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ADAPTIVE ARRAY ANTENNAS

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Abstract

Adaptive array antennas also known as smart antennas, digital antenna arrays, multiple antennas and, recently, MIMO are antenna arrays with smart signal processing algorithms used to identify spatial signal signatures such as the direction of arrival (DOA) of the signal, and use them to calculate beam forming vectors which are used to track and locate the antenna beam on the mobile/target. Smart antennas should not be confused with reconfigurable antennas, which have similar capabilities but are single element antennas and not antenna arrays. Smart antenna techniques are used notably in acoustic signal processing, track and scan radar, radio astronomy and radio telescopes, and mostly in cellular systems like W-CDMA, UMTS, and LTE.smart antennas have many functions: DOA estimation, beam forming, interference nulling, and constant modulus preservation.

Keywords: MIMO, direction of Arrival (DOA), Cellular Systems, CDMA, Beam Forming.

1. Introduction

The main benefit of smart antenna systems is its ability to simultaneously increase the useful receiving signal and lower the interference level, increasing the signal-to-interference ratio (SIR) in more densely populated areas. Smart antennas can essentially filter out the unwanted noise made by other users in the system so that important signals can be transmitted and received clearly. Additionally, because smart antennas are more directional than omnidirectional and sectorized antennas, they can focus their energy toward the intended users, instead of wasting it by directing it in unnecessary directions. This means that base stations can be spaced further apart, as they would be in less-populated areas. Smart antennas are also harder to tap into. In order to successfully tap into the connection, the intruder must be positioned in the same direction as their user as seen from the base station. Consequently, smart antennas provide more security, making them extremely vital in the present day, where organizations and individuals routinely transmit confidential information to one another. Lastly, smart antennas' spatial detection capabilities allow for geo-location services. For example, they can locate humans in emergency situations.

2. Related Work

Direction of arrival (DOA)

The smart antenna system estimates the direction of arrival of the signal, using techniques such as MUSIC (MUltiple Signal Classification), estimation of signal parameters via rotational invariance techniques (ESPRIT) algorithms, Matrix Pencil method or one of their derivatives. They involve finding a spatial spectrum of the antenna/sensor array, and calculating the DOA from the peaks of this spectrum. These calculations are computationally intensive. Matrix Pencil is very efficient in case of real time systems, and under the correlated sources.

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Beam Forming

Beam forming is the method used to create the radiation pattern of the antenna array by adding constructively the phases of the signals in the direction of the targets/mobiles desired, and nulling the pattern of the targets/mobiles that are undesired/interfering targets. This can be done with a simple Finite Impulse Response (FIR) tapped delay line filter. The weights of the FIR filter may also be changed adaptively, and used to provide optimal beam forming, in the sense that it reduces the Minimum Mean Square Error between the desired and actual beampattern formed. Typical algorithms are the steepest descent, and Least Mean Squares algorithms. In digital antenna arrays with multi channels use the digital beam forming, usually by DFT or FFT.

MIMO System

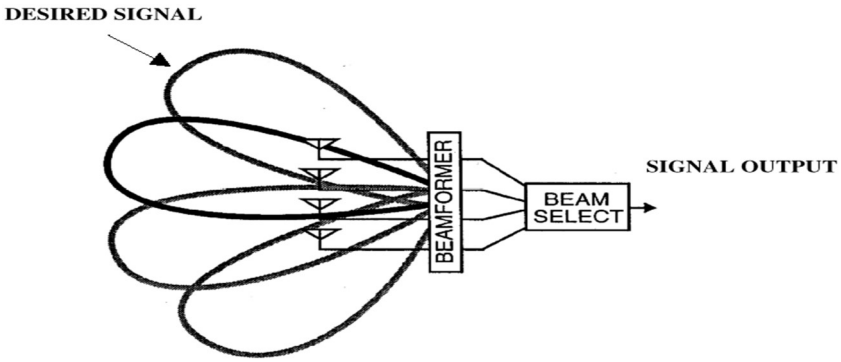
Multiple-input and multiple-output, or MIMO is a method for multiplying the capacity of a radio link using multiple transmissions and receiving antennas to exploit multipath propagation.MIMO has become an essential element of wireless communication. At one time, in wireless the term "MIMO" referred to the use of multiple antennas at the transmitter and the receiver. In modern usage, "MIMO" specifically refers to a practical technique for sending and receiving more than one data signal simultaneously over the same radio channel by exploiting multipath propagation. Although this "multipath" phenomenon may be interesting, it's the use of orthogonal frequency division multiplexing to encode the channels that's responsible for the increase in data capacity. MIMO is fundamentally different from smart antenna techniques developed to enhance the performance of a single data signal, such as beam forming and diversity.

