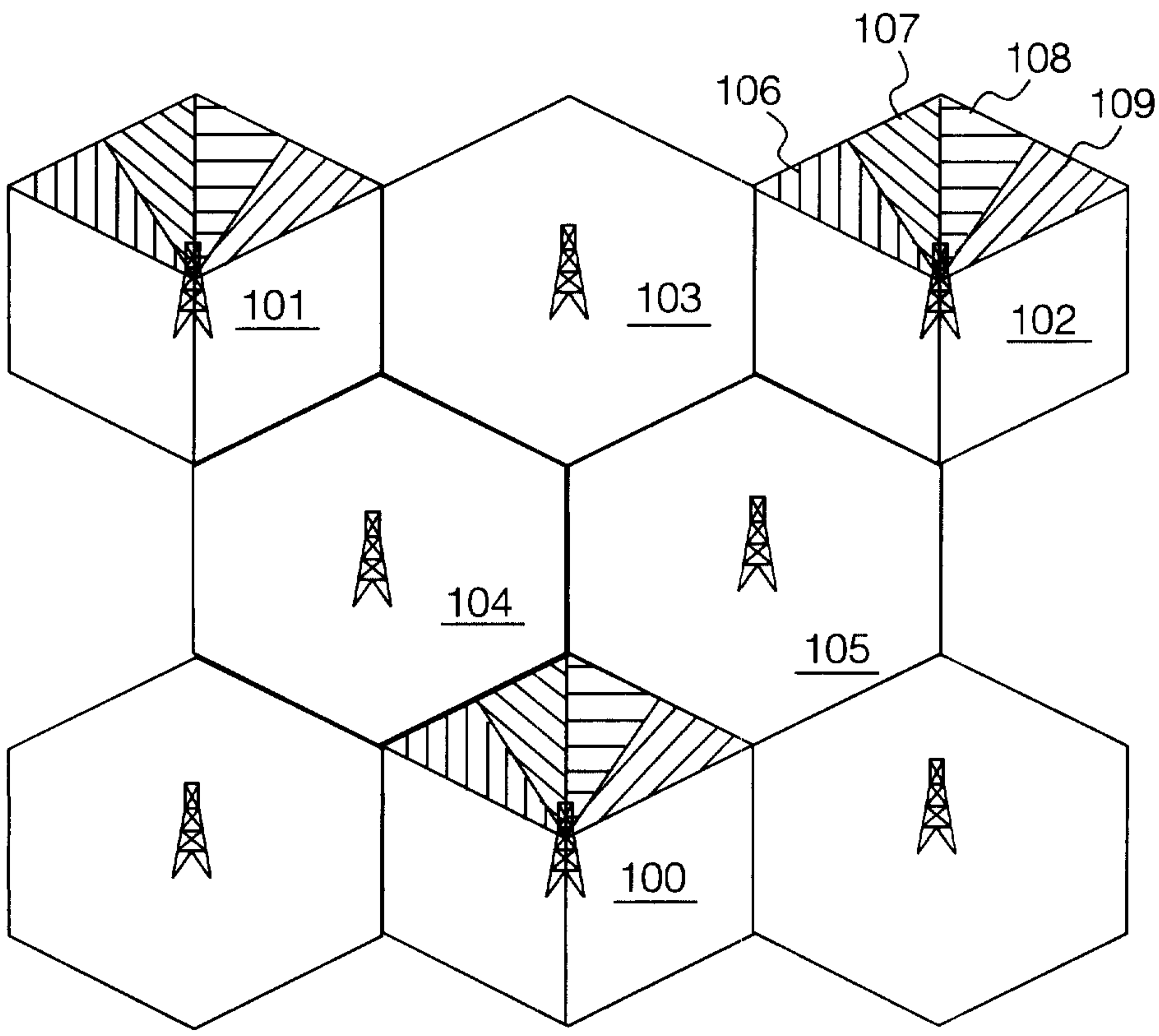


Fig. 1

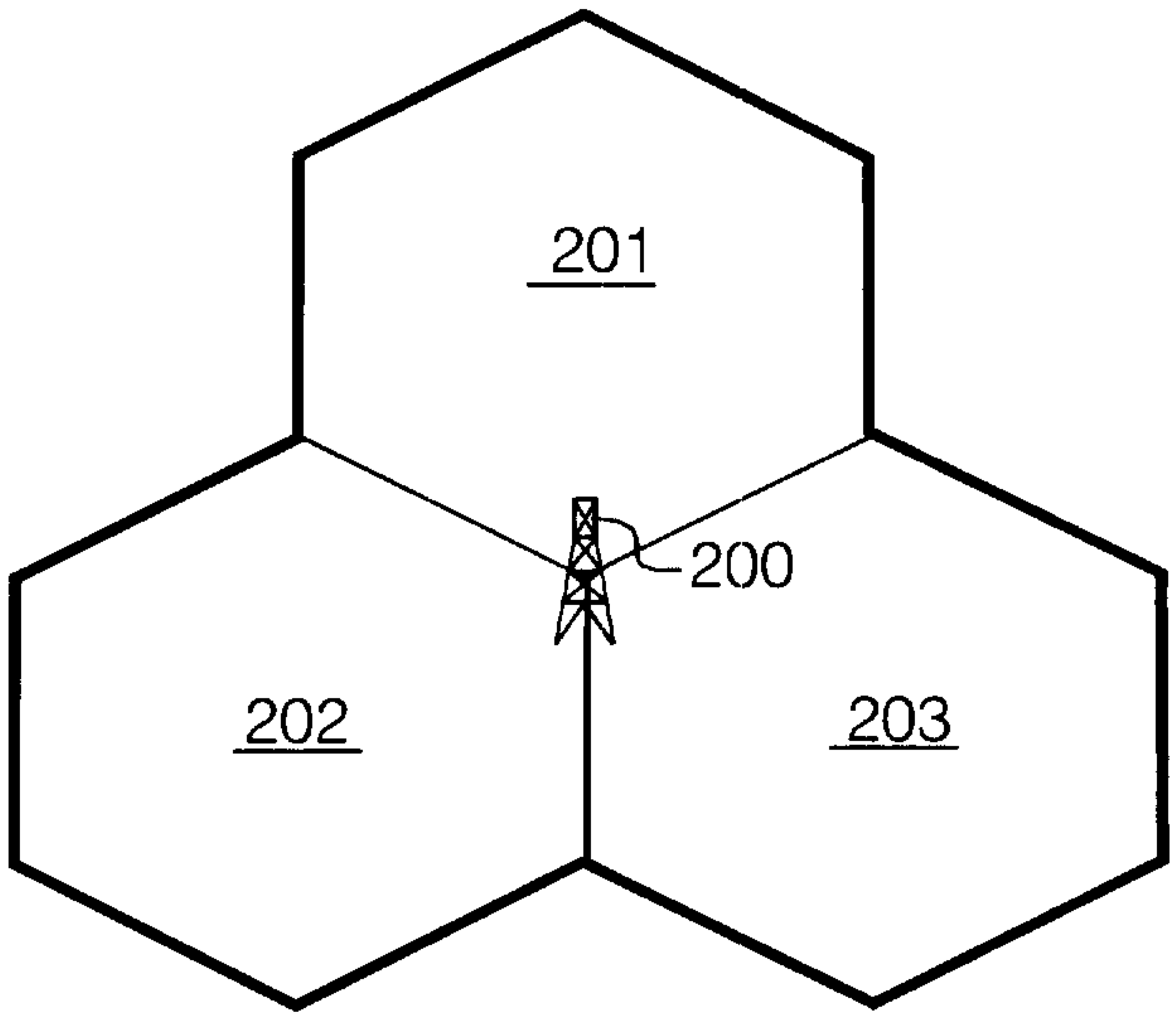


Fig. 2
