Genetic Algorithm Technique for Improving Smart Antenna System

Gurpreet Singh
Chandigarh Group of Colleges, Gharuan Campus, Mohali, Punjab
gp_cgc@yahoo.com,

Varun Nayyar
Department of Electronics and Communication Engg., RBCENT for Women Hoshiarpur, Punjab,
varunnayyarnayyar@gmail.com

Abstract: *Smart antenna is such that it can sense its environment and can adjust its gain in different directions accordingly. They provide a smart solution to the problem of communication traffic overload i.e. they increase the traffic capacity. They also improve the QOS. RF spectrum is a limited resource and is becoming crowded day by day due to the advent of new technologies. The sources of interference are increasing as well and hence interference is becoming the limiting factor for wireless communication. Smart Antenna adapts its radiation pattern in such a way that it steers its main beam in the DOA (direction of arrival) of the desired user signal and places null along the interference. It refers to a system of antenna arrays with smart signal processing algorithms.*

Keywords: *DOA, QOS, GA.*

1. INTRODUCTION

The challenge of next generation wireless communication systems comes from the fact that they will have to offer data rates in the hundreds of megabits per second. This requirement translates into the demand for wide frequency bands. The problem of overcoming spectrum limitation while delivering high data rate requirement can be achieved using smart antennas .The adaptive antenna array is capable of automatically forming beams in the directions of the desired signals and steering nulls in the directions of the interfering signals. The dual purpose of a smart antenna system is to augment the signal quality of the radio-based system through more focused transmission of radio signals while enhancing capacity through increased frequency reuse. There exist many adaptive algorithms that have been used in the adaptive antenna array. But to improve the efficiency of adaptive antenna, there is requirement to implement it some more efficient algorithms. So we will be using here a hybridized technique of Genetic Algorithm for its implementation. Here some important parameters are defined that are basic and related to every type of antenna.

1.1 Antennas

Antennas are a very important component of communication systems. By definition, it is a device that converts guided electromagnetic waves into unguided ones and vice versa. Antennas demonstrate a property known as reciprocity, which means that an antenna will maintain the same characteristics regardless if it is transmitting or receiving. Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency band. An antenna must be tuned to the same frequency band of the radio system to which it is connected; otherwise the reception and the transmission will be impaired [1]. When a signal is fed into an antenna, the antenna will emit radiation distributed in space in a certain way.

(a) **Input Impedance:** For an efficient transfer of energy, the impedance of the radio, of the antenna and of the transmission cable connecting them must be the same. Transceivers and their transmission lines are typically designed for 50Ù impedance. If the antenna has impedance different from 50Ù, then there is a mismatch and an impedance matching circuit is required.

(b) **Return loss:** The return loss is another way of expressing mismatch. It is a logarithmic ratio measured in dB that compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line. The relationship between SWR and return loss is the following:

$$\text{Retrun Loss (in dB)} = 20 \log_{10} \frac{SWR}{SWR-1}$$

(c) **Bandwidth:** The bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly. The antenna's bandwidth is the number of Hz for which the antenna will exhibit an SWR less than 2:1. The bandwidth can also be described in terms of percentage of the center frequency of the band.

$$BW = 100 \times \frac{FH\text{-}FL}{Fc}$$

Where FH is the highest frequency in the band, FL is the lowest frequency in the band, and FC is the center frequency in the band. In this way, bandwidth is constant relative to frequency [1]. If bandwidth was expressed in absolute units of frequency, it would be different depending upon the center frequency. Different types of antennas have different bandwidth limitations.

2. Smart Antenna

Many refer to smart antenna systems as smart antennas, but in reality antennas by themselves are not smart. It is the digital signal processing capability, along with the antennas, which make the system smart. Although it may seem that smart antenna systems are a new technology, the fundamental principles upon which they are based are not new. In fact, in the 1970s and 1980s two special issues of the *IEEE Transactions on Antennas and Propagation* were devoted to adaptive antenna arrays and associated signal processing techniques [3]. The use of adaptive antennas in communication systems initially attracted interest in military applications. Particularly, the techniques have been used for many years in electronic warfare (EWF) as countermeasures to electronic jamming. In military radar systems, similar techniques were already used during World War II. However, it is only because of today's advancement in powerful low-cost digital signal processors, general-purpose processors and ASICs (Application Specific Integrated Circuits), as well as innovative software-based signal processing techniques (algorithms), that smart antenna systems are gradually becoming commercially available.

