A Review of Various Soft Computing Techniques in the Domain of Nano-Antenna Design

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This paper presents different Soft computing techniques for the design of NANO Antenna. The performance of antenna is basically influenced by the choice of technique used to design antenna. A Bow-Tie Antenna has been designed using CST software, but which soft computing technique has to use with better result is a challenging task. So In this paper various soft computing techniques are presented and compared. The most recently used techniques Artificial Neural Networks (ANNs), Fuzzy Logic (FL),Particle swarm optimization(PSO), Genetic algorithm(GA), Adaptive Neuro-Fuzzy Inference System (ANFIS), A hybrid technique consisting both ANFIS and Genetic Algorithm (ANFIS-GA),A hybrid Bacterial Swarm Optimization and Nelder-mead (BSO-NM) algorithm are described. A literature review is also presented on various soft computing techniques which are previously used in design of antenna. Antenna design is simulated for all techniques and result is compared with each other. After the reviewed previous work deeply, ANFIS or A hybrid technique consisting both ANFIS and Genetic Algorithm (ANFIS-GA) techniques is the most efficient technique to use. But As far as number of training data set is concern ANFIS requires small data set and hence ANFIS provides optimization too.

Keywords- ***Soft Computing Techniques; Artificial Neural Networks; Genetic Algorithms; Fuzzy Logic, Particle swarm optimization, Adaptive Neuro-Fuzzy Inference System, Bow-Tie.***

I. INTRODUCTION

An Antenna is usually a metallic device for radiating and receiving radio waves. Antennas are employed in systems such as radio and television broadcasting, point to-Point radio. Several critical parameters affecting an antenna's performance are resonant frequency, directivity, gain, radiation pattern and its efficiency. A bow-tie antenna is awire approximation in two dimensions of a bi-conic dipole antenna. It is an antenna that consists of two triangular flat metal plates, arranged in the configuration of a bowtie with the feed point at the gap between the apexes of the triangles. A bow-tie antenna is a form of bi-conical antenna which is a broad bandwidth antenna made of two roughly conical objects, nearly touching at their points. It has a broad bandwidth because it is an example of travelling wave structure. It is generally used for UHF television reception. Bow-tie antenna has an Omni-directional radiation pattern. Bandwidth of this antenna is considerably higher than a dipole antenna. It gives a moderate gain of about 3.5-7 dB. A bow-tie antenna is a miniaturized antenna. In present day wireless communication systems, compactness is a must. Designing a miniaturized antenna and covering the lower spectrum of microwave frequency is a challenging task. The French mathematician B.Mandelbrott introduced the term Fractal and it was used for miniaturization of antenna and also provides multiband operation which can perform over a single antenna. The term fractal has mainly two important characteristic which provide multiband coverage and compactness of antenna – (1) self similarity, and (2) space filling. By using this functionality these fractal structures can be implemented in any antenna for providing broad band coverage applications. Here, the fractal structure is implemented on a bow-tie antenna. The bow-tie antenna can, thus, be regarded as a compact antenna and it can provide multi-band operation. In this project, we design the bow-tie antenna using several soft computation techniques.

II. SOFT COMPUTING TECHNIQUES INVOLVED IN BOW TIE ANTENNA OR MICRO STRIP PATCH ANTENNADESIGN

The various soft computation techniques used to find out the dimensions of the bow-tie patch antenna are as follows –

2.1 Artificial Neural Networks (ANN)-Artificial Neural Networks (Anns) is an important processing paradigm that is inspired from the biological nervous system, such as brain. It is composed highly inter connected processing elements called as neurons. Artificial Neural Networks (Anns), like people learn from example. A neural network is an artificial representation of the human brain. It tries to simulate its learning process. The term artificial means that neural networks are implemented in computer programs that are able to handle the large number of necessary calculations during the learning process. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons.

2.2 Fuzzy Inference System

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves membership functions, logical operations, and if-then Rules. You can implement two types of fuzzy inference systems in the toolbox: Mamdani-type and Sugeno-type. Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modelling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy systems

2.3 Particle Swarm Optimization

The PSO was originally designed by Kennedy and Eberhart. The technique involves simulating social behaviour among individuals (particles) "flying" through a multidimensional search space, each particle representing a single intersection of all search dimensions. The particles evaluate their positions relative to a goal (fitness) at every iteration, and particles in local neighbourhood share memories to adjust their own velocities and thus subsequent positions. PSO is basically developed through simulation of bird flocking in two dimension space. The position of each agent is represented by XY-axis position and also, the velocity is expressed by Vx (the velocity of x-axis) and Vy (the velocity of y-axis). Modification of the agent position is realized by the position and velocity information. Bird flocking optimizes a certain object function. Each agent knows its best value so, far (pbest) and its XY position. This information is analogy of personal experiences of each agent. Moreover, each agent knows the best value so far in the group (gbest) among bests