(Prior Art)

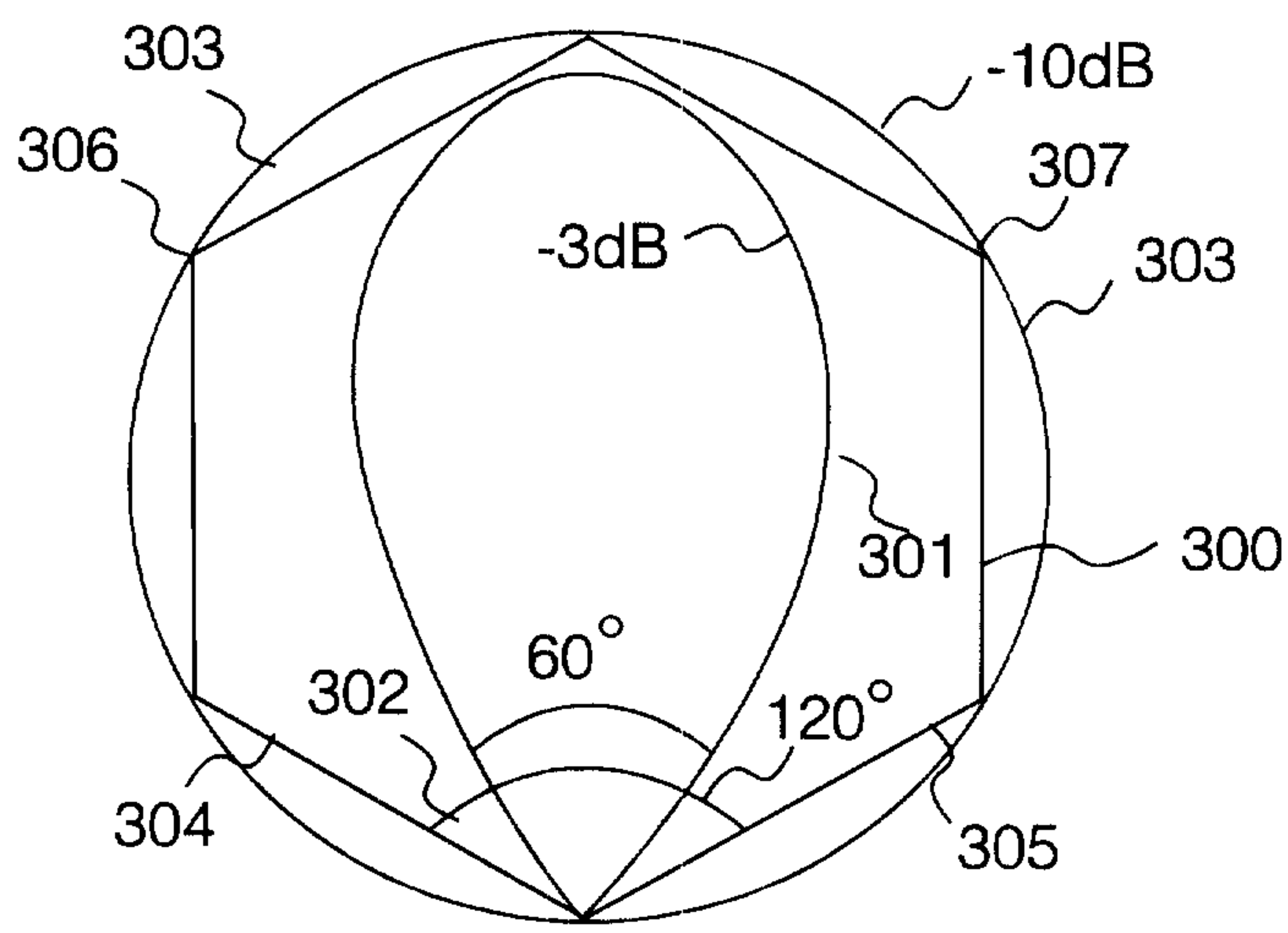
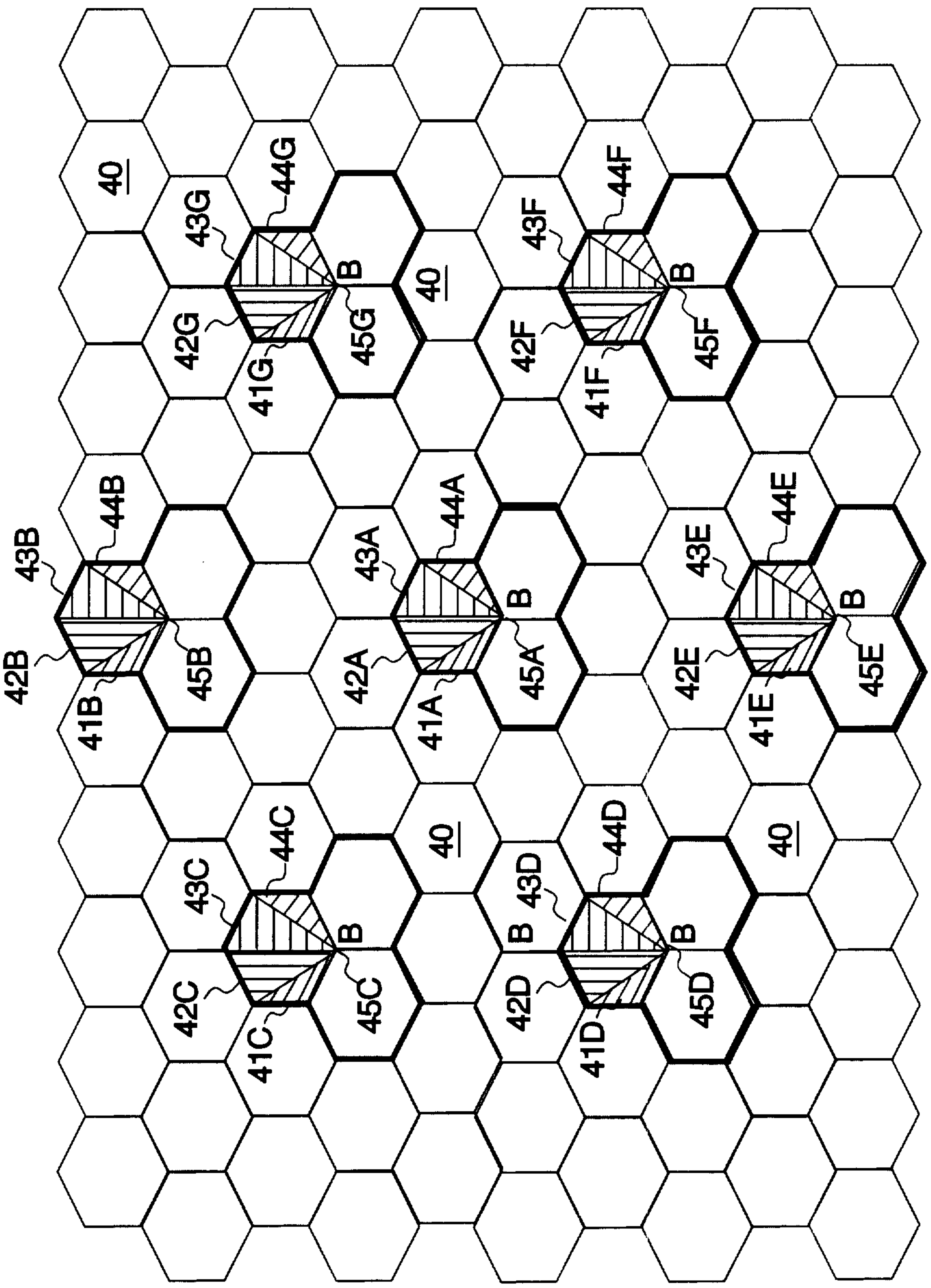


Fig. 3
