Novel smart antenna system design using directional elements for wireless communication systems

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***Abstract*— Number of subscribers for mobile communication are growing dramatically from the last decade. New methodologies need to be exploited to satisfy the demand. Smart antenna technique improves the performance of system by increasing the gain in the desired direction. This can be achieved by focusing the antenna beam towards the desired user and decreasing interference with other users. The antenna directivity is effectively controlled by employing multiple antennas for transmission and reception. The smart antenna system increases system capacity by combating the co-channel interference. Adaptive arrays are employed for steering the beam in desired direction by simultaneously nulling the interference with undesired users. In this paper, the smart antenna system using butler matrix along with single-pole-quadruple-throw (SPQT) switch is proposed. The antenna is designed and simulated on ADS software.**

***Keywords*— Adaptive antenna array, beam forming, butler matrix, SPQT switch, smart antenna system**

I. INTRODUCTION

Demand for high data wireless mobile communication services has increased drastically over the last decade, resulting in the development of enabling technologies from GPRS (2.5G), WCDMA (3G), and CDMA2000 evolution data optimized (EVDO) services towards Smart Antenna system (4G) [1]-[4]. With increasing demands, it is difficult to provide services to all users. Also, the wireless mobile communication device has been compact personal computer system with all the options. These systems for seamless radio access provide a standard by establishing a mobile-Internet environment carrying traffic from desktop PCs, smart-phones, and laptops with embedded wireless communication system inside. The data rate performance of wireless signal is suffered by multipath propagation. Mitigating multipath propagation signal is of primary importance in wireless communication systems.

Traditional omni-directional antennas were used initially as shown in figure 1A which radiates equally in all directions. The signal energy radiated in undesired direction results in

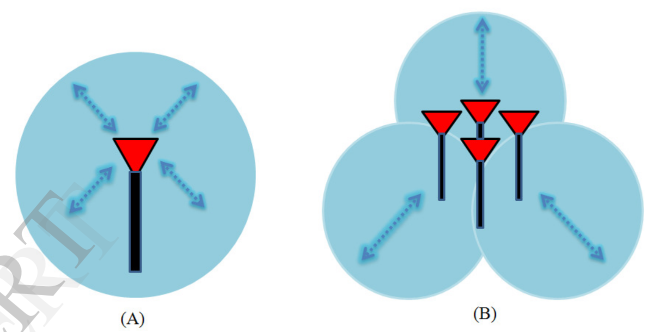


Figure 1.Non-smart antenna system beam forming

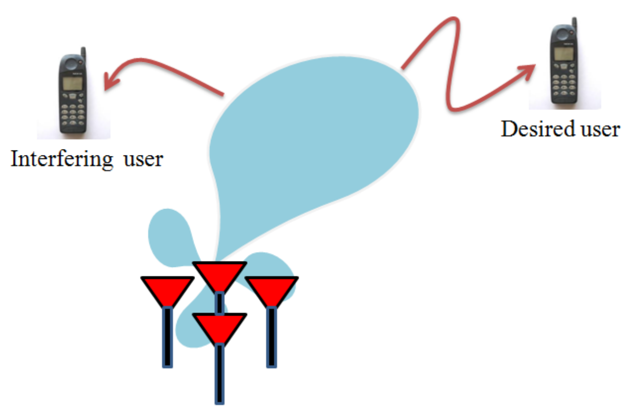


Figure 2. Smart antennas system beamforming

wastage of resources. Also, not efficient to combat inter-cell and intra-cell interferences. Cost-effective solution to this problem is to divide the entire cell into multiple sectors using sectorized antenna concept. As shown in figure 1B, sectorized antennas transmit and receive only in a desired direction and range of the cell to combat interference, one-third of the circular area is covered by each antenna, thereby reducing the overall interference in the system. Efficiency can be further increased by using spatial processing or beamforming (i.e. by focusing a narrow beam on a target) which is the main idea behind smart antenna systems [5]. In Smart antenna system (i.e. beamforming), it requires multiple number of antennas and powerful processors for "smart" transmission and reception of signals for focusing the beam on the desired user thereby nullifying the interference with undesired user as shown in figure 2. The SAS commonly also known as adaptive antenna array, also recently named as a multiple - input– multiple- output (MIMO) system employing multiple antenna signal processing at both transmission and reception ends of communication system which is the promising and reasonably efficient technique for high spectrum efficiency.

In this paper, we have presented the design and simulation results for smart antenna system of complete transceiver system. The next step is to focus the beam in desired direction thereby nulling in the undesired direction which is done by beam forming algorithm.

II. SMART ANTENNA SYSTEM

A. Introduction

The concept behind smart antenna is not new, because similar techniques were already used in military radar systems. The smart antenna technology is becoming one of the promising technology in wireless communication by improving significant quality of communication link, especially when the antenna gain is maximized in desired direction and simultaneously minimizing the radiation pattern in interfering direction [6]-[7].

