International Journal of Electronics Engineering (ISSN: 0973-7383)
Volume 9 • Issue 2 pp. 261-268 June 2017-Dec 2017 www.csjournals.com

Comparison of Smart Antenna Parameters using Genetic Algorithm and Fuzzy Logic

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Abstract: The most important function of beam forming is to change the beam pattern of the antenna for a given angle. Very high signal loss will occur when the antenna does not change its direction based on the receiving signal. So, in order to increase the parameter values and to reduce the signal losses in the system, here we propose a new method for comparison between smart antenna parameters with and without spatial diversity. In order to provide training for neural network and fuzzy logic, a huge personalized training dataset is generated using Genetic Algorithm (GA). Given a desired angle as input, the proposed method gives the corresponding antenna parameters and phase angle as output.

Key words: Smart antenna, Gain, Interference ratio, spatial diversity, Fuzzy logic, Neural network, Beam forming.

1. Introduction

Smart antenna system consists of multiple antenna elements that are connected to a digital signal processor where spatial filtering takes place [8]. Smart antenna technology either increases the directivity of the antenna beam using antennas with multiple radiating elements in order to improve the signal at the intended receiver without causing interference to other radio users, or increases the consistency and data capacity of the link using multiple receive/transmit antenna channels simultaneously. [2]. Smart antennas or adaptive antennas have to satisfy two additional functions, in addition to their main purpose of effectively transmitting and receiving radio signals, they are direction of arrival estimation and beam steering [10].

A smart antenna is an antenna array system aided by some smart algorithm designed to use in diverse signal environments [11]. Normally, the gain of a smart antenna is higher than that of an Omni-directional antenna. Also, when compared to an omni-directional antenna, smart antenna has higher reachability or in other words, a better directional range. [3]. Two important functions of Smart antennas are Direction of arrival and Adaptive Beam forming [6] [7]. Adaptive beam forming system uses adaptive array processing which creates nulls in the direction of interference and strong beams in the direction of preferred user [12]. The adaptive antennas uses an adjustable weighting set in order to create a main beam towards the desired user and a null beam towards the undesired interferences [13]. Target surveillance and modern communication systems necessitate Directional-of-arrival (DOA) estimators [14].

Beam forming is a signal processing technique which is used to define the application of weights to the inputs of an array of antennas for focusing the function of the antenna array in a particular direction, called the look direction or the main lobe [5]. Beam forming is a technique that aims to enhance the captured sound quality by utilizing the diversity in the received signals of the microphone array [9]. Beam forming presents several benefits to antenna design. As a beam former steer its look direction towards a certain signal, the space division multiple access (SDMA) is achieved. And other signals from diverse directions can reuse the same carrier frequency [10]. Smart antennas are used in Performance Analysis of MUSIC and LMS algorithm and also used in mobile and base stations in an OFDM/TDMA System [1] [4].

One possible way for improving the capacity of system is by using smart or adaptive antennas which uses spatial diversity to compensate for channel impairments without rising the transmitted power or bandwidth [4]. The communication resources in time, frequency and/or space domain are reused by several approaches. Among all other approaches, smart antennas that utilize the spatial diversity of the mobiles are appearing as one of the most capable solutions [16]. In order to identify the direction of the client, an adaptive antenna arrays that give spatial diversity from the propagation channel and signal-processing algorithms, are used by smart antenna technology [15]. The spatial diversity necessitates sufficient antenna spacing to provide low spatial correlation [17]. The highest spatial diversity order of a non frequency-selective fading MIMO channel is equivalent to the product of the number of receive and transmit antennas [18].

In most of the recent works, one or two factors are used for beam forming in smart antenna. By using one or two factors, the other factors affect the overall efficiency of the system. By considering this drawback, here we proposed a new method for beam forming with spatial diversity using fuzzy and neural network. The rest of the paper is organized as follows. The related works are briefly reviewed in Section 2; proposed technique with sufficient mathematical models and illustrations are described in section 3; implementation results are discussed in Section 4 and section 5 concludes the paper.