(Prior Art)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41E
45E
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Fig. 4

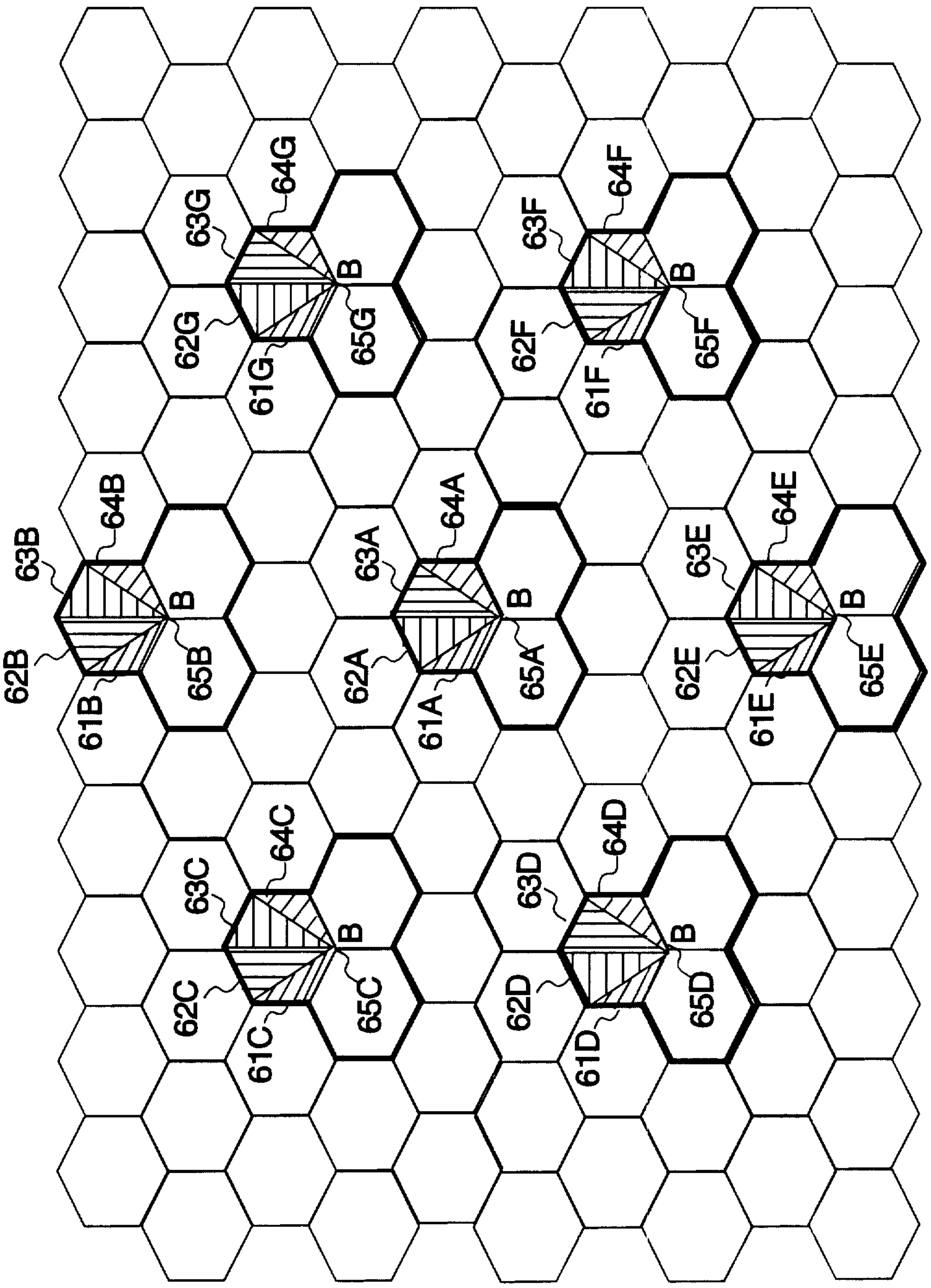
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