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Designing of Microstrip Patch Antenna Using Artificial Neural Network: A Review

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Abstract- In the modern era of wireless communication there is a need for an antenna with reduced size, higher bandwidth (to support high data rate), fewer losses and ability to operate at high frequency. The microstrip antenna is one of the most favorable candidates in this context and is compatible with today's wireless scenario because of their smaller size, ability to operating at high frequency, and ease of installation. The microstrip antenna is used in mobiles, satellite communication devices, radars etc. Because of the versatility of the microstrip patch, a lot of research work have been done and is going on today. There are different kinds of neural techniques that can be used based on the application. The most commonly used neural techniques are feed forward with back propagation algorithm, which operates on the gradient descent method, and the RBF (radial basis function) NN, which work based on the principle of span between the input and the weight vector. These two techniques are widely used and accepted in the application of the neural network in the field of antenna. The size of the antenna plays a central part in today's wireless scenario because of less space availability and the portability issue. In this paper, we have made a study and survey on microstrip patch antenna designs parameters using artificial neural network.

Keywords: Microstrip, ANN, Gradient Descent, MoM, Levenberg-Marquardt Back propagation

1. INTRODUCTION

The microstrip antenna was evolved in the early 1950s, they got popular in the 1970s. They are likewise known as patch antennas and planar antennas. It is composed of substrate, patch and ground plane. Substrate is made of dielectric material while the patch and ground plane are conductor. Microstrip antenna was evolved in the early 1950s as planar antenna. Microstrip patch is considered as a narrowband antenna in their basic form, they enjoy the advantages of low profile, ease of integration, planar and conformal to the base, low cost manufacturing etc. Microstrip antennas are utilized in diverse areas such as biomedical application, radio communication and other government & commercial application, such as mobile radio and wireless communication having similar specification to meet some of its requirements [1]. Microstrip antennas are utilized in high frequency operations, mostly for the microwave communication bands. The limitations are low bandwidth and low power handling capacity, which can be overcome by proper selection of substrate thickness and dielectric constant as well as proper means of feeding [3]. One of the common problems related to this antenna is the surface wave excitation. Microstrip antennas are very significant device for the next generation wireless systems. They can be of different shapes and sizes like rectangular, square, circular, elliptical etc. These antennas have some limitations such as low radiating efficiency, poor polarization immaculateness and scan performance, narrow frequency bandwidth, must be atministered at low power levels, and produce spurious feed radiation, among others. Many limitations can be mitigated by considering the careful design. Research on microstrip patch is aimed for its size reduction, high gain, wide bandwidth [4]. The major design task is to optimize the dimensions of the rectangular microstrip patch antenna. An increase in the height of substrate leads to increase in efficiency of the antenna, by placing antenna elements in array arrangement the scanning and directivity properties of antenna system can be improved. Although caution must need to be taken while designing because there is a tradeoff between various factors, so improvement in one parameter can lead to decline the performance of another one. Thus, settlement and tradeoffs are always essential during the design process, regardless of the antenna type. Square patch is the special case of rectangular patch. The most commonly used structures are chosen because of ease of analysis in the form of radiation characteristics described in the mathematical form. If the complexity of taken design increases than the there will be difficulty in sculpting the radiation attributes. Microstrip antennas provide choice in selecting numerous performance characteristics, such as operating frequency, radiation pattern, polarization, and element impedance by relatively simple alteration in the structure.

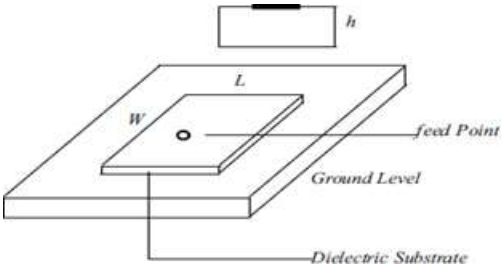

Figure 1 Basic structure of microstrip patch [2]

A practical width of the patch that leads to good radiation efficiencies is given as

$$W=\frac{1}{2f\sqrt{\varepsilon_0\mu_o}}\sqrt{\frac{2}{\varepsilon+1}}$$

where $\varepsilon_o\mu_o = c$,= 3×10^8 m/s and f defined resonant frequency.

Effective dielectric constant of antenna for w/h > 1 is given as

$$\varepsilon_{reff}=\frac{\varepsilon+1}{2}+\frac{\varepsilon-1}{2}\frac{1}{\sqrt{1+12\frac{h}{w}}}$$

The antennas had been designed for given application according to the required performances. Nowadays the task was to catch the available symmetrical factors of the patch (like dimensions of patch, dimensions of ground and feed position) that consumes a portion of time due to trial and error practice. To decrease this consumption of time, vast amount of techniques were used (such as optimum algorithms, ANN techniques etc).