Smart antenna system consists of multiple antenna elements at the transmitting and/or on the receiving side of the communication system, a coupler/isolator/crossover networks and a controlling unit known as digital signal processor (DSP). In reality, smart antenna systems are not smart, the system becomes smart by the combination of powerful DSP along with adaptive beamforming system and multiple directional antennas which makes the system smart. The system combines antenna array signal with DSP to optimize reception and radiation patterns dynamically in response to the signal environment, i.e. user moving within the coverage area [8]. The smart antenna technique is defined as multiple-input single-output (MISO), single-input multiple- output (SIMO), or multiple-input multiple-output (MIMO) depending on whether the processing is performed at the transmitter, receiver, or both ends of the communication link. It is obvious that a smart antenna base station system is much more complex that traditional omni-directional one because it must include very powerful numeric processors and beamforming control systems.

Smart antenna technology is widely used because nowadays wireless companies are facing some of major problems:

- Limited capacity as limited frequency spectrum is allocated.
- Co-channel interference
- Adjacent channel interference.
- Signal fading due to multipath propagation.

Several researches have been made to overcome these challenges. The result of these research are multiple access schemes, channel coding and equalization and Smart antenna employment. The smart antenna system is divided into three types depending on its level of its intelligence.

B. Types of smart antenna system

1) Switched Beam
2) Adaptive array
3) Dynamically Phased Arrays

III. SMART ANTENNA SYSTEM DESIGN

Microstrip Patch Antenna is designed in ISM Band, edge feed square microstrip Patch Antenna as shown in figure 3.

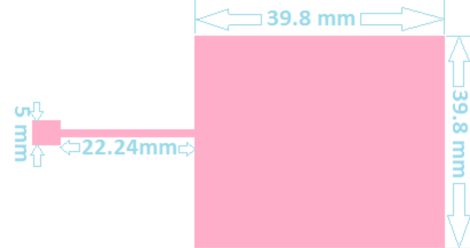
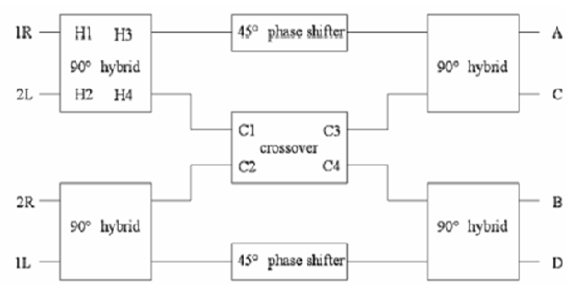
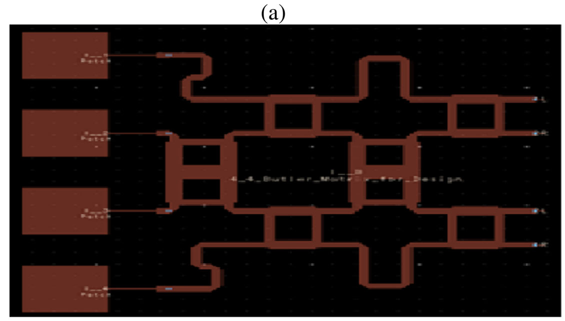


Figure 3. Edge feed microstrip patch

The concept of butler matrix is used and the concept is described by Jesse Butler and Ralph Lowe [9]. It is a type of microwave network and consists of N input ports and an equal number of output ports. Some basic properties of a butler matrix are isolation between input and output, linearity in phase with respect to the position of output and the increment in phase depending upon the selection of input. Also, Butler matrix can steer a beam with magnitude and fixed phased. A signal introduced at one input produces equal amplitude excitations at all outputs but with a constant phase difference between them, resulting in radiation at a certain angle in space. The design of Butler matrix is designed by combining hybrid couplers, phase shifters and crossover as illustrated in figure 4a.



(a)



(b)

Figure 4.a) Block diagram of butler matrix ;
b) Butler matrix with antenna

The beamforming is implemented by integrating planar microstrip patch antenna with butler matrix. The planar microstrip antenna array has four beams at four different directions by implementing the 4×4 Butler matrix as a feeding network to the 4×4 planar microstrip antenna array is designed as shown in figure 4b. Antenna system along with DSP steers the radiation beam towards desired user. The system follows the user as he moves and it minimizes the interference from other users by introducing nulls in their directions.

SPQT (Single Pole Quad Throw) chip is used for switching and to focus the radiation pattern on desired user [10]. SPQT Chip comprises of 3 SPDT(Single Pole Dual Throw). When Gate is at 0 volt, RF flows from Source to Drain. All series FETs have input at source and output at Drain. Single DC bias is used to connect all ON devices and another single DC bias is used to connect all OFF devices.

