Optimize Cellular Network Performance Using Phased Arrays

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Abstract. In conventional telecommunication systems, the base station does not know the user equipment location; it broadcast in all directions to fully cover the entire cell area. This represents power waste in addition to transmitting the signal in directions where users do not exist, which seen as interference for co-channel cells. This reduces SNR that limits the capacity and impedes the use of the spectrum effectively. This consideration led to the use of smart antenna (SA) technology that uses the Space-division multiple access (SDMA technique, Based on extracting spatial data for users within the network. In this work, Phased Arrays are used to improve the performance of the GSM network in terms of (decrease power, raise coverage, increase capacity, reduce co-channel interference) with the comparison to conventional antennas. Simulation has studied and realized using Matlab, simulation results, and performances have presented. Introduction.

Keywords: SDMA, GSM network, smart antenna, DOA, phased arrays.

1. Introduction
Smart antenna (SA) suggested that wireless systems are a significant development that improves the performance of wireless networks. A smart antenna is an antennas array connected to a signal processor to the transceiver in an adaptive technical, i.e., adaptively directing the radiation pattern towards the signal established in response to the signal circumference [1]. The smart antenna multiple beams can be routed to track many mobile phones, expand range Coverage, and raise the capacity of the channel and increase user capacity by effectively and efficiently constriction the scattering, multi-path, and co-channel interference and thereby improve the data rate and spectral efficiency [2].

The structure of the smart antennas illustrated in Figure 1 [3]. The digital signal processor interprets incoming data by antenna array elements. Calculates the complex weights (phase information and amplification) and multiples/weights for each component output toward improving the radiation pattern. This improvement based totally on a specific norm, which r the interference, then maximizes the gain in the desirable orientation. Therefore, for computing and updating the optimum weights, several adaptive beamforming algorithms made to improve the signal to interference - plus - noise - ratio (SINR) [4].

Beamforming defines the application of load on the antennas array inputs to direct the pickup of the antenna array in specific orient, named by the search-direction or the main-lobe. Beamforming technologies boost the sound capture quality by using the signal diversity in the received side by the microphone-amplifier array depend on the location of the obstruction with the source.
SA categorized into two types. One is switched beam, whilst the different is an adaptive array system. The switched beam system makes use of more than one fixed beams to serve the user in desired directions. In this base, the station switches between several beams and selects the one who affords the great overall performance and accuracy as the mobile user adjustments its position via cell [1].

The switched beam system uses multiple arrays. In the case of phase-shifting network multiple beams used to search for desired signal in a specific area, and the logic controller used to control the selection of the beam, which governed by an algorithm. Based on the detection of the detector, this algorithm decides and selects the strongest signal. However, this technique is less [5].

**Figure 1** Smart antenna structure [1]

**Figure 2** smart antenna concepts (Senapati & Roy, 2016).

- Phased arrays or multibeam antenna
It consists of several selectable beams; each beam covers a specific part of the cell area. The antenna beam system detects the signal strength and selects the strongest signal from the pre-determined signals, the antenna beam switches from one to another as shown in Figure 2 [6].

- Adaptive antenna arrays

The beam digitally configured, the radiation direction automatically changed to be able to track the user and cancel interference. Thus maximizing SINR that will help them cope with multipath scattering by changing their radiation pattern [7]. In general, it identified that the framework beam antenna structure achieves a lesser amount of performance benefits but requires a smaller amount of hardware complexity and less arithmetic time compared to the adaptive array antenna geometry design [8], as shown in figure 3.

![Figure 3 adaptive antenna array](image)

The limitation factor in wireless communication system is the interference that reduce the overall capacity of the system. The system capacity increased by adding new cells and equipment’s to the geographic area but this is costly and inefficient because it produce extra interference in the network. Thus new techniques are becomes an urgent need.

In this paper SA systems are utilized to:

- Decrease the co-channel interference of the system and increased C/I for the whole system.
- Increase the capacity by introducing the SDMA technique that increase the capacity by a factor of 8.
- Reduce the transmitted power and increase the coverage of the network.
- Improve the overall performance of the network.