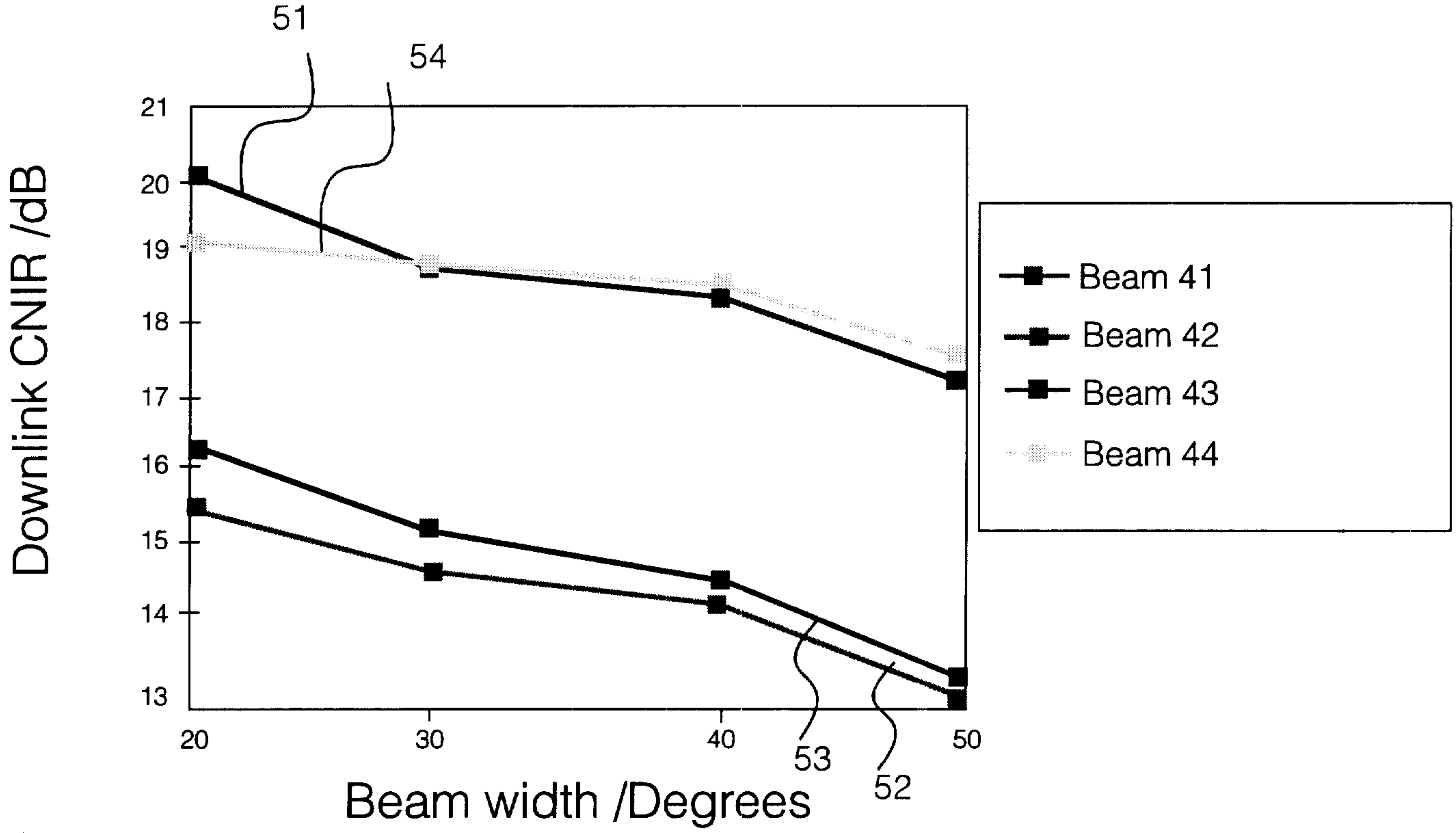
Fig. 6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