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Enhancing CDMA Network Capacity Using Adaptive Beamforming Technique

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Abstract- As the demand for wireless service increases, the number of channels assigned to a cell eventually becomes insufficient to support the required number of users. This has been a major concern for both the users and network operators. Every Communication network is required to offer a very high capacity within limited spectrum allocation. The allocated spectrum gradually becomes congested and eventually becomes used up. Congestion in the spectrum leads to increase in call blocking probability which is not desired in the system. There are many techniques available that can be used to enhance the capacity of code division Multiple Access Systems. Some of the techniques include cell splitting, acquiring additional spectrum, using directional antennas. These directional antennas seem not to be as smart as required, since they do not carry dedicated digital signal processors like adaptive antennas do. Omni-directional antenna which is believed to radiate signal in all directions consumes more energy because it radiates signal even where it is not required unlike adaptive antenna that radiate signal to where it is desired and as such consumes less energy. Adaptive antenna will be more efficient, since it is actually a combination of an array of individual antenna elements and dedicated signal processing algorithm. Such system can distinguish signal combinations arriving from different directions and subsequently increase the received power from the desired users. This work tends to improve the signal quality of Code Division Multiple Access by the use of Multiple Element Antenna consisting of sixteen (16) elements on 0.5λ wavelength separation distance. Based on this antenna variable and Least Mean Square (LMS) algorithm simulation of the performance of the system is carried out. Result shows that as offered traffic increases, the Cumulative Density Function (CDF) is constant initially from 5-6 users and drops to 0-2 users. When the number of arrays is kept constant and the distance of separation varied for the following 0.1, 0.5, 2 and 5 times the wavelength, it was found that antenna elements of half the wavelength (i.e. 0.5λ) was, however, the best performed of all the distance of separation. Element spacing of less or more than 0.5λ wavelength increases sidelobe which can interfere with mainlobe, its evident that it is possible to direct the Radiations maximum pattern for user position into desired direction, also direct a null for undesired interferences and sources. This work shows that adaptive antenna has powerful capabilities to reduce interference and sending data towards the wanted direction only, and it can be recommended in Base Station to ameliorate power problem, also in radio and astronomy.

Indexed Terms: CDMA, Antenna, Beamforming, Communication

I. INTRODUCTION

With the rapid increasing demand of cell phones users, wireless communication has become a very dynamic area of research due to the limited spectrum to accommodate many users. Multiple access schemes allow the network to maximize the number of users that can occupy a channel [1], [2] There are three multiple access schemes which are:

- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)

Each multiple access scheme aims at better use of the spread spectrum by allowing multiple users to share the same physical channel. FDMA assigns each user a frequency slot within the channel. This is the simplest multiple access scheme which needs no synchronization. Its disadvantage is that excess bandwidth cannot be reassigned to other congested users which lead to insufficient use of the bandwidth. Hence, FDMA is more suitable for users with relatively constant data. TDMA does this by assigning unique time slots to each user within the channel where users take turns transmitting and receiving one after another. It is very efficient and fast when the traffic is heavy because time slots are always filled. However, it has a disadvantage because it needs synchronization and central timing which makes it more complex. Users are also constrained to their time slots only. This is called fixed assignment TDMA [1],[2]. Latest researches have shown that there is a new technique where the large number of subscribers can be accommodated called on demand access TDMA. Borrowing from Miller [3], [4], each user allocated a fixed percentage of bandwidth can be allocated to the user on demand. This technique guarantees quality of service because it saves a slot of bandwidth. However, it achieves this at the expense of propagation time. It is more complex to implement due to its complex software and hardware.

CDMA cellular mobile systems find widespread acceptance particularly in regional centers where there are large geographical areas to cover. However, temporal changes of user density due to formation of congregated population centre's (called hot spots) can seriously undermine the system design goals in terms of Quality of Service (QoS) and system capacity. To improve on the capacity and coverage of CDMA cellular systems, several techniques have been deployed with some reasonable solutions. The related research presented in this study represents the various techniques that have been deployed to enhance mobile system capacity at various locations.

