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Advancements in GSM Technology Using Smart Antenna: An Overview

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ABSTRACT
In this paper, we discuss about the problems facing by GSM technology and how a smart antenna system can efficiently counter these problems. Here we present an overview about smart antenna system and how it can be used to eliminate or reduce the problems which limits the performance of GSM. We show here the potential improvements like range extension, multipath diversity, interference suppression, capacity enhancement and increment in data rate.
Keywords- Adaptive array system, beam forming network, diversity, fading, interference, switch beam.

I. INTRODUCTION

The performance of GSM is limited mainly by four major problems. First is the multipath fading (Fig 1). In this the information signal propagates through different paths. One signal arrives as a direct signal while other signals as multipath signals. Indirect signals are generated due to reflection, refraction or diffraction of signals by the objects lie in between transmitting antenna and receiving antenna. The signals from these paths add with different phases, resulting in a received signal amplitude and phase that vary with antenna location, direction, and polarization, as well as with time [1].

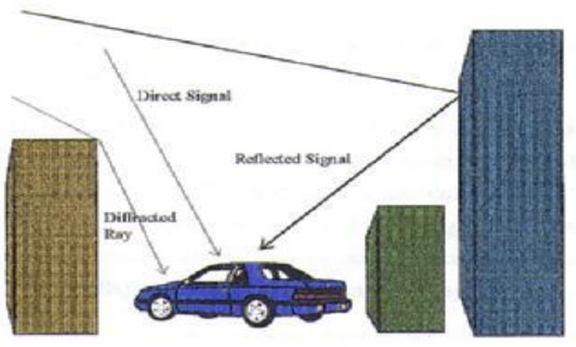

Fig 1: Multipath Fading

Second is the delay spread, which is the difference in propagation delays among the multiple paths. When the delay spread exceeds about 10 percent of the symbol duration, significant inter symbol interference can occur, which limits the maximum data rate.

The third major problem is co-channel interference. To increase the system capacity the concept of frequency reuse came into existence. Although it helped in solving the problem of scarcity of spectrum but its main disadvantage is co-channel interference. Frequency reuse implies that there are several cells that use the same set of frequency in a given coverage area. These cells are called co-channel cells, and the interference between signals from these cells is called co-channel interference [2].

The fourth problem is the limited availability of spectrum. One of the most important challenges with respect to wireless access is the limited capacity of the air interface which is due to the fact that the available transmission bandwidth is finite. Since the number of wireless subscribers is still growing rapidly and the desire for higher data rates is rising – partially due to an ever growing popularity of the Internet – a more efficient use of frequency resources is inevitable to meet future capacity needs.

Although techniques like cell splitting and sectorization are used to increase the capacity of the system but still the optimum solution is not achieved. Cell splitting improves the capacity by decreasing the cell radius R and keeping the D/R ratio unchanged; D is the distance between the centers of clusters. The main disadvantage in this is the enhancement in the cost by installing new base stations and increasing the handoffs (the process of transferring communication from one base station to other). In sectorization omnidirectional antennas are replaced by directional ones, thus reducing the interference. But in this no solution is provided for the capacity problem. So in order to overcome these problems the concept of smart antenna system is introduced.

II. SMART ANTENNA SYSTEM

A smart antenna (Fig 2) is an intelligent system consists of digital signal processor, along with antennas which make the system smart. Smart antenna systems are basically the extension of the concept of sectorization of cells in which the sector coverage is composed of multiple beams. This is achieved by the use of antenna arrays and number of beams in sector is the function of geometry of array. As smart antennas can focus their radiation pattern towards desired users while rejecting the unwanted signals, they provide greater coverage area for base station [3]. Smart antennas have the unique capability to reconfigure their radiation pattern so that they can obtain the most favorable response as per propagation conditions or the position of mobile user in particular moment. Smart antenna usage at base station allow us to find the location of each mobile offering not to transmit the energy specifically towards the intended user but also to reject co-channel interference, which limit the system capacity [4].

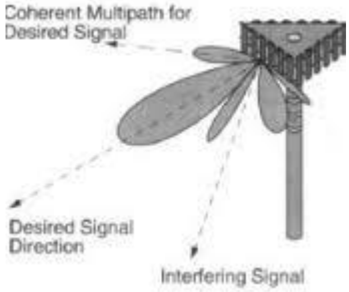

Fig 2: Smart Antenna

III. SMART ANTENNA TECHNIQUES

3.1 Switched Beam System

In this a smart antenna system has the ability to choose from many predefined patterns in order to increase the receiving signal. This is basically the extension of cell sectoring as sector is divided into smaller sectors. As mobile moves from one place to another, the switched beam system detect the signal strength, choose from the appropriate predefined beam and continually switches the beam as per requirement. The main aim of this is to increase the gain as per the user's location.

Although this is not the optimal approach switched beam system the ability to use spectrum more efficiently than conventional antenna system, resulting in increased capacity. For an array of M elements resultant beam formed gain is given as

Array Gain = $10\log_{10} M$ dB

M= 4

Array Gain = $10\log_{10} 4$ = 6 dB

Now if existing 120˚ sector antenna has +14 dB gain then using four element in beam former will be 14+6=20 dB using a fourth power.

Increase in antenna gain allows base station transmit power to significantly be reduce by a factor of four, as well as the mobile can lower its transmit power (at the same range) by a factor of four, since 6 dB of gain is added to the receive capability. These result in significant increase in battery life and overall electrical power cost savings.