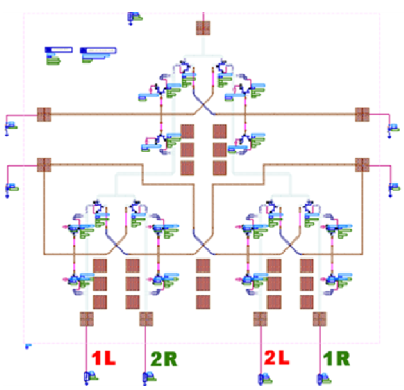


Figure 5. SPQT chip

Smart antenna system using concept of Microstrip Patch antenna, Butler Matrix and SPQT switch is shown in figure 6.

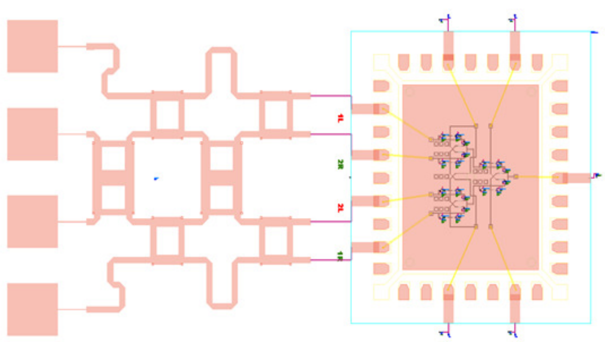
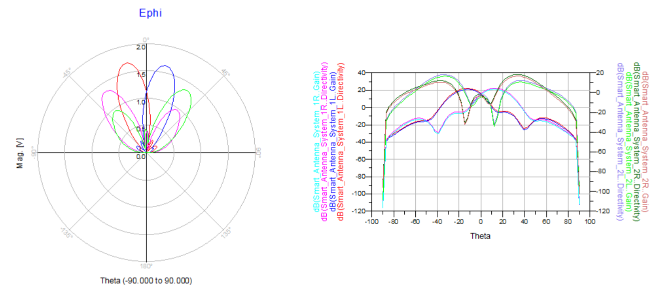


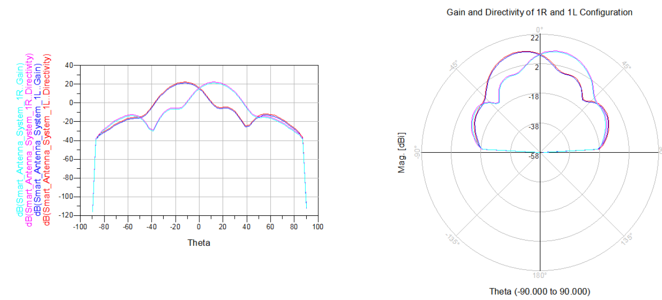
Figure 6. Smart antenna system

IV. SIMULATION RESULTS

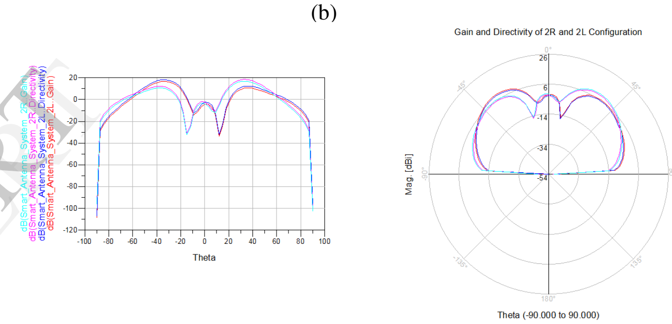
The main objective of the simulation is to qualitatively improve the capacity of the system by switching the antenna elements to focus the beam or radiation pattern in the desired direction and simultaneously decreasing the radiation pattern in the undesired direction. The smart antenna absolute fields for gain, directivity and beam for all four configuration (1L, 2R, 2L, 1R) are shown in figure 7a. Also, the antenna network field plot with gain, directivity for all four configuration is shown in figure 7b and figure 7c respectively.



(a)



(b)



(c)

Figure 7. Simulation result of smart antenna system
(a) Absolute fields for (1L,2R,2L,1R)
(b) antenna network field plot for (1R,1L)
(c) antenna network field plot for (2R,2L)

The simulation results indicate that the system throughput can be increased by switching antenna elements to focus the main beam in the desired direction and form nulls in other directions.

CONCLUSION

In this paper, smart antenna system by using multiple directive antennas and powerful DSPs is designed and simulated. Multiple directive antennas give rise to narrow beam. Concept of SPQT switch along with butler matrix is used to switch and steer the narrow beam in the desired direction and simultaneously placing nulls in interfering direction. Therefore, co-channel interference is negligible.

Traditional omni-directional antennas radiate energy in all directions leading to wastage of power. Smart antenna system radiates energy only in the desired direction. The overall power required for transmission is comparatively reduced. The use of smart antenna system ensures increase in gain, directivity, range and overall system capacity.

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