2. Literature review

[10] The proposed Smart antenna with adaptive radial modulation and multiple access technologies can include coverage without loss of communication over a long space. The main objective is to find the direction of arrival (DOA) of the signal received from the fishing vessel moving at a constant speed for the adaptive orientation of the antenna beam.

[11] Users of wireless networks face the problem of capacity of the system due to the increase in the number of users, and the transfer problem is complicated and challenging due to noise and multipath and battery life of phones. Using the system of the multi-input antenna (MIMO) to improve the state of the system increase and efficiency antennas at the same time, it provides less energy which leads to the longevity of battery phones.

[12] The qualifying sheet in this paper shows adaptive antenna this will improve the system and work efficiently at the same time while reducing the energy required for transmission, which provides perfect overall performance at a lower cost.

3. Result and Discussion
3.1. Increase the coverage
The first enhancement the smart antenna offer to the GSM cellular network is improve radius range of the base station or cell by take advantage of the high gain provided by the antenna array. To illustrate the improvement in coverage compare the range of the base-station obtained by using conventional antennas (120-degree sector directive antenna with different gain (17-12-10)), to the range obtained by using smart-antenna with different number of beams per sector as shown in Figure 4. That the range obtained by SA increased as the number of beams (elements) per sector increased.

![Figure 4](image.png)

**Figure 4** Increase the range using smart antenna instead of directive antenna with different gain.

In Figure 5 the percent increase in coverage is obtained, it can be noticed that by using 20 elements per sector the coverage extends approximately 110%.

![Figure 5](image.png)

**Figure 5** enhance the coverage using smart antennas

3.2. Reduce the transmitted power
Smart antenna (base station) array in height gain used to reduce the entire transmitted power when keeping the range constant as shown in Figure 6. If the range of the cell remain constant and with M-element base station antenna array, the output power from amplifier is reduced by $M^{-2}$ and the total output energy lessening by $M^{-1}$. As well as mobile can lessening its transmitted energy by $M^{-1}$ since the array gain will be added more efficiency and thus increasing the battery life.

![Figure 6 Reduce the Transmitted Power using Smart Antenna](image)

3.3. Reduce co-channel interference and increase Carrier to Interference ratio (C/I)

Most of the antenna in base stations have omnidirectional or sectored. Regarded as a “waste of power” as well as the power radiated in all directions will be encountered as interference by other users since GSM cellular network is interference-limited; this will have led to inefficient use of spectrum as well as reduce the capacity of the system. To solve the problem by using smart antenna will be an optimum technique to reduce interference. By using the smart antenna, it reduces the interference by tow strategy:

- reduce the interference by decreasing the gain in the direction of interfering mobile units; this technique refers to the abbreviation “spatial filtering for interference reduction” (SFIR);
- Reduce interference by use switched smart beam antenna with several beams directed toward the mobile phone. in this case, the interference reduced by $M^{-1}$.

The interference by using a conventional antenna the interference by using conventional antenna. $I$ give by

$$I = \sum_{i=1}^{m} \frac{\alpha}{D^\gamma} \quad \ldots \quad (1)$$

Where $D$ is the minimum distance to reuse the frequency, $\gamma$ is the path loss exponent variant between 2&6 depending on the area, $\alpha$ is a constant. $m$ Is the interfering cells number, assume cell radius remains constant. The transmitted power stays constant and hence $\alpha$ is consistent for all cells i.e., interference is in depended on the transmitted power.

To illustrate the reduction in interference using a switched beam smart antenna. A comparison was made between the interference result obtained by the conventional (directive antenna) of a base station with (3& 6) sector respectively at the worst case with (N=7 & 4) where N is the number of cluster size as given by the following equations. Where the cell radius, $\sigma$ is a constant, and the interference result obtained by using a smart antenna with (M) Number of beams per sector, as shown in Figure 7.
Figure 7 Reduce co-channel interference and increase C/I ratio

For, N=7&3 sectors

\[ I = (D + 0.7R)^{(-3)} + D^{(-3)} \] ............................. (2)

N=7&6 sectors

\[ I = (D + 0.7R)^{(-3)} \] ............................. (3)

N=4&3 sectors

\[ I = (D + 0.7R)^{(-3)} + D^{(-3)} \] ............................. (4)

N=4&6 sectors

\[ I = (D + R)^{(-3)} \] ............................. (5)

\[ \sigma = D/R = \sqrt{3N} \] ............................. (6)

\( \sigma = 4.6 \) for N=7, \( \sigma = 3.46 \) for N=4.