2.1 NEED FOR SMART ANTENNAS

Wireless communication systems, as opposed to their wire line counterparts, pose some unique challenges [7]:

- the limited allocated spectrum results in a limit on capacity
- the radio propagation environment and the mobility of users give rise to signal fading and spreading in time, space and frequency
- the limited battery life at the mobile device poses power constraints

In addition, cellular wireless communication systems have to cope with interference due to frequency reuse. Research efforts investigating effective technologies to mitigate such effects have been going on for the past twenty five years, as wireless communications are experiencing rapid growth [7]. Among these methods are multiple access schemes, channel coding and equalization and smart antenna employment. Fig. 1 below summarizes the wireless communication systems impairments that smart antennas are challenged to combat.

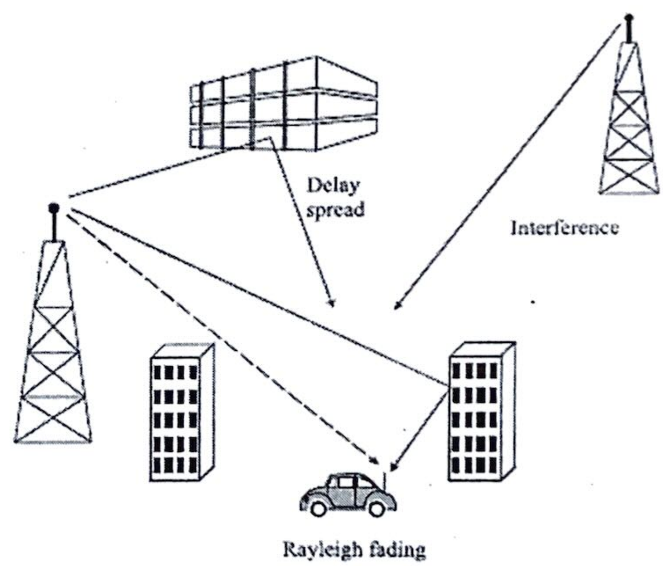


Fig. 1: Wireless systems impairments

An antenna in a telecommunications system is the port through which radio frequency (RF) energy is coupled from the transmitter to the outside world for transmission purposes, and in reverse, to the receiver from the outside world for reception purposes. To date, antennas have been the most neglected of all the components in personal communications systems. Yet, the manner in which radio frequency energy is distributed into and collected from space has a profound influence upon the efficient use of spectrum, the cost of establishing new personal communications networks and the service quality provided by those networks. The commercial adoption of smart antenna techniques is a great promise to the solution of the aforementioned wireless communications' impairments.

3. Architecture Of A Smart Antenna System

Any wireless system can be separated to its reception and transmission parts. Because of the advanced functions in a smart antennas system, there is a greater need for better co-operation between its reception and transmission parts.

3.1 Receiver

Figure 2 below shows schematically the block diagram of the reception part of a wireless system employing a smart antenna with M elements. In addition to the antenna itself, it contains a radio unit, a beam forming unit, and a signal processing unit [14]. The number of elements in the array should be relatively low (the minimum required), in order to avoid unnecessarily high complexity in the signal processing unit. Array antennas can be one, two, and three-dimensional, depending on the dimension of space one wants to access. The first fig shows different array geometries that can be applied in adaptive antennas implementations [14]. The first structure is used primarily for beam forming in the horizontal plane (azimuth) only. This will normally be sufficient for outdoor environments, at least in large cells. The example shows a one-dimensional linear array with uniform element spacing of x. Such a structure can perform beam forming in one plane within an angular sector. This is the most common structure due to its low complexity [2].

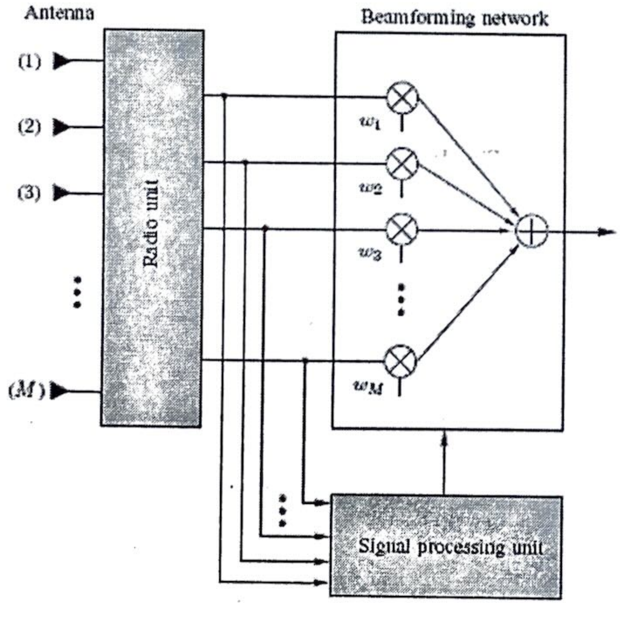


Fig. 2: Reception part of a smart antenna

The estimate of the weights can be optimized using one of the two main criteria depending on the application and complexity:

- Maximization of the power of the received signal from the desired user (e.g., switched beam or phased array), or
- Maximization of the SIR by suppressing the signal received from the interference sources (adaptive array).

