Performance appraisal of Smart Antennas System for Next Generation Wireless Communication

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Abstract — The limitations caused by the antenna system on the cost, quality and performance of the wireless communication have left the world to develop antenna system which is much more prominent and efficient in performance. The smart antenna systems are efficient than the existing 3G antenna systems as they can track the location of the mobile user, and transmit the signal at its maximum strength in the direction of the user increasing both the quality and range. The Smart antenna systems also increase the channel capacity through spatial diversity. This paper evaluates the characteristics of the Smart Antennas and its comparison with conventional antenna system used in 3G with respect to interference response, data rate support, cost, efficiency and range. A MATLAB simulation is also presented to show the effects of phased array smart antennas.

1. Smart antennas

Smart antennas are also known as adaptive array antennas or the 4th generation antennas. These are known as smart antennas because they follow smart signal processing algorithm which are capable of identifying the signal signatures such as direction of arrival (DOA) and this is further used to calculate the beamforming vectors. This beamforming vectors have the ability to track and locate the antenna beam on the mobile device.

Smart array antenna systems have the ability to monitor the user continuously and it can divert its beam pattern as per the requirement, that is, it can rotate its beam pattern as the receiver’s location is changed. This causes the maximum power transfer to be in the direction of the user.

Smart antennas utilize the services of the multiple antennas to increase the signal reliability. However, it is not an easy to achieve task. In order to achieve this task, the smart antenna base station has an array of antenna along with a control unit so that to divert the beam pattern of the smart antenna array systems according to the requirement. There are certain types of antenna diversity system which includes adaptive processing technique which is based on switched/selection, equal-gain combining and maximal ratio combining. There are several antenna techniques which are used in conjunction with the antenna processing diversity. This includes spatial diversity which is based on multiple antennas, pattern diversity which utilizes the services of the co-located antennas, polarization diversity which uses dual antenna system and transmit/receive diversity which uses separate antennas for transmission and receiving. Smart antennas have the ability to be operated in the forward or the reverse mode both with single and multiple users. The smart antennas utilize different kind of sampling techniques and signal suppression. Smart antennas are versatile enough to be operated in the TDD (Time Division Duplex) and the FDD (Frequency Division Duplex). [4]

1.1 Direction of Arrival estimation

There are many techniques used to estimate the Direction of Arrival (DOA) of the signal to the smart antennas. This includes Multiple Signal Classification (MUSIC) and Estimation of Signal Parameters via Rotational Invariant Technique (ESPRIT) algorithms. These techniques are based on finding the spatial spectrum of the antenna, and then the peaks of this spatial spectrum are used to determine the DOA. [4]

1.2 Beamforming

There is a concept of beamforming in smart antennas. The beamforming is used to determine the radiation pattern of the smart antennas. The beamforming involves the interference of the signals constructively in the direction of the target device. Any interference by the undesired device is cancelled out in this technique. [4]

2. Types of smart antennas

The smart antennas follow the MIMO algorithm which involves the use of multiple antennas both at the receiver and the transmitter side. There are two main types of smart antennas which includes switched beam smart antennas and adaptive array smart antennas. Switched beam smart antennas have several fixed beam patterns
which is switched on the basis of the requirement by the receiver. The adaptive array smart antennas have the ability to rotate the beam to any direction of interest depending on the requirement. This paper will further discuss the adaptive array smart antennas only. [5]

3. Smart antenna advantages
Smart antenna can be helpful to achieve the requirements of the future communication system. Both switched beam and adaptive array smart antenna systems has a very high gain. The switched beam provides higher gain by switching the beam to the receiver at a much higher frequency. Similarly, the adaptive array antenna places the main beam in the desired direction along with the power of the different antennas present in the system.

The smart antenna system also has the ability to reduce the interference. The switched beam antenna system achieves this task by using a much narrow beam pattern. Similarly, the adaptive array antenna system achieve this task by adjusting the beam pattern in such a way so that to reduce the interference. [5]

4. Uses of smart antennas
The smart antenna systems are still in the research process. Many of the companies are doing much research work on the phased array or adaptive array or both. The phased array antenna systems are usually studied for point-to-point wireless communication system. It is also being studied for macro-cells base stations.