When M=1, i.e. (conventional antenna) and the interference reduces as the number of beams (M) per sector increased, i.e. (smart antenna). From this, the ability of a switched beam smart antenna to reduce the interference in the channel and increase the C/I ratio.

3.4. Increase the capacity

System capacity increased by adding new cells and equipment’s, but this is costly and insufficient because it produces further interference in the network. The demand for increased spectrum efficiency has become challenging, to achieve an intelligent system with self-configuration systems that are highly efficient and cost-effective and certainly taken into consideration. A smart antenna system in telecommunication generation is possible today; this allows introducing the SDMA technique that can increase system capacity [13]. There are two methods to improve the system capacity as explained below-

3.4.1 Reduce Co-channel Interference

Co-channel interference can be reduced by allocating low gain in the interference direction and this is referred to as SIFR, that help in reduce the distance of the frequency reuse and reduce cell size [14]. So, more channels allocated to each cell, however, this technique requires new frequency planning associated with different cells.

3.4.2 Spatial orthogonality

Smart antenna system adopts the technology of space division multiple access (SDMA), which differentiates Frequency and time use the same signal slot [13]. A new orthogonality produced among various signal sources in addition to the conventional orthogonality (FDMA, TDMA, and CDMA) this is called spatial orthogonality. Where the physical channel allocated to multiple users simultaneously and if the arrival angles are separated enough. The result is a rise in the number of channels available, since multiple users can share the same physical channel, and this is called Spatial Multiplexing Gain.
It is related to the number of antenna array sensors, SMG can reach a maximum value of 8. The capacity of the mobile communication system measured in ch/square km [2].

\[
C = \frac{BW}{A \cdot B \cdot N} \quad \text{........................................ (7)}
\]

Where:
- \( C \) the capacity of the system
- \( A \) the area of cell (Km)
- \( B \) the bandwidth of channel
- \( BW \) the bandwidth of the communication system
- \( N \) the number of cell in one cluster

With use SDMA technique and if the number of spatial channels for each physical channel is SMG then the capacity will be

\[
C = \frac{SMG \cdot BW}{B \cdot N \cdot A} \quad \text{........................................ (8)}
\]

Which means that the capacity can increase by a factor equal to SMG. The SMG value can be considered equal to 4, thus increasing the capacity again by factor 4, in any case reasonable.

To illustrate the increase in capacity obtained using the smart antenna with SDMA technique. A comparison made between the capacity received by a conventional antenna at a cluster size equal to 4&7. The capacity obtained by a smart antenna with a different number of spatial channels (SMG=2, 4, 8) for each case as shown in Figure 8. That the capacity increased as the area decrease, and the capacity can maximum increase by a factor of 8.

![Figure 8 Increasing the Capacity using Smart Antenna](image)

4. Conclusion

In this work, SA technique was used to improve GSM cellular network performance in terms of (reduce power, increase coverage, reduce co-channel interference, increase capacity), with comparison to the system performance using conventional techniques. Matlab has used to simulate the result. It found that by use SA: Coverage can be increased by taking advantage of the high gain provided by the antenna array, with M=4 per sector, the coverage increased by about 40%. Maintaining the same range is reducing the power of the amplifier by M-2, and M-1 reduces the overall output power. The co-channel interference is reduced by M-1 and the C/I ratio increase by M. This interference reduction increase the capacity either by reducing the frequency of reuse of distance and cluster size or by allocating a common physical channel among multiple users. Which means that capacity can increase by a factor equal to SMG. A value of SMG equal to 8, can increase the capacity by a factor of 8, from all these results, it
can be concluded that the introduction of SA technology to the wireless communication system becomes an urgent need.

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