The author [3], [4] in their works, proposed the use of concentric circle geometry in the estimation of the capacity of multi-cellular CDMA system. They analyzed the system by asserting that once the interference effects of a single cell by the number of cells within the surrounding layer is specified, one can simply multiply the effects of a single cell by the number of cells within the geographical area. However, this technique tends to assume that all the cells that cover the geographical area are homogenous and of similar characteristics, which is not always the case. Hence, though this technique provides good analysis of the improved system, it cannot be applied in heterogeneous areas, where cells do not have similar characteristics and properties.

In the investigation of interference on CDMA network, [4] the researcher analyzed the effect of adjacent channel interference (ACI) on capacity in a hybrid TDMA/CDMA system using Time Division Duplex (TDD). Statistical approach on user distribution was used in the investigation. The results obtained shows that the level of improvement in the system capacity is dependent on the number of cells in the cell clusters within the area as it describes the number of ACI, which degrades the service quality.

Besides, [5], [6] summarize the effect of interference on cellular system by measuring the Carrier-to-Interference (C/I) levels of the system independently. This helps to specify the level of interference and its effect on signal quality of wireless network.

[6] Analyzed the effect of other cell (inter-cell) interference on the capacity of wireless network with special emphasis on the adjacent channel interference (ACI). The authors deployed power control technique in the reverse channel to reduce the interference in the system thereby increasing the channel capacity. The result shows a good success in the interference reduction. [7], [8] studied Adaptive and Switched Beam Smart Antenna System for SDMA schemes using 2-D Butler matrix method for switched beam and vector modular method for adaptive system in which their result shows that an increased beam steering capability gained in the adaptive system and satisfactory beam switching and steering capability is gained with the switched beam.

An appropriate resource allocation is also effective way of addressing the interference problem between M-BS and F-BS and it can be implemented either in a centralized or a distributed manner. A centralized scheme is discussed where a M-BS restricts F-BS from using an operating resource used by it, thereby reducing the downlink M-UE (user equipment served by a M-BS) interference [9]

Least Mean Square (LMS) is one of the simplest algorithms for adaptive processing; it depends on the Least Mean Square (LMS) error. It gives accurate results in many cases of beam forming. Beamforming is the act of bringing multiple antenna to receive a particular signal or using multiple antenna to transmit a particular signal. It possess low complexity algorithm that is stable with fewer computations. There are other algorithms that can be used for this study, but LMS algorithm will be considered owning to its low complexity.

Therefore in this research Least Means Square is used to get accurate result in terms of Beamforming.

The below equation explains the signal gotten from the antenna yield.

$$X(t) = \sum_{\ell=1}^{L} \alpha_\ell S(t-\tau) \mathrm{a}(\theta_\ell) + \mathrm{I(t)} + \mathrm{N(t)}$$

x(t) = signal arriving from the antenna cluster

l = length of array

l = time deferral

α_l = eigen value

S(t) = transmitted signal with complex path alternative

□e = angel of arrival

I(t) = different access obstruction

n(t) = complex valued additive while Gaussian noise

a(□q) = array response vector for multi path arriving at direction of arrival (DOA).

N = numbers of subscribers in a cell or a sector

II. DESIGN OF ADAPTIVE ANTENNAS

The methods employed in the simulation of a smart antenna-based communication system using MATLAB, the choice of simulations was considered in other to reduce costs, risks, and for performance improvement by the use of antenna arrays. During simulations, certain criteria must be met; these include ability to perform operations fast and determine the parameters of performance accurately. The basic antenna arrays were simulated, and program codes were written about the design variables and optimization were made with the help of the beam forming algorithm as designed.

A. Determination of Optimum Sepration Distance

Table 1 explains the determination of separation distance when number of elements was kept constant at four (4). The separation distance was varied from 0.1, 0.5, 1, 2, 5. Result shows that at 0.5 λ distance of separation the beamform got better.

Table 1: Characteristics of the Antenna as Separation Distance is Varied

Separation distance between element λ	Number of elements	Mechanical & electrical tilting	Beam width in (dB).	Antenna height (m)	Statement
0.1 λ	4	0	0 - ± 80	25	The beam width increase
0.5 λ	4	0	0 - ± 30	25	The beam width reduces
1 λ	4	0	0 - ± 20	25	Side lobe almost interferes with the main lobe
2 λ	4	0	0 - ± 20	25	Side lobe interferes with main lobe
5 λ	4	0	0 - ± 70	25	There was increase in interference between side and main lobes

Where λ is lamda.