2. Related works

Several literary works related to beam forming in smart antenna exist in the literature. A few is most recent literature works in this topic are reviewed in this section.

Bahri et al. [20] have proposed a flexible beam forming algorithm using downlink multiple-input multiple-output multi-carrier code division multiple access system (MIMO MCCDMA) for smart antennas. Least mean square based algorithm has been used, the receiver has incorporated pilot channel estimation and zero forcing equalizer and reference signal and no knowledge channel has been required. Robustness against multi path effects and multi-user flexibility multi-carrier code division multiple access and channel diversity provided by multiple-input multiple-output systems for radio mobile channels have been efficiently exploited by learning multi-carrier code division multiple accesses in a multiple antenna setting.

Shaukat et al. [21] have presented an all-inclusive comparison of flexible algorithms and analyzed the parameters of beam pattern, amplitude response, error plot and BER. They have also evaluated the system in a stringent SNR environment. Highly inadequate response has been played by the LMS algorithm in nullifying the co channel interference though the importance of LMS algorithm in producing better main lobe in a particular direction of user could not be denied. More dependable result has been produced by

CMA when compared to LMS and RLS focusing on co channel interference, though it has produced maximum errors.
Deepa et al. [22] have discussed the evaluation of Spatial Diversity (SD), applied to multi-antenna systems that necessitate modifications at the physical level - the use of multiple antennas at the transmitter and/or the receiver. The spatiotemporal variation in the wireless channel is the problem often faced by the designers of wireless communication systems. Mostly, these variations happen due to the occurrence of multipath fading which is unavoidable in scattering environments because those are dependent on changes over time. An extensive variety of pre/post processing methods have been utilized to alleviate the degrading effects of such channels, but with limited improvements in performance. They have analyzed and compared the performance of SISO, SIMO, MISO and MIMO systems in Additive White Gaussian Noise (AWGN) and fading channels.
Castaldi et al. [23] have proposed an adaptive beam forming algorithm based on magnitude-only constraints and it is implemented using RBF-ANNs. Particularly, they have assessed, via a wide parametric study, the potential improvements (in terms of MSE reduction) by comparison with a standard MSE-based approach, and addressed the basic computational implication. Overall, their proposed scheme appears as an attractive alternative to the standard one, mainly in the presence of a number of desired signals comparable with the number of array elements, with median improvements as large as ~10 dB in the MSE reduction, at the expense of a moderate increase in the computational burden.
Mathur et al. [24] have proposed a decision directed approach for blind adaptation of smart antenna system using a complex neural estimation. They have presented a simulation study of the decision directed smart antenna system with neural estimation (DDSA-NE) for multi-quadrature amplitude modulated (M-QAM) signal with 4, 16 and 64 constellations.
Kadri et al. [25] have presented a new technique for the synthesis of planar antenna arrays using fuzzy genetic algorithms (FGAs) by optimizing phase excitation coefficients to best meet a desired radiation pattern. They have presented the application of an exact optimization technique based on fuzzy genetic algorithms (FGAs). The optimizing algorithm is obtained by means of altering the control parameters of a standard version of genetic algorithm (SGAs) using a fuzzy controller (FLC) dependent on the best individual fitness and the population diversity measurements (PDM).

3. Beam forming in smart antenna with spatial diversity

Smart antenna is now getting high attention in all the recent wireless communication systems. As already stated, beam forming plays a major role in smart antenna. Smart antenna is commonly used because the beam pattern and phase angle can be manipulated based on the requirement. There are number of antennas are receiving and sending the signals at a time. The signal which required by us can be received correctly by fixing the angle of the antenna in exact direction. In this paper to improve the beam forming performance of smart antenna along with the communications systems, spatial diversity is used. By using the spatial diversity, the occurrence of interference can be made less and also efficiency of our method can also be increased, by hybridizing NN and Fuzzy.