Types of Smart Antennas

The classification of Smart Antennas depends on the type of environment and the requirements of the system. There are mainly two types of Smart Antennas. They are

1. Phased Array/Beam Smart/Multi-beam Antenna

In this type of array, there will be numerous amounts of fixed beams amongst which one beam will turn on or will be steered towards the wanted signal. This can be done only with the help of adjustment in the phase. In other words, as the wanted target moves, the beam will also be steered. The figure of a phased array antenna is shown below.



2. Adaptive Array Antenna

In this type of antenna, there will be a change in the beam pattern according to the movement of the wanted user and the movement of the interference. The signals that are received will be weighted and later combined to increase the wanted signal to interference in addition to the noise and power ratio [S/N]. Thus, the direction of interference will be balanced as the wanted signal will be in the direction of the main beam. The antenna can easily steer the main beam to any direction, while at the same time

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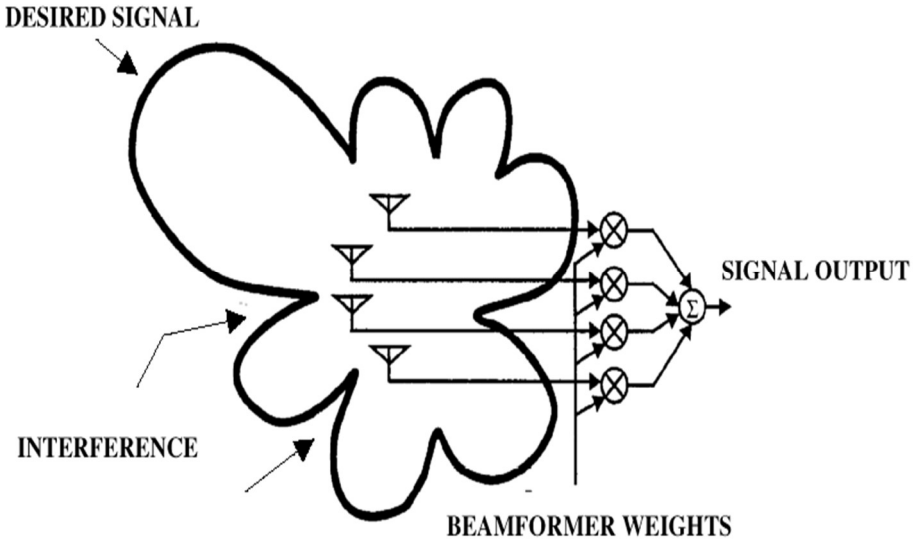
nullifying the interfering signal. The direction of the beam can be calculated using the DOA method. The figure of an adaptive array antenna is shown below.



Adaptive antenna technology represents the most advanced smart antenna approach to date. Using a variety of new signal-processing algorithms, the adaptive system takes advantage of its ability to effectively locate and track various types of signals to dynamically minimize interference and maximize intended signal reception. Both systems attempt to increase gain according to the location of the user; however, only the adaptive system provides optimal gain while simultaneously identifying, tracking, and minimizing interfering signals.

Useful Analogy for Adaptive Smart Antennas

For an intuitive grasp of how an adaptive antenna system works, close your eyes and converse with someone as they move about the room. You will notice that you can determine their location without seeing them because of the following. You hear the speaker's signals through your two ears, your acoustic sensors. The voice arrives at each ear at a different time. Your brain, a specialized signal processor, does a large number of calculations to correlate information and compute the location of the speaker. Your brain also adds the strength of the signals from each ear together, so you perceive sound in one chosen direction as being twice as loud as everything else. Adaptive antenna systems do the same thing, using antennas instead of ears. As a result, 8, 10, or 12 ears can be employed to help fine-tune and turn up signal information. Also, because antennas both listen and talk, an adaptive antenna system can send signals back in the same direction from which they came. This means that the antenna system cannot only hear 8 or 10 or 12 times louder but talk back more loudly and directly as well. Going a step further, if additional speakers joined in, your internal signal processor could also tune out unwanted noise (interference) and alternately focus on one conversation at a time. Thus, advanced adaptive array systems have a similar ability to differentiate between desired and undesired signals.

Conclusion and future scope

Smart antenna systems are also a defining characteristic of MIMO systems, such as the standard. Conventionally, a smart antenna is a unit of a wireless communication system and performs spatial signal processing with multiple antennas. Multiple antennas can be used at either the transmitter or receiver. Recently, the technology has been extended to use the multiple antennas at both the transmitter and receiver; such a system is called a multiple-input multiple-output (MIMO) system. As extended Smart Antenna technology, MIMO supports spatial information processing, in the sense that conventional research on Smart Antennas has focused on how to provide a digital beam forming advantage by the use of spatial signal processing in wireless channels. Spatial information processing includes spatial information coding such as spatial multiplexing and Diversity Coding, as well as beam forming.

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