In theory, with *M* antenna elements *M*" 1 sources of interference can be "nulled out", but this number will normally be lower due to the multipath propagation environment. The method for calculating the weights differs depending on the type of optimization criterion. When the switched-beam (SB) is used, the receiver will test all the predefined weight vectors corresponding to the beam set) and choose the best one giving the strongest received signal level. If the phased array approach (PA) is used, which consists of directing a maximum gain beam toward the strongest signal component, the weights are calculated after the direction-of-arrival (DOA) is first estimated.

3.2 Transmitter

Normally the adaptive process is applied to the uplink/reception only (from the mobile to the base station). In that case the mobile unit consumes less transmission power, and the operational time of the battery is extended. However, the benefits of adaptation are very limited, if no beam forming is applied in the downlink transmission (from the base station to the mobile). In principle, the methods used in the uplink can be carried over the downlink .The transmission part of a smart antenna system is schematically similar to its reception part as shown in Fig. 3 below. The signal is split into *N* branches, which are weighted by the complex weights *w*1, *w*2. . . *wN* in the lobe forming unit. The signal-processing unit calculates suitably the weights, which form the radiation pattern in the downlink direction. The radio unit consists of D/A converters and the up-converter chains [8]. In practice, some components, such as the antennas themselves and the DSP, will be the same as in reception. The principal difference between uplink and downlink is that since there are no smart antennas applied to the user terminals (mobile stations), there is only limited knowledge of the *Channel State Information* (CSI) available. Therefore, the optimum beam forming in downlink is difficult and the same performance as the uplink cannot be achieved.

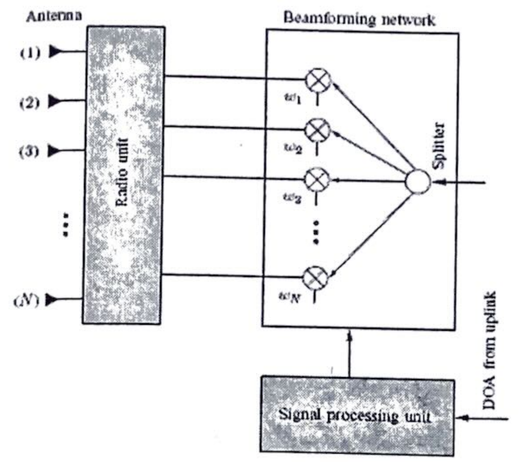


Fig. 3: Transmission part of a smart antenna

Typically there exist two approaches to overcome this impairment. The first one is to devise methods that do not require any CSI, but with somewhat limited performance gain. The second one is the assumption of directional reciprocity, i.e., the direction from which the signal is arrived on the uplink is closely related to the downlink CSI. This assumption has been strengthened by recent experimental results. Physically an adaptive antenna looks very much like an ordinary antenna but has built-in electronics and control software. It cooperates with the receiver's adaptive control system in real time. It may also communicate interactively with the cellular radio network control system. Smart antenna techniques have only recently been considered for implementation in land mobile stations and vehicle installed units because of their high system complexity and large power consumption. A number of smart antenna arrays for base station applications have already been proposed in [12]. However, only limited efforts have been yet considered for developing adaptive antenna array receivers suitable for handsets. In fact, there exist several practical difficulties with the implementation of such a solution at the handset level. These are:

- The space on the handset device is limited and does not allow the implementation of an antenna array with number of elements necessary enough for efficient spatial signal processing. In addition, two (or multiple) antennas in proximity may reduce the effectiveness of the antenna system due to coupling.
- The problem related to the movement of the mobile that provides an Omni directional scenario.
- The cost and the complexity of the implementation at every mobile is much greater than the implementation at each base radio station. Besides these difficulties, the adaptive algorithm for signal processing at the handset must be fast; however it needs only a few simple calculations, and requires a simple hardware implementation. To justify further research efforts in employing multiple antennas at handsets, the gain in performance should be large enough to offset the additional cost and power consumption. Finally, it can be stressed that the use of digital beam forming antennas, both in satellites and in land-fixed and mobile units, remains a challenge for future satellite communication systems.