The radiation pattern at different separation distances when the number of elements is kept constant at four (4) are depicted from fig.1 to fig5 below. In each figure, the diagram at the left is polar plot, why the one in the right is normalized radiation pattern.

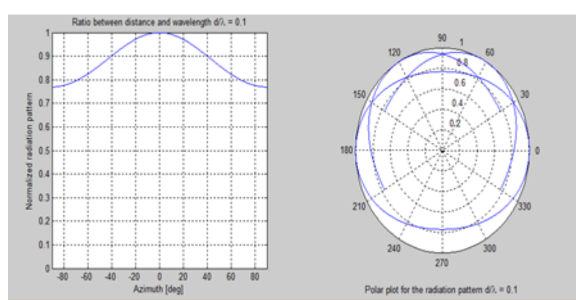

Figure 1: Plot of radiation pattern with 4 element array and separation distance 0.1λ

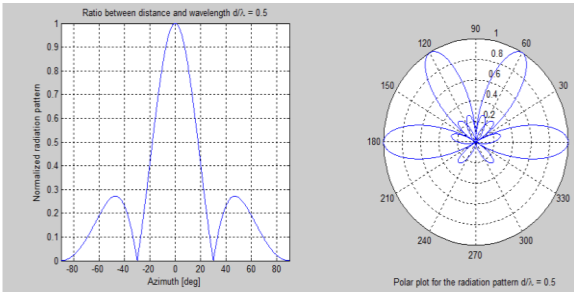

Figure 2: Plot of radiation pattern with 4 element array and separation distance 0.5λ

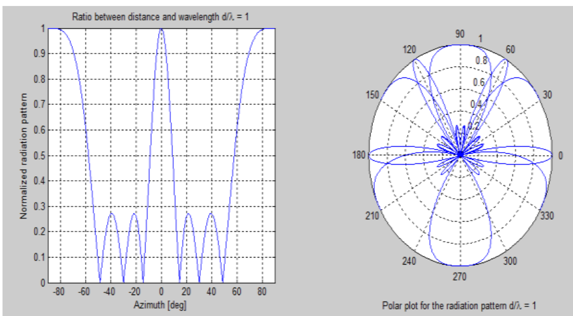

Figure 3: Plot of radiation pattern with 4 element array and separation distance 1λ

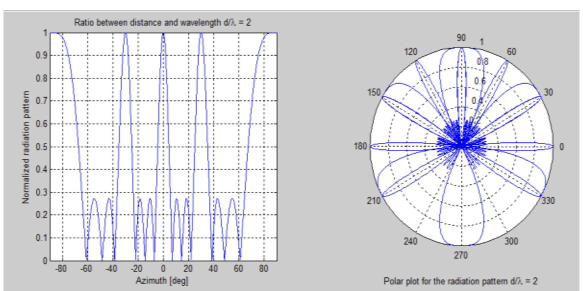

Figure 4: Plot of radiation pattern with 4 element array and separation distance 2λ

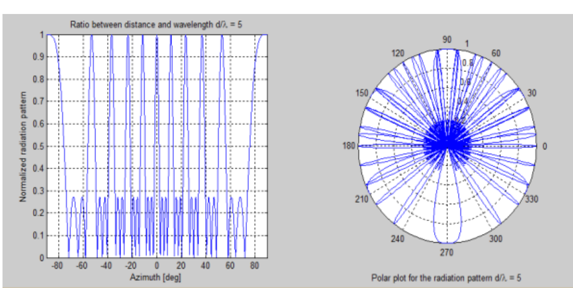

Figure 5:Plot of radiation pattern with 4 element array and separation distance 5λ

The deduction from these plot of different radiation patterns of table 1 shows that as the beam width reduces, more directed radiation pattern is achieved.

B. Determination of Optimum Number Of Elements

From the table 2 below, the element of the antenna was varied with separation distance kept constant at 0.5λ, result shows that Antenna element of 16 with separation distance of 0.5 λ is the best preformed of the distance of separation.