International Journal of Electronics Engineering (ISSN: 0973-7383)
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The factors used for beam forming in smart antenna is interference, length of the beam, number of patterns, phase angle, position, gain, spatial diversity etc. By considering the above factors the smart antenna parameters like main beam, beam pattern and side lobe are calculated. In most of the recent works one or two factors are used for calculating the smart antenna parameters. Here, in our proposed method all the above factors are considered. If angle is given as an input it gives corresponding beam length, number of beam pattern, phase angle and position as output. Here fuzzy logic and neural network is used to find the phase angle and position for the corresponding angles that are given as input. For training neural network and fuzzy logic, a personalized training dataset is to be generated. GA is used for this purpose. The proposed method is explained briefly in the below sections.

3. Training fuzzy logic

Fuzzy logic is used here for calculating the phase angle and position for a given set of angles. The input to the fuzzy logic is angle values and the output of fuzzy logic is phase angle and position. We can give one or more angles as input to the fuzzy logic. For training fuzzy logic triangular member function is used. Fuzzy logic training stage consists of three different processes. They are fuzzification, generating fuzzy rules and defuzzification. In the fuzzification process the input system data is converted in to fuzzy data. After fuzzification the next process is to generating fuzzy rules.

3.1 Generating fuzzy rules

Generating fuzzy rules is one of the most important processes in fuzzy logic training. The input variable is in the range $[\theta_{\min}, \theta_{\max}]$ and the output variables are in the range $[x_{\min}, x_{\max}]$ and $[\phi_{\min}, \phi_{\max}]$. The minimum and maximum θ value is 0 and 360 respectively. By considering this range the input variables are fuzzified in to three sets namely large, medium & small and the output variables are fuzzified in to five sets namely very large, large, medium, small & very small. By using these variables fuzzy rules are generated.

After completion of fuzzy rules generation, the next step is training fuzzy logic. Next process after training fuzzy logic is defuzzification. In the defuzzification process the fuzzy data is converted in to system data. After completion of training, fuzzy logic is ready for practical application. If we give angle as input to the fuzzy logic, it gives the position and phase angle.

3.2 Calculating final position and phase angle for a given angle

After completion of training fuzzy logic and neural network, if we given angles as input it gives corresponding position and phase angle as output. The correct position and phase angle values are calculated by calculating the best values of fuzzy logic and neural network output.

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$$x_p^{\,final} = best\left(x_p^{\,fuzzy}, x_p^{\,neural}\right) \tag{16}$$

$$\phi_p^{\,final} = best\left(\phi_p^{\,fuzzy}, \phi_p^{\,neural}\right) \tag{17}$$

Equation 16 & 17 gives the final position and phase angle value for the given angles.

4. Result and discussions

The proposed technique was implemented in MATLAB. In the proposed method, if we given angles as input it gives the corresponding position and phase angle as output.

a. Beam forming for angle at 0 degree

i. Proposed method with spatial gain:

