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A Brief Review of Antenna Technologies for Various Wireless Communication Applications

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Abstract—**This paper presents a brief review of the various types of smart antennas & is the most efficient leading innovation for maximum capacity and improved quality and coverage. A systematic comparison of the performance of different types of smart antennas for beam-forming has been extensively studied in this work. Beam formation and coverage pattern for switched beam systems and adaptive arrays are comprehensively presented. Different approaches used to provide fixed beams in a Switched Beam system are detailed. Various training sequence algorithms like Recursive Least Squares (RLS) and Least Mean Squares (LMS) are discussed. A qualitative comparison between switched beam and adaptive arrays has been made. The major benefits of smart antennas are also listed.**

Keywords —Co-channel Interference, Multipath Interference.

INTRODUCTION

A smart antenna typically comprises an array of 4 to 12 antenna elements that transmit and receive signals from a base station [9]. A smart antenna focuses on radio energy in the vicinity of users, Unlike a traditional antenna that covers a vast area with a signal. This reduces interference from other users who are accessing the same tower, and it extends the range of the signal. This increases the capacity of the radio spectrum by as much as a factor of 20 (depending on the application), giving more users clearer signals [10].

Capacity and performance are the two major impairments for mobile communications. They are multipath and co-channel interference[3]. The condition which arises when a transmitted signal undergoes reflection from various obstacles in the propagation environment is called Multipath. It is called so since multiple signals arriving from different directions and have different phases when they reach the receiver. The result is degradation in signal quality when they are combined at the receiver due to the phase mismatch. Co-channel interference is the interference between two signals that operate at the same frequency. In cellular communication the interference is usually caused by a signal from a different cell occupying the same frequency band.

Smart antenna is one of the most promising technologies that will enable a higher capacity in wireless networks by efficiently reducing multipath and co-channel interference [4], [5]. Smart antennas employ a set of radiating elements arranged in the form of an array. In a Smart antenna system the arrays by themselves are not smart, it is the digital signal processing that makes them smart. The method of combining the signals and then focusing the radiation in a particular direction is often referred to as digital beamforming [6], [7]. This term will be extensively used in the following sections. The early smart antennas helped in interference suppression and the smart antenna systems [8] were designed for use in military applications to suppress interfering or jamming signals from the enemy. It is a major challenge to apply smart antenna technology to personal wireless communications since the traffic is denser and the time offered for complex computations is inadequate.

ANTENNAS TYPE

Switched Beam and Adaptive Arrays are basically two main methods to implement antennas that dynamically change antenna pattern and lessen interference and multipath affects while increasing coverage and range. The Switched Beam approach has a good network capacity and generates beams that cover surrounding area as shown in figure1. The base station is used to detect an incoming signal and align the beam to get the best signal of interest to communicate [11].

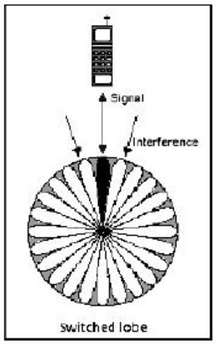

Fig 1: Beam formation for switched beam antenna system

ADAPTIVE ALGORITHM CLASSIFICATIONS

The adaptive algorithms can be classified into categories based on different approaches [13].

Based on adaptation

1. *Continuous Adaptation*: algorithms based on this approach adjust the weights as the incoming data is sampled and keep updating it such that it converges to an optimal solution. This approach is suitable when the signal statistics are time varying.

Examples: The Least Mean Square (LMS) algorithm , and the Recursive Least square (RLS) algorithm.

2. B*lock Adaptation*: algorithms based on this approach compute the weights based on the estimates obtained from a temporal block of data, which is used in a non-stationary environment provided the weights are computed periodically.
   Example: The Sample Matrix Inversion (SMI) algorithm [14],[15],[16]

Based on information required:

1. *Reference signal based algorithms*: These types of algorithms are based on minimization of the mean square error between the received signal and the reference signal. Therefore it is required that a reference signal be available which has high correlation with the desired signal.
   Examples: The Least Mean Square (LMS) algorithm, The Recursive Least square (RLS) algorithm and the Sample Matrix Inversion (SMI) algorithm. The reference signal [17] is not the actual desired signal, in fact it is a signal that closely represents it or has strong correlation with it.

2. *Blind adaptive algorithms*: These algorithms do not require any reference signal information. They themselves generate the required reference signal from the received signal to get the desired signal.
   Examples: The Constant Modulus Algorithm (CMA), The Cyclostationary algorithm, and the Decision-Directed algorithm [18],[19],[20].

Table I: Comparison between types of antennas

Switched Beam System	Adaptive Array System
It uses multiple fixed directional beams with narrow beamwidths.	It steers the beam towards desired signal-of-interest and places nulls at the interfering signal directions[21]
The required phase shifts are provided by simple fixed phase shifting networks like the butler matrix	It requires implementation of DSP technology
They do not require complex algorithm simple algorithms are used for beam selection	It requires complicated adaptive algorithms to steer the beam and the nulls[22]
It requires only moderate interaction between mobile unit and base station.	It requires high interaction between mobile unit and base station.
Interference rejection capability is not very good	It has better interference rejection capability
Integration into existing cellular system is easy and cheap	It is not easy to implement in existing systems, i.e. up gradation is difficult and expensive
Increase in coverage and capacity is not significantly good	It provides better coverage and increased capacity because of improved interference rejection
Since multiple narrow beams are used, frequent intra-cell hand-offs between beams have to be handled as mobile moves from one beam to another	Since the beam continuously follows the user; intra-cell hand-offs are less[24],[25].

BENEFITS OF SMART ANTENNA TECHNOLOGY

*Range improvement: S*mart antennas contain collection of individual elements in the form of an array and hence give rise to narrow beam with increased gain using the same power of conventional antenna. The increase in gain leads to increase in range and the coverage of the system [26],[27].

Increase in capacity: Smart antennas enable reduction in co-channel interference [28], which leads to increase in the frequency reuse factor. That is smart antennas allow more users to use the same frequency spectrum at the same time bringing about tremendous increase in capacity.

Reduction in transmitted power: Energy is conserved in smart antennas since they are directional. Comparatively smart antennas radiate energy only in the desired direction. Therefore less power is required for radiation at the base station..

Reduction in handoff: The capacity of cell in a crowded cellular network is improved by further breaking into micro cells to enable increase in the frequency reuse factor [29],[30],[31]. Therefore, handoffs occur rarely, only when two beams using the same frequency cross each other.

CONCLUSION

Smart antennas vastly improve the efficiency of wireless transmission and have become the standard in use for connections between wireless devices. A qualitative comparison between switched beam and adaptive arrays is presented in this work. Due to the low-priced technology almost all devices make the most of smart antennas. This transition could be compared to the use of hubs in wired computer networks and their replacement with switching technology has opened a wide market as the cost of implementation is reduced.

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