4. Genetic Algorithm

A genetic algorithm is a search technique used in computing to find exact or approximate solutions to optimization and search problems as shown in Fig. 4. Genetic algorithms are a particular class of evolutionary algorithms (also known as evolutionary computation) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination). Genetic algorithms are search algorithms based on mechanics of natural selection and natural genetics. In every generation, a new set of artificial creatures or strings is created using bits and pieces of the fittest of the old.

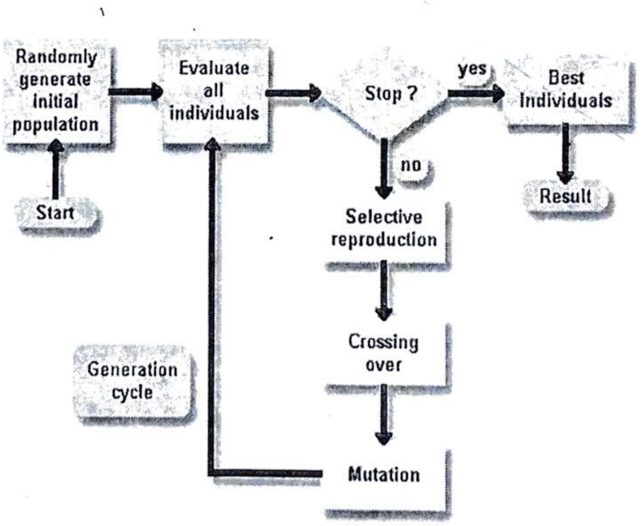


Fig. 4: Flow Diagram of Genetic Algorithm

(a) Fitness is a measure of the "goodness" of a chromosome, that is, a measure of how well the chromosome fits the search space, or solves the problem at hand. For the Standard Genetic Algorithm, the fitness f is a function from the set of possible chromosomes to the positive reels.

(b) Selection is a process for choosing a pair of organisms to reproduce. The selection function can be any increasing function, but we will concentrate on fitness-proportionate selection, whose selection function is the probability function

(c) Crossover is a process of exchanging the genes between the two individuals that are reproducing. There are several such processes, but we will consider only one-point crossover, a process that is both standard and simple. A random integer i is selected uniformly between 1 and n. This is the place in the chromosome at which, with probability pc, crossover will occur. If crossover does occur, then the chunks up to i of the two chromosomes are swapped. For example, the chromosome 11111111 when crossed with 00101010 at i = 4 gives the chromosomes 00101111 and 11111010.

(d) Mutation is the process of randomly altering the chromosomes. Say that pm is the probability that bit i will be piped. Let i vary from 1 to n. For each i a random number is selected uniformly between 0 and 1. If the number is less than pm, then the bit is flipped.

Using the preceding notions, we now describe the seven steps in the Standard Genetic Algorithm:

1. Start with a population of n random individuals each with l-bit chromosomes.
2. Calculate the fitness f(x) of each individual.
3. Choose, based on fitness, two individuals and call them parents. Remove the parents from the population.
4. Use a random process to determine whether to perform crossover. If so, refer to the output of the crossover as the children. If not, simply refer to the parents as the children.
5. Mutate the children with probability pm of mutation for each bit.
6. Put the two children into an empty set called the new generation.
7. Return to Step 2 until the new generation contains n individuals. Delete one child at random if n is odd. Then replace the old population with the new generation. Return to Step 1.

4.1 Major Elements of the Genetic Algorithm

The simple genetic algorithm (SGA) is described and is used here to illustrate the basic components of the GA. A pseudo-code outline of the SGA is shown in Diagram. The population at time *t* is represented by the time-dependent variable *P*, with the initial population of random estimates being *P (0)*. Using this outline of a GA, the remainder of this Section describes the major elements of the GA [9].

```
procedure GA
begin
t = 0;
initialize P (t);
evaluate P (t);
while not finished do
begin
t = t + 1;
select P (t) from P (t-1);
reproduce pairs in P (t);
evaluate P (t);
end
End
```

5. Methodology

In our proposed technique, first of all antenna senses its environment and receives the signal as shown in Fig. 5. Then it calculates its direction of arrival. Once its direction has been calculated, it matches its characteristics to that stored in memory, if a match is found then it immediately produces the stored response. If a match is not found it runs the algorithm in the routine manner.