Another very practical benefit of the switched beam smart antenna is in interference reduction. A 120˚ cell sector with a 30˚ beam steered towards a desired signal. The two interferes that would have seen by the original 120˚ sector antenna are not within the beamwidth of the desired signal. These interferers are, therefore, reduced in power to the receiver by the amount of the array gain, or 6dB (for M=4). There is a one-in four chance that an interferer in a 120˚ sector will be in the desired beam. In the statistical sense, the four- beam per sector system reduces the interference level roughly by a factor of four [5].

3.2 Adaptive Array System

These systems possess the ability to adapt in real time the radiation pattern to RF signal environment. They are characterized by the property that they can direct the main beam towards the signal of interest while suppressing the antenna pattern in direction of interference. Adaptive array system can locate and track signals (interferers and users) and dynamically adjust the antenna pattern to enhance reception while minimizing the interference using signal processing algorithms.

For adaptive array system the signal adaptive processor is necessary. The smart antenna adaptive array system is based on temporal references. These antenna employ training sequence code as a reference signal, in order to dynamically optimize and shape the radiation pattern. The reference signal is used by adaptive algorithm to update the complex weights of array, in such a way that combination of signal in each element of array, turns out a output signal as similar to reference signal as possible minimizing the mean square error between signals [6].

The adaptive antenna array processor is based on direction of arrival (DOA) estimation. It consists of four main parts:

- DOA estimation. From the received input data in uplink the number of incoming wave fronts and their DOAs is estimated.
- DOA classification. In a next step we identify those wavefronts that are originated from the user: First, we extract from the input data, with a spatial pre-filter, the spatially resolved wavefronts, each incident from an estimated DOA. Then, a user identification decides whether a wavefront (DOA) belongs to a user or to an interferer.
- Tracking: The user's DOAs are tracked to increase the reliability of the DOA estimates.
- Signal reconstruction – beam forming: Finally a beam forming algorithm forms an antenna pattern with a main beam steered into the direction of the user, while minimizing the influence of the interfering wave fronts [7].

The most important feature of the adaptive array is its ability to reconfigure the radiation pattern in order to refuse co-channel interferences, forming nulls in the directions of these interferences, while maintaining an optimum response in the desired user direction. To achieve this, the adaptive algorithm must use the typical training sequence codes of the wireless communication system (fig 3).

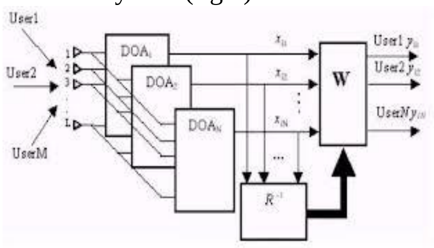

Fig 3: Adaptive Array

3.3 Space Division Multiple Access

To tackle the problem of scarcity of spectrum SDMA technique is used by smart antenna system. The SDMA enables to locate many users creating different beams for each user. This means that same physical communication channel is allotted to different users simultaneously with only an angle separation.

The demand for wireless communication capacity is permanently growing. Not only is the number of mobile subscribers ever increasing, additionally higher data rates are needed for applications such as wireless Internet access. In order to meet the future capacity requirements and keeping in mind that bandwidth is a scarce resource it becomes increasingly important to use the frequency spectrum as efficiently as possible. In order for various users to communicate over the air interface with a base station simultaneously multiple access schemes are needed.

However, the space domain has not been exploited within a cell so far. Base stations equipped with adaptive (smart) antenna arrays use beam steering as compared to omnidirectional or sectorized single antenna systems. Thus, it becomes possible for base stations (BS) to radiate in a specific direction to specific users on the down-link as well as receive directed on the up-link. This helps in reusing channels within a cell for mobile stations (MS) which are spatially separable by the smart antenna array. This gives an additional orthogonal multiple access component called Space Division Multiple Access (SDMA) which can be used [8].

In a smart antenna system, one user's signal must be considered as other users' interfering signal. In downlink processing, SIR equals the antenna's transmitting power from one user' radiation pattern over the total antenna's transmitting power in the same direction from other users'. A mimetic algorithm is used to adjust the phase shift and amplitude weights based on the power of the array in the desired directions and in the interfering signals' directions. The goals are to minimize the total output power of the interfering signals and maximize output power of the desired signal to each user. During the process of mimetic iteration, the weighting vector kept for the next step iteration should make the output power of the desired signal to be increased and the output power of the interfering signal to be decreased monotonically. So, the memetic algorithm is applied to find the weighting vector of the proposed smart antenna by using the two-way convergent method. Obviously, this technique can maximize the signal to interference ratio (SIR). Then, the (SDMA) optimization of smart antennas can be achieved [9]-[11].

IV. ADVANTAGES OF USING SMART ANTENNA

- The most important reason of employing smart antenna is capacity increase. It helps in limiting the interference i.e. it keep signal to interference ratio much smaller than signal to noise ratio.
- It helps in enhancing the gain of signal of interest and suppressing the interfering signal.
- It increases the range as compaired to omnidirectional and sectored antenna.
- It adds up security to users' information as these are less prone to detection.

V. CONCLUSION

In this paper various problems related to GSM technology is being addressed. Their effects on the quality of signal, range and capacity is also considered. Then with the usage of smart antenna system it is being shown that how these problems can be tackled. Here various techniques of smart antenna system is being analyzed which help in improving gain, range, capacity and quality of signal. It is also being addressed here how to mitigate the effects of fading and interference can be reduced by using smart antenna.

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