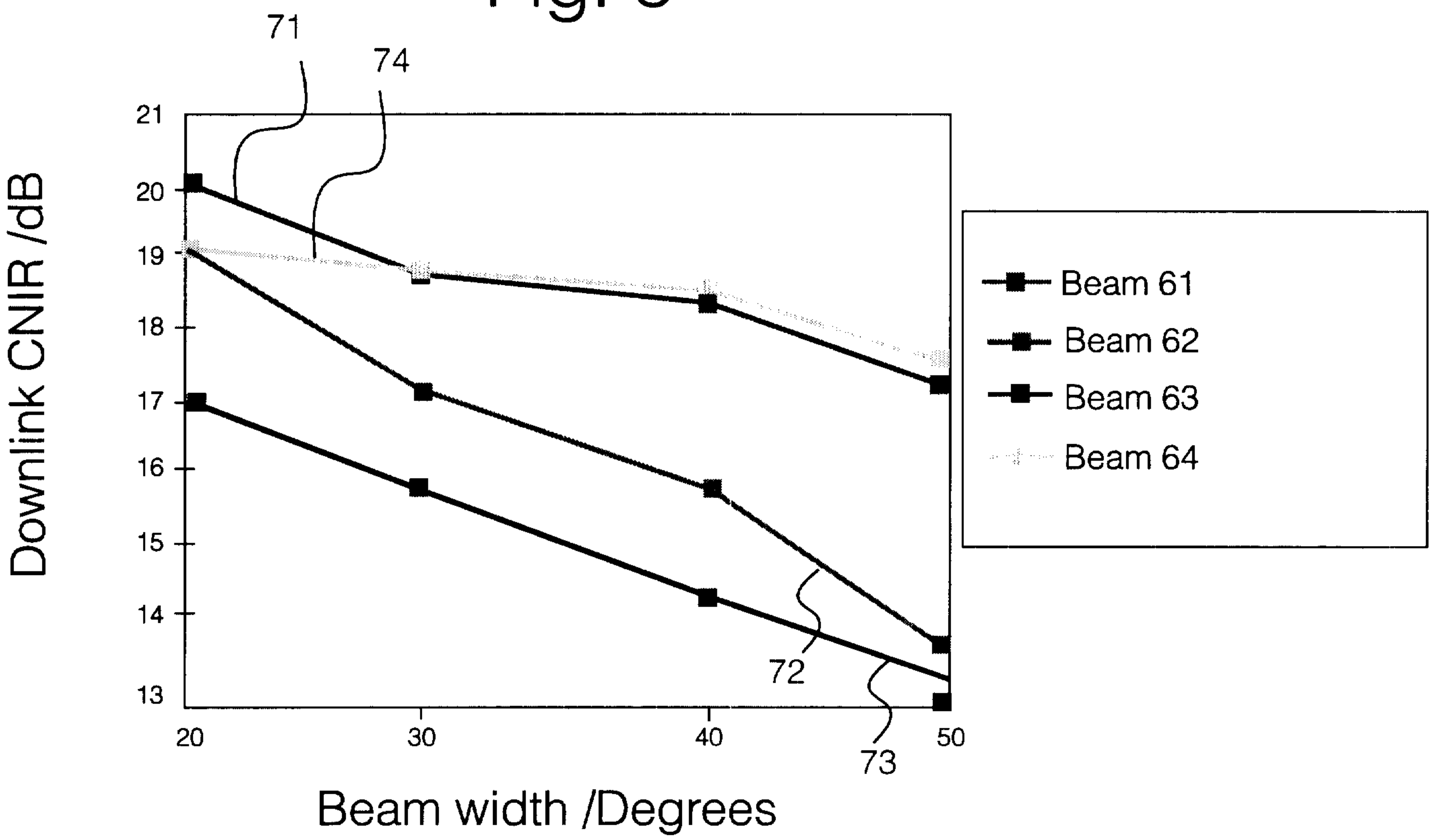
Beam width /Degrees
Beam 41
Beam 42
Beam 43
Beam 44