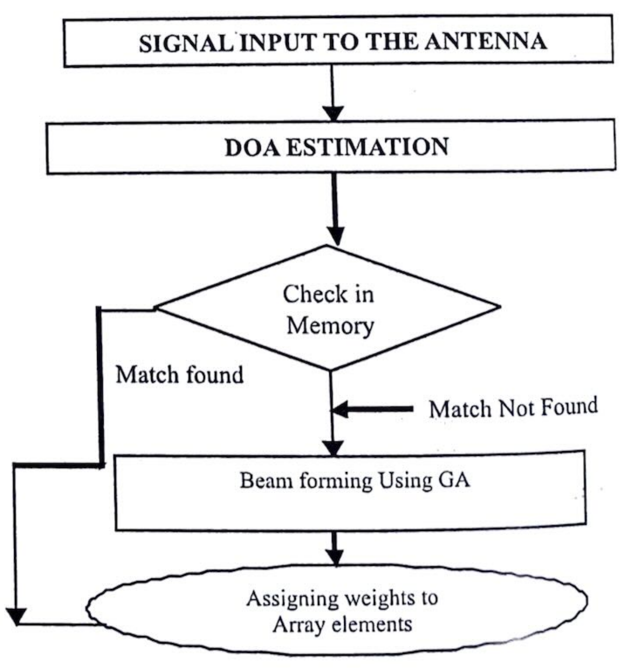
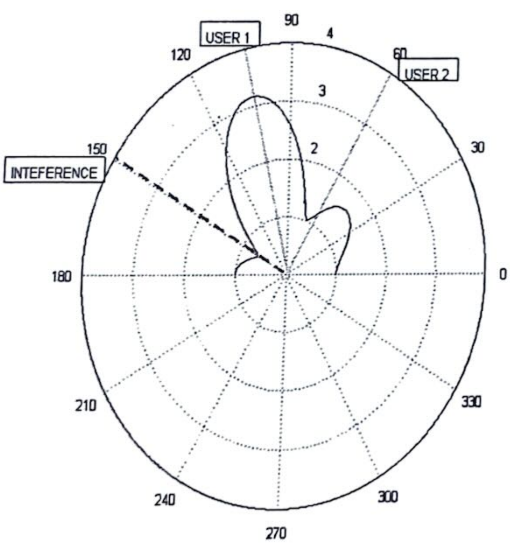


Fig. 5: Our Proposed Techniqu

DOA Estimation: A signal that impinges on the array elements induces current in them. The magnitude of induced currents in the array elements will be same, but with a successive phase difference. We now multiply the induced currents with the weights (randomly assigned through GA) of the array elements and add them. This becomes the cost function which is to be maximized. This is done using the same steps of Genetic algorithm i.e. natural selection, cross over and mutation. The new population thus formed is treated in the same manner. This process goes on until the algorithm is converged. Once it is converged, we select the best chromosome of the last population that gives us the optimized complex weights, giving us the direction of arrival of the user.

AIS Scanning: Now AIS scanning is performed i.e. match is found in the stored response in the memory. If the DOA is within 50 of the stored DOA and magnitude at the interference is within a Specific margin then we can directly provide the stored weights to the array elements instead of running the entire algorithm again. In case a match is not found, then beam forming is done using GA as explained earlier.



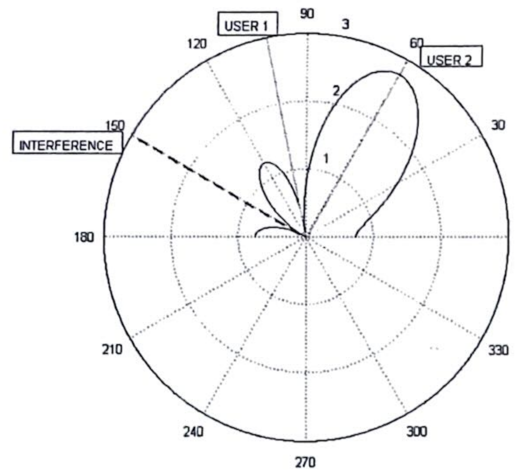


Fig. 6: Simulations of two user signals

The two simulations shown in Fig. 6 show the case of two user signals environment. First their direction of arrival is calculated and the beams are formed accordingly. Note that user 1 is interference for user 2 and vice versa.

6. Conclusion

In the recent years, advancement in elecommunication technologies and the increasing demand of data rate has motivated the optimized use of frequency spectrum. One technique for the efficient usage of frequency is Smart Antenna system. Smart Antennas are though developed using different algorithms, but the urge was felt for improving the technique to increase their efficiency.

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