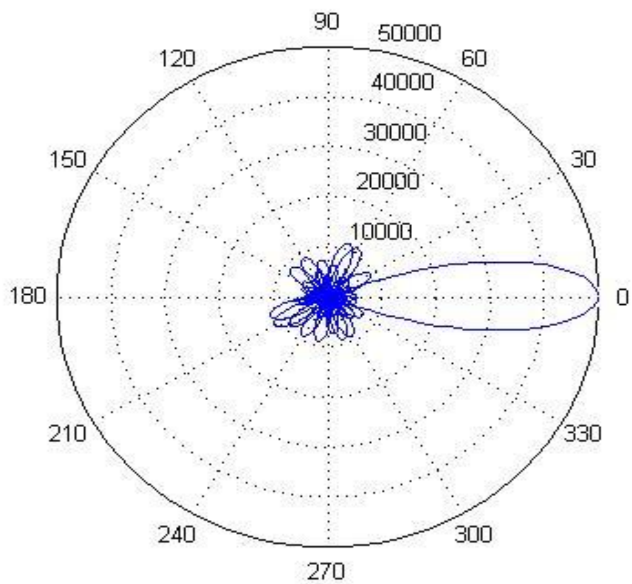

Figure 3: Beam forming angle with spatial diversity at 0 degree

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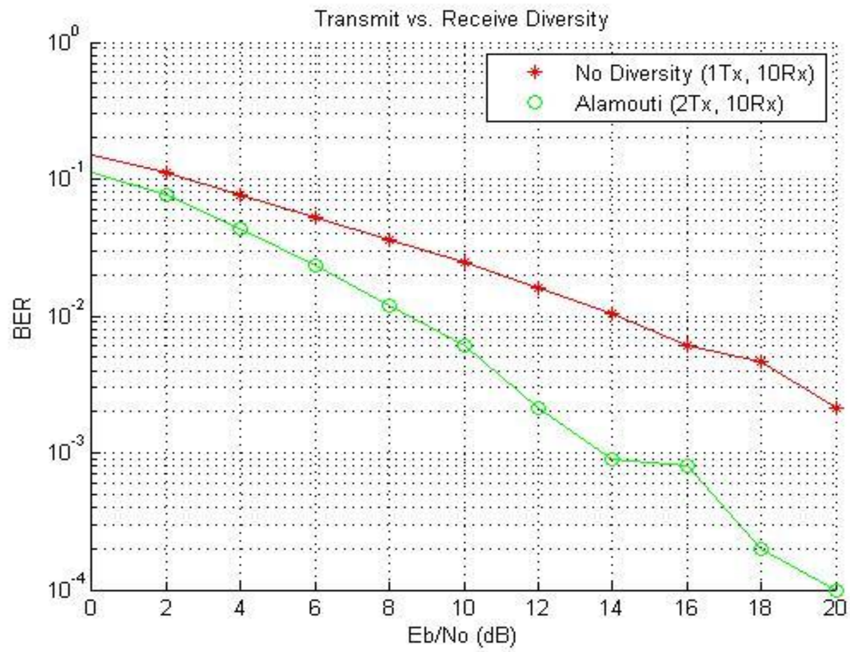

Figure 4: Bit error rate vs SNR graph

Here, the input angle given is 0 degree, and from the above figure it is clear that the main beam is focused towards 0 degrees, and except the main beam, all the other beams are only side lobes. The main beam will focus towards the direction of the angles given as input.

The best direction and phase angle obtained after applying the neuro fuzzy is as follows.

Beam length (m)				17						
Number of beam patterns				10						
Phase angle (radian)	10.5555	17.48	17.48	17.48	10.55	17.48	17.48	17.48	17.48	17.48
Position (m)	17.4802	10.54	10.54	10.54	17.48	10.54	10.54	10.54	17.48	17.48

The proposed method is compared with GA (genetic algorithm) beam forming without spatial gain

ii. GA Beam forming with out spatial gain:

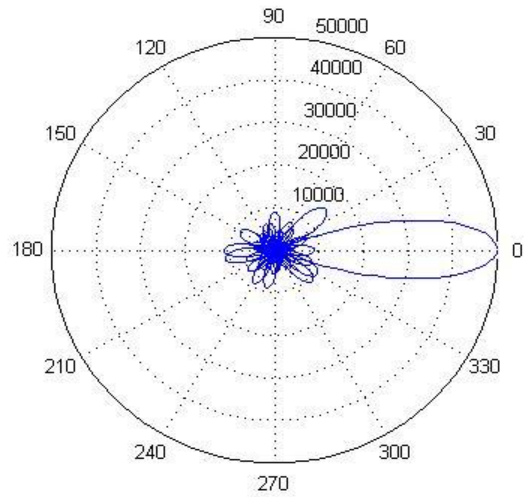

Figure 5: GA Beam forming angle without spatial diversity at 0 degree

5. Conclusion

In this paper, fuzzy and neural network is used to find the direction and phase angle for a given angle in smart antenna. In the proposed method, genetic algorithm is used for generating training dataset and using this dataset, the fuzzy logic and neural network is trained. After completion of training, an angle is given as input to the system and its corresponding position and phase angle is received as output. The proposed method is implemented in MATLAB and tested by giving different angles as input to the system. Our proposed method is compared with the GA beam forming without spatial gain and PSO beam forming without spatial gain. From the comparison results, it is clear that our proposed method increases the peak signal to interference ratio and computational efficiency of our proposed method is high.

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