Soft computing provides solution to compute hard task. It is used where the algorithm is not known that can simulate an accurate solution in less time. It differs from conventional computing due to tolerance of imprecision, partial truth and uncertainty to achieve robustness, practicability and low computation cost. In effect, it works as a human mind. Soft computing is used when enough information is not known about the problem. Soft computing eliminates the use of complex mathematical system and provides the solution in less time. Soft computing is a biological inspired techniques rather than a single methodology. These techniques are used during complex problems that require repeated analysis.

Now days, technologies in antenna design and optimization have achieved faster convergence. Soft computing methods can be broadly patitioned as: Fuzzy logic, Artificial Neural Network, Evolutionary Algorithm. An artificial neural network is an immensely commensurate extended processor that has a common tendency for storing practical information and creating it accessible for usage. It look like the mind in two respects: information is attained by a net over a learning procedure, and neuron linking assets are identified as synaptic loads that can be used to store the observed knowledge. It has been observed that in dynamic era, artificial neural network has exceptional contributions and important advancement in the field of wireless communication. ANN is a model operated as biological neural networks that had been used to estimate the functions that are largely depend upon the large number of inputs which are generally unknown. ANN is well-defined as a calculating system prepared by number of unpretentious, highly organized handling elements, which processes data by their vibrant state reply to exterior inputs. Artificial Neural network are the simplified model of neural processing that are used as artificial intelligence in the brain [5].

They can perform many tasks such as system identification, adaptive control, function approximation and optimization. A neural network yields some features like distributed association, ability to handle imprecise data and nonlinear mapping. In ANN, hidden patterns can be found out from the training data sets. It provides the results with minimum MSE and can provide non- linear relationship without any need of existing models. ANN can perform many tasks such as system identification, adaptive control, function approximation and optimization. A neural network yields some features like distributed association, ability to handle imprecise data and nonlinear mapping. In ANN, hidden patterns can be found out from the training data sets. It provides the results with minimum MSE and can provide non- linear relationship without any need of existing models. The main advantage of ANN are that the Network can solve complications without relating any technique of such problematic solving, without constructing any algorithms, and also without any individual information about the nature of solved problem [6].

Neural networks applications are based on software solutions. The learning difficulty in neural networks was expressed in relations to the minimization of loss function. This function is collection of an error and a regularization terms. The error term estimates how a

neural network fits the data set and the regularization term is used to avoid the overfitting, by controlling the complexity of the network [7].

Training algorithm can be observed as a function approximation problem to adjust the parameters and to minimize the error function between the network output and the desired output. The GD algorithm is used to reduce the mean square error for the model between the output and the desired output. The model error can be reduced to particular threshold level, then the model is said to be trained [8]-[9].

Resilient Back Propagation (RP) is used to overcome the effect of updating the negative gradient by performing the local weight updating by the behavior of the error function. The reaction of the adaptation process is not damaged by derivative size, but by the temporal behavior of its sign. Resilient Back propagation is much faster when compared to steepest descent algorithm as it provides a modest increase in memory requirements. Levenberg-Marquardt Back propagation (LM) provide improved conjunction effects than ordinary back propagation algorithm, it needs O(N2) storing and calculations of instruction O(N2) where N is the entire number of masses in back propagation algorithm [10]. The LM training process is actual profitable when the training has done up to rare hundred masses and much higher computation is required for each iteration to provide high precision.

2. ARTIFICIAL NEURAL NETWORK

Most common ANN training algorithm used is the Back Propagation which was also known as error back propagation based on error correlation learning rule. It maps input onto the output data. Back propagation consists of 3 or more layers with each connected to the other one. It operates in such a manner that output of first layer will work as input to another one and this connection process will continue till the end [11]-[12]. The ANN is the data processing models comprising of nodes known as neurons and the connection between the neurons is called weights. Weights are used for determining the output of neurons, higher the weight of the link stronger effect will be provided by the input

In the given sections, neural network application is used for designing of various antennas. In this article the references are chosen according to the technology and design parameters.

Neog et al. [10] proposed design of multislot hole coupled microstrip antenna for obtaining wideband characteristics. Substrate chosen for design is 2mm. A tunnel-based artificial neural network (ANN) was idolized to estimate the radiation patterns of the antenna. The radiation patterns were measured experimentally at 10.5 GHz and 12 GHz. The simulated results were found in good affinity with the simulated results from IE3D and those of the artificial neural network. A new method of using a genetic algorithm (GA) in an artificial neural network was also discussed. The return loss and radiation patterns of the multiple-slot hole-coupled microstrip antenna presented clearly emphasizes that the antenna is a wideband, multiple frequency antennas.