Table 2: Characteristics of the Antenna as Number of Element Varies.

Separation distance of element λ	Number of element	Mechanical & electrical tilting	Beamwidth in (dB).	Antenna height (m)	Statement
0.5 λ	*8*	*0*	*0 - ± 18*	*25*	Radiation pattern got a lot better when no of element increased
0.5 λ	12	0	0 - ± 10	25	The radiation pattern got narrower and more focused.
0.5 λ	16	0	0 - ± 5	25	The beam width reduces from 0 to ± 5, and is most directed to its desired user.

The radiation pattern at different number of antenna elements when the separation distance is kept constant at 0.5λ are depicted from fig.6 to fig8 below.

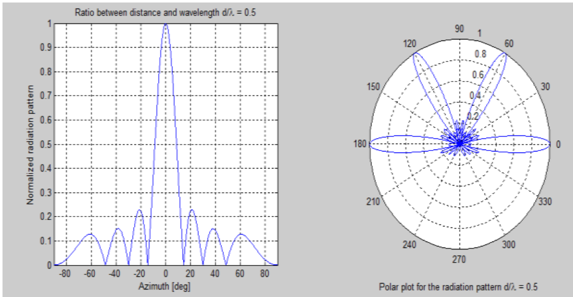

Figure 6: Radiation pattern when array element is 8 while the separation distance is 0.5λ

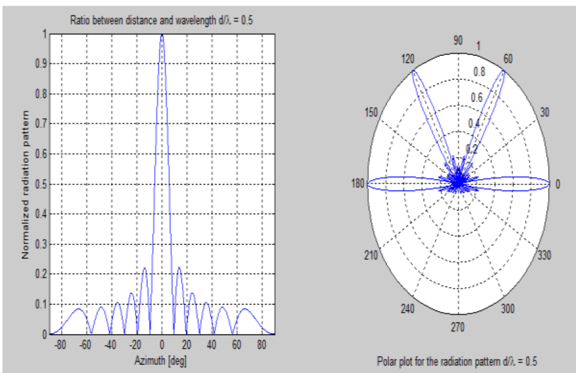

Figure 7: Radiation pattern when array element is 12 while the separation distance is 0.5λ

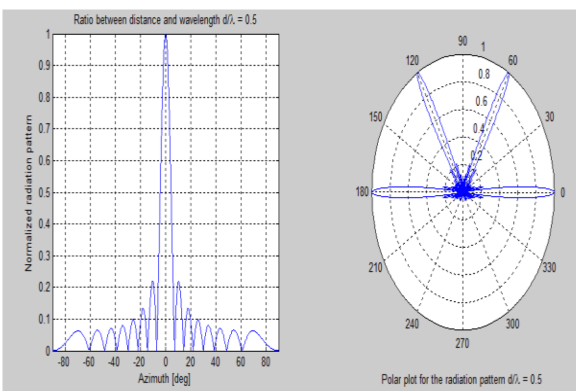

Figure 8: Radiation pattern when array element is 16 while the separation distance is 0.5λ

The deduction from these plots of different radiation patterns are explained in table 2. Above.

III. RESULT

Simulation results When b =5, m = 3, Gc= [1.0] for d/do = 1 are shown from fig9,fig10. From the mathematical model n = bmGc [Monte Carlos]

Where: Gc is the offered traffic per channel in the network, m = number of traffic channels available. b =number of cells. n=total traffic at a given time. This graph shows the Monte Carlos analytical simulation evaluation of the blocking rate, for b = 10, m = 5, Gc = 1.0 and d/do = 1.0. You can notice a sharp decrease as Gc, offered traffic increases.

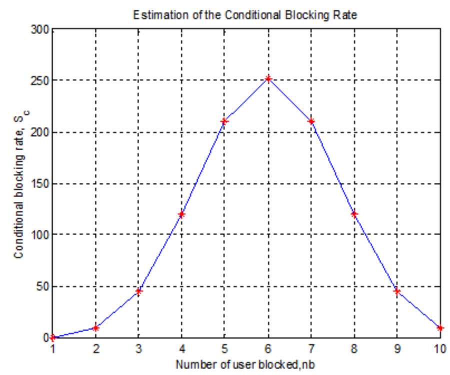

Fig 9: Conditional block rate against number of users blocked.