Fig. 5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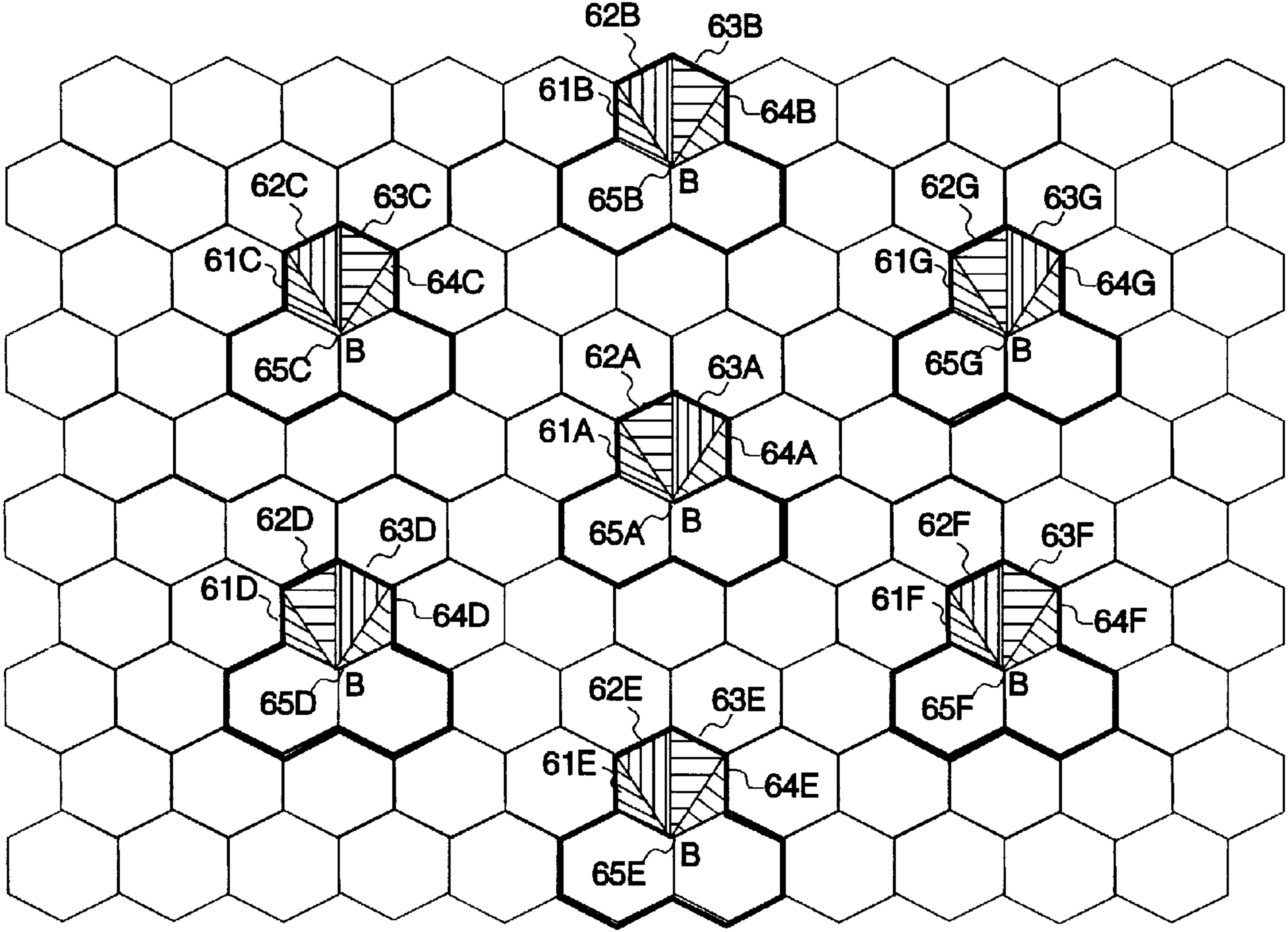
Beam width /Degrees
Beam 61
Beam 62
Beam 63
Beam 64

Fig. 7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