Aneesh et al. [14] proposed design procedure of rectangular microstrip antenna using RBF- ANN. The resonant frequency of antenna with respect to the length is calculated with the variation of maximum numbers of neurons .It required 21 neurons to get target frequency value. By using RBF significant amount of accuracy is achieved with less computational time. The resonant frequency of microstrip Patch has successfully determined with use of RBFNN.

Neog el at. [13] investigated the Multi-slot hole-coupled Microstrip antenna with multi-frequency characteristics to achieve wide bandwidth. This antenna had complicated geometries and difficult to design therefore, ANN is used to estimate the radiation pattern. They recommended the use of Genetic Algorithm to fixed initial weights of a multilayer perceptron network for faster convergence, by coupling of GA with ANN to select the initial weights. This antenna showed simplicity and flexibility in controlling the bandwidth with high isolation between frequency bands. ANN technique with tunnel-based model provides less computation time and more accurate results. Tunneling is achieved by the condition that any unit located at a lesser perturbation from the equilibrium point will travel away from the existing point to another point within an infinite amount of period. GA was used for coupled technique, which provide great amount of accuracy in small computation time and it also reduces the simulation time by half. The comparison between the experimental results, theoretical results and results by Genetic Algorithm technique is shown in Fig. 2. The comparison shows that the GA technique provides the accurate results for resonant frequency very easily and with less computation cost.

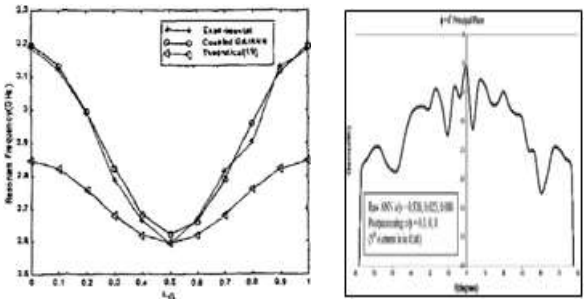

Fig. 2 Rectangular microstrip patch antenna with a shorting post and graph showed resonant frequency of the tuned antenna as a operation of the post position [13].

Patnaik et al. [15] proposed a model for locating faults in Antenna Array using Artificial Neural network. When Antenna Array is used in communication system many radiating elements are needed and there is probability that one or more radiating elements may be failed. Failure in antenna may destroy the symmetry and cause pattern distortion. ANN is used for resulting out the location of fault element. ANN also provide the advantage to bypass the iterative process after obtaining trained network. Multi-layer perceptron Back propagation model is used for mapping the impaired radiation design with the position of faulty elements in the Antenna collection. When ANN is used at the base station it will find the amount and position of faulty features in the array. The network output is rounded off to get the fault element and its position. Fig. 3 display that an output of .397, produce the value 0.4, which means that the fault is in 4th element. This methodology is tested for linear array as well as for planar array to provide results which provide good agreement with simulated results.

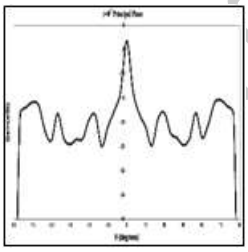

Fig. 3 Simulated radiation pattern without faulty elements and fault element pattern with the equivalent ANN output in the inset [15].

Arora el at. [22] investigated that now a days, in wireless communication systems for both profitable and military applications smaller size multiband antenna are in huge demand. The fractal geometry means fragmented statistical figure that can be divided into groups, each part is a compact size copy of the total. Therefore, the fractal designed antenna are better selected to diminish the antenna dimension, to provide multiband presentation and light weight, low cost and compatibility with incorporated circuitry. Microstrip antennas can work at many bands of interest using fractal geometry with thought-out choice of the schemes and iterations as shown in Fig. 4. The advantages offered by Fractal antennas are light weight, conformability to designed exterior, low cost and combined circuit compatibility. Artificial Neural Networks (ANN) is accomplished with Back propagation method for computing the resonant frequency and gain of antenna. Data set for 100 different values was obtained using IDE3 software at antenna feed positions for unlike repetitions. This information was obtained to train Artificial Neural Network. Trained data set was verified by compelling unidentified input value and then the ANN outcomes are related with IE3D Software. The resulted gain attained by ANN method are in good arrangement with the simulated result.

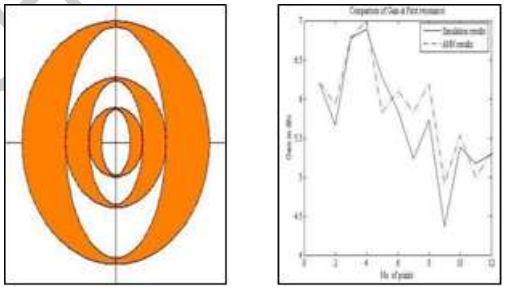

Fig. 4 Proposed Elliptical Fractal Antenna and Comparison of ANN outcomes for gain in initial resonance band with simulated results [20].