Figure 9: Conditional blocking rate and number of users being blocked is maximum when the cumulative block rate is at 250 and number of users blocked is 6

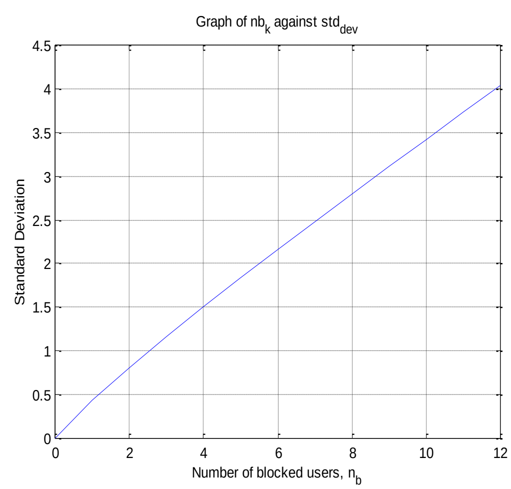

Figure 10: Standard deviation against number of blocked uses

Figure 10: This is said to be constant because it possess sign of proportionality to each other, that is standard deviation is almost proportional to number of users.

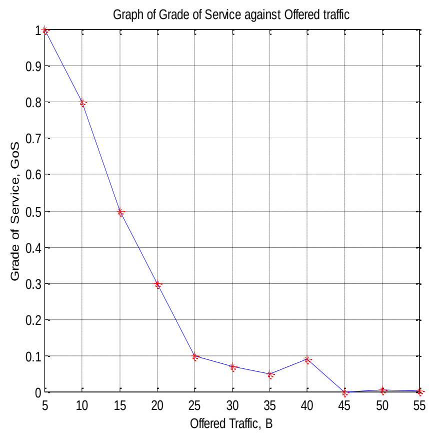

Figure 11: Grade of service against offered traffic.

Figure 11: Shows that increase in the offered traffic reduces the rate at which users are being blocked. When values for m and b are varied and Gc fixed at 0.4 For b =5, Gc = 0.4, m = 5

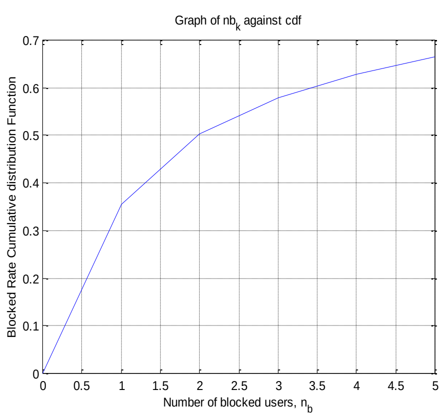

Figure 12: Block rate cumulative distribution function against number of block users.

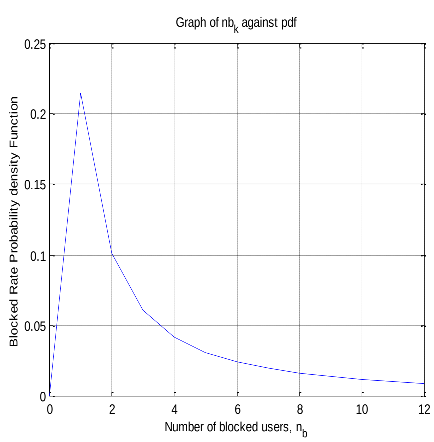

Figure 13:Block rate probability distribution function against number of block users