While on the other hand, the adaptive array antenna system are usually studied for the scenario where the received power is spread over a wide angle. It is also studied for micro-cells base station. [5]

5. Smart Antenna in 3G systems
Now Smart Antenna Systems are extensively used in wireless communication systems. It is because of the fact that Smart Antennas have the ability to provide high gain in the direction of the desired signal and forming nulls in the direction of the interferences. In this the interference can be reduced and the desired signal can be retrieved. [2]

5.1 Smart Antenna Algorithms
The most crucial step for the Smart antenna system to be used is the selection of the smart algorithms. We can use each algorithm to adjust the weights of the antenna arrays to form certain amount of adaptive beams to track corresponding users automatically. Presently, many algorithms are applied to the smart antenna systems. Generally there are two categories: Blind algorithms and Non-blind algorithms. [2]

5.1.1 Blind algorithm
The algorithm in which a system requires a reference so that to adjust the weights is known as blind algorithm. In case, we know the direction of the signal, we can determine the response of the channel which then leads to the
determination of the weights according to some principles. LMS, RLS, SMI, LCMV etc. are included in this algorithm class. [2]

5.1.2 Non-blind Algorithm
Non-blind algorithm do not require a reference signal, however, in this, transmitted signal is estimated and is seen as the reference signal by the receiver for further signal processing. In this algorithm, the inherent characteristic of the modulating signal which is by nature independent of the carried information is used extensively. [2]

5.2 Smart Antenna System effects on cost
The main goal of the mobile operators is to provide new and better services in view of cost effectiveness. The main problem in 3G technologies such as UMTS and CDMA2000 is the shortage of network resources. Implementing more base stations is not a feasible and better solution. Similarly, cell splitting with more sites extensively reduces the throughput per site due to the co-channel interference.

Smart Antenna can help greatly to solve this problem because the use of smart antennas in wireless networks is well known to increase the number of voice calls and the amount of data throughput. This is because of the fact that the smart antennas reduce the effects of interference and in this way ease the network management. The BS which is equipped with smart antenna has the ability to track the MS by measuring the relative signal strengths at multiple antennas. In this way, smart antennas increases capacities which in turn provide more profit because of the efficient use spectrum and power. The spectrum and power both depends on the antenna’s radiation and reception pattern. Increase in capacity along with the provision of the QoS services are the main benefits of the deployment of the Smart Antenna Systems. [3]

5.3 Smart Antenna Systems in 3G shared channels
In 3G system, the use smart antennas enhance the user capacity which in turn increases system packet data throughput. Shared channels are used in 3G systems to transfer that are delay tolerant such as email or other downloads. On such channels, users share code resources and scheduling algorithms. There are two smart antenna concepts; adaptive beamforming in which beams are pointed to the desired user and fixed beam switching in which fixed preformed antenna beams are assigned to the user.

It has been observed that the use of beamforming antenna with four antenna elements increases the throughput over 100% in relation to the three sectors approach. On the other hand, the fixed beam switching even shows more positive results as the adaptive beam antennas are more sensitive to the link degradation caused by poor channel estimation. [1]

5.4 Results of simulation of adaptive beamforming Smart Antenna

Figure-3 Adaptive beamforming at 0 degree

Figure-4 Adaptive beamforming at 180 degrees

Conclusion

In this paper, characteristics and efficiency factors of the smart antennas are comprehensively discussed. The Smart Antenna Systems can prove to be efficient antenna systems for the 3G communication systems such as UMTS and CDMA2000. These communication systems are facing shortage in the network resources which can be compensated by the use of Smart antenna as it has
the ability to enhance the capacity as well as the user throughputs. Also it can track the desired user to transmit the maximum power in the right direction. These are the major factors of the efficiency of the Smart Antenna Systems. Major network operators are looking forward to deploy Smart antennas because of its efficiency to enhance the user capacities and ultimately the throughput.

The Smart antenna systems are beneficial to be used as they have the ability to provide lower mobile terminal power consumption, range extension, ISI reduction, high data rate support, and ease of the integration into the existing base station systems. However, the initial cost would larger, as the other 3G antenna systems are widely installed, and their replacements would require a lot of initial investments. But, Smart antenna systems would be providing long term benefits, once installed.

References