Manh et al. [34] investigated the optimization of electromagnetic problems in Microstrip antenna because of its low cost and low profile. The twin rectangular ring arrangement is shown in Fig. 4 which produces more units of freedom to inventers then at the same period produces more complication. Further, to diminish the computational determinations for adjusting electromagnetic field in antenna, ANN had been used. Proximity coupled-feed microstrip antenna had been optimized by full-wave spectral analysis but this antenna provided more complexity. To reduce the calculation effort, accurate and rapid ANN modeling with Gradient Descent training method was used. They proposed an LM access that managed both the non-

liners difficulties and ANN magnitude and its characteristics. ANN design saved a critical amount of computation time and the results obtain by ANN was authenticated by Full wave investigation to exam the accuracy. Antenna radiation observed as a loss technique and return loss was composite therefore, for bandwidth optimization difficulty real and imaginary parts were combined to generate Amplitude. The graph shown in Fig. 5 validates that all future approaches had a good competition with target data. LM approach provide a better performance as the complete modification among the targeted information and ANN outcome was only 0.0005.

Donnell et al. [17] proposed design of neural based beamformer to adapt low cost phased arrays. Aim for introducing this technique is to decrease the antenna manufacturing and maintenance cost. Devoloped ANN is utilized for the purpose of signal detection and DF(Direction finding). Firstly the simulated data was obtained using the conventional simulation, this data is used to train the a RBF network. Thus a RBF beamformer to approximate signal detection and DF is used in ideal and degraded conditions. However the results obtained were not as good as obtained from

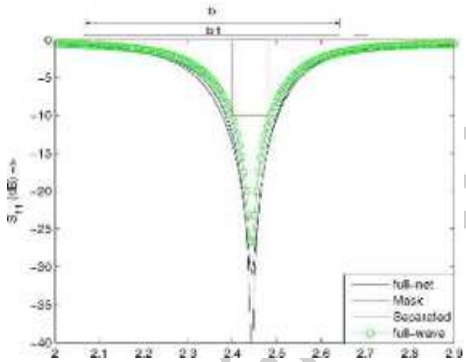

Fig. 5 Test object antenna view and ANN optimization and full-wave analysis validation [34].

Malmathanraj et al. [16] proposed to develop a neural network model to optimize the microstrip patch parameters. Firstly the analytical results for microstrip patch were obtained for different dimension and different radiation pattern, then these results were checked using EM simulating software. Then neural network was applied to optimize the parameter to get wide bandwith and directivity with high gain. Thus ANN application ensured an optimum design methodology for designing of microstrip patch antenna.

Kumar et al. [4] proposed design of multislot microstrip Antenna on 2mm thick substrate which is monopulse tracking, but the developed network showed good performance from the perspective of time efficiency and cost of antenna designing further optimized by application of GRNN, SVM and BFO ANN techniques. These techniques are used to calculate resonant frequency. Initially IE3D software is utilized to simulate the results for return loss, resonant frequency, radiation pattern and gain. Estimation for resonant frequency by utilizing ANN and BFO is emphasized.

3. INFERENCES DRAWN OUT OF LITERATURE REVIEW

The main advantage of using the Soft computing technique is that it increases the robustness and antenna performance. Results obtained from Soft computing technique and the HFSS simulation take less computation time and accuracy is provided by soft computing technique. Microstrip antenna is used because of small size, low profile and operation at different frequencies. Optimization is used to design an antenna of small size, provide quick response, performance constraints and accuracy.

ANN is used because of their ability to estimate complex relationship between input and output data and flexibility to learn and generalize features [17]- [20]. It requires high processing time for the large network. The performance of Rectangular microstrip antenna can be improved by predicting the slot size and air gap among ground plane and substrate plate for achieving resonant frequency (1.5-3GHz), Gain (6.2-9.6dBi), radiation efficiency (85%-100%). It has concluded that neural approach require less time for achieving the required result.

4. DISCUSSION

Antenna parameters like bandwidth is need to be improved to expand the performance of the antenna. The design optimization involve the position of the feed, dimension of the radiating patch and the height of the shorting plate, this is a time consuming task. The resonant frequency of any antenna plays a key role in its operation. From the mathematical formula we know that resonant frequency is inversely proportional to the length of patch, which shows that antenna parameters are highly non linear to each other. To model these parameters conventional parameters used although produce good results but on the other hand inefficient in terms of time taken and computational complexity.ANN is utilized to estimate the Resonant frequency of microstrip patch antenna at different lengths. So to model this non linearity

between the parameters a RBF ANN is utilized, which shows good performance in terms of time taken and not much complex in terms of computational complexity.

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