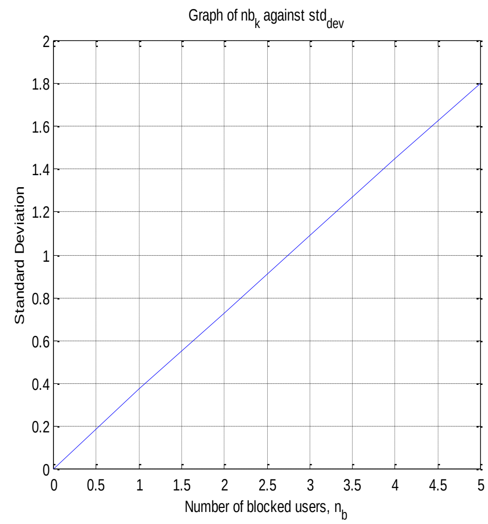

Figure 14: standard deviation against number of block users

From the graph of fig.12, fig. 13 and Fig 14, a proportional increase on users blocked was observed. Furthermore, blocked rate Cumulative Distribution Function (CDF), block rate Probability Distribution Function (PDF) and Standard Deviation (STD-DEV) were obtained and recorded. The result shows that the probability of a call being lost/blocked is 100% when number of traffic channel is (m=1). But when the number of traffic channel was increased to (m=5) traffic lost reduced, due to decongestion of the traffic making available several trunks. A significant improvement occurred in the capacity.

3.1 Probability Distribution Function (Pdf)

From the graph of figure 13, it was observed that the blocked rate Probability Distribution Function (PDF) was at peak when user was blocked. Then as the total traffic of a given number of user's increases, there was a sharp decrease in blocked rate, pdf. This means that as the value of offered traffic Gc increases, the likelihood that any user will be blocked reduced drastically.

3.2 Co-Channel Interference

As reviewed or shown in fig 8, Smart antennas have the ability to lower the interference level, by totally forming null to the angles of signal of not-of interest (SNOI) while forming beam to wanted signal of interest (SOI). This leads to total rejection of the interfering signal, increase the SIR and enable more users to be served (capacity increase). When both the transmitting and receiving antenna are of smart antenna system, multipath effect are remedied or eradicated, due to the fact that smart antenna system channel signals only in the direction of the signal of interest SOI, thereby reducing to its barest minimum the inter-symbol-interference, (ISI) and co-channel interference and or any other form of unwanted signal. This is done due to the ability of the smart antenna to dynamically adjust the gains and phase towards generating a radiation pattern that concerns itself to the signal of interest only.

3.3 Blocked Rate Cumulative Distribution Function.

From the graph of fig. 12, notice that blocked rate cdf, which is sum total of the blocked rate distribution function was uniform all through Gc = [0.4] which increases proportionally as block rate increases from 0 to 1 blocked user before increasing exponentially, a block user increases from 1–2. This is used here because it determines cumulatively total number of blocked users when Gc is 0.4.

3.4 Range Improvement

From the graphs of radiation patterns presented in figures 6, 7, and 8. It was observed that the central beam formed is towards the wanted signal course of arrival. This is because wanted signal has the strongest received signal strength (RSS) or signal power. And as the number of element array increases from 8, 12 and 16, the beam width reduces and a more directed pattern is obtained. This pattern means more range is covered and more energy focused towards the desired user only, thereby covering long range of distance and reduces interference. Due to the increased range, for mobile network scenario, cost of installing base stations can be reduced placing base stations farther from each other. This is helpful Base on simulation process and results, its evidence that it is possible to direct the radiations maximum pattern for user position into desired direction, also direct a Null for undesired Interferences and sources. Smart antenna system technologies had been studied as concept and its uses in communication systems. Using MATLAB computer simulation, we have seen that smart antenna has powerful capabilities to reduce interference and sending data towards the wanted direction only.

3.5 Capacity Enhancement

In urban areas, the main source of interference is signal from other users; Smart antenna simultaneously raises signal level of the useful or desired signal and lowers the interference level. This can be seen in the polar plot of fig.8, it raises useful signal level, increases the signal-to-interference level, SIR and enable more users to be served. Serving more users implies enhanced capacity (capacity increase).

IV. CONCLUSION

This work was realized by employing the LMS algorithm in the study of Smart Antenna behavior regarding beam forming and desired signal tracking technology. Simulation of antenna arrays (smart antenna) using smart signal processor to identify algorithms such as direction of arrival (DOA) of the signal, also using it to calculate beamforming vectors and directing the antenna beam on the user/target in order to achieve enhancement of capacity, range improvement and reduce interference were carried out. A study of smart antenna system concept along with system simulation using MATLAB was achieved by providing step by step process of communication system using an array factor pointing towards the desired direction.

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