2.4 Genetic algorithm (GA) – GA can be defined as a search heuristic and it mimics the process of natural selection. It is a global optimization algorithm derived from evolution and natural selection. This heuristic or a meta-heuristic is used to generate useful solutions to optimization and search problems. Genetic algorithms belongs to the larger class of evolutionary algorithms, which generate solutions to optimization problems using techniques such as inheritance, mutation, selection, and crossover i.e. the techniques inspired by natural evolution. Genetic algorithm finds application in bio-informatics, computational science, engineering, Economics, chemistry, manufacturing, mathematics, physics, and several other fields. Genetic algorithms are inspired by Darwin's theory about evolution. Solution to any problem solved by genetic algorithm process is evolved. Although genetic algorithm cannot always provide optimal solution, it has its own advantages and is a powerful tool for solving complex problems. In this antenna design, genetic algorithm is used to findout the various bow-tie antenna parameters such as its length and the width. Genetic algorithm technique is utilized to find out the fittest or the optimum solution of each of these parameters. Using the values of the dimensions obtained from the technique, the antenna can be developed using IE3D software.

2.5 Adaptive Neuro Fuzzy Inference System (ANFIS) – ANFIS is a kind of artificial neural network that is based on Takagi-Sugeno fuzzy inference system. Since it integrates both neural networks and fuzzy logic principles, it has potential to capture the benefits of both together in a single framework. Using a given input/output data set, the toolbox function ANFIS constructs a fuzzy inference system (FIS) whose membership function parameters are adjusted or tuned using either a back propagation algorithm alone, or in combination with a least squares type of method. In the simulation, the ANFIS architecture is employed to model non-linear functions, identify non-linear components online in a control system, and predict a time series, all yielding results. In this technique, a sequence of data is trained i.e. a training sequence is developed. Using this training sequence, optimized value of the output parameter corresponding to the respective input parameter can be obtained. Let us suppose that a sequence of resonant frequencies are trained corresponding to the length of the antenna.

The ANFIS technique gives us the optimized value of resonant frequency corresponding to any length within the limits of the training sequence. Then, the antenna can be designed using IE3D software and the resonant frequency corresponding to that particular length can be checked.

2.6 A hybrid technique consisting both ANFIS and Genetic Algorithm (ANFIS-GA) – As the name suggests, this technique is a mixture of both the optimization techniques already used to design the bow-tie antenna. Genetic algorithm, here, is used to find out the dimension of the bow-tie patch antenna. It employs fitness function and various constraints to find out the optimum solution of the required dimension. An ANFIS code is developed in which sequence of output parameter is trained corresponding to the dimension of the antenna. Then for a particular value of the dimension, the output parameter is obtained. The antenna is, then,

designed using IE3D software and the validity of result obtained from the hybridization technique is checked.

2.7 A hybrid bacterial swarm optimization and nelder-mead (BSO-NM) algorithm

2.7.1 Nelder-Mead (NM) Algorithm

A simplex method for finding a local minimum of a function of several variables has been devised by Nelder and Mead. It is the most popular direct search method since it does not require the calculation of derivatives. The Nelder-Mead method is described for the minimization of a function of n variables, which depends on the comparison of function values at the $(n + 1)$ vertices of a general simplex. The function values are found at each of these points. The points with the low (PL), high ($P1$), and second high ($P2$) function values are determined. Next, the centroid of the points except $P1$, ¹ P, is determined to replace the vertex with the highest value by another point. The simplex method essentially has four steps possible during each iteration: Reflection, contraction in one dimension, contraction around the low vertex, and expansion.

2.7.2 Bacterial Swarm Optimization (BSO) Algorithm

II.The idea of BFA is based on the fact that natural selection tends to favour animals having successful foraging strategies and eliminate animals with poor foraging strategies or reshape into good ones after many generations. This activity of foraging inspired the researchers to utilize it as a novel optimization tool. The Escherichia coli bacteria present in human intestines also practice a foraging strategy. The control system of the E. coli bacteria governing their foraging process can be subdivided into four sections, which are chemo taxis, swarming, reproduction and elimination and dispersal. The BSO algorithm combines PSO and BF techniques in order to make use of PSO ability to exchange social information and BF ability in finding a new solution by elimination and dispersal. Where, after undergoing a chemo tactic step, each bacterium also gets mutated by a PSO operator. In BFA, a unit length direction of tumble behaviour is randomly generated; random direction may lead to delay in reaching the global solution. However, in the BSO, the unit length random direction of tumble behaviour is decided by the global best position and the best position of each bacterium.

II. REVIEW OF RELATED WORK DONE

F.F.Dubrovka, et al. [2008] have presented in their study A novel efficient combination of genetic algorithms and inversion of neural networks to be applied for the optimized design of UWB planar antennas with respect to return loss and gain. The goal of the optimization is achieved by properly modifying the radiating contour profile of the conventional triangular taper of the bow-tie antenna. The key feature of the optimization is an inversion of Artificial Neural Networks (ANN) with a modular architecture using Genetic Algorithm (GA). An optimized prototype antenna shows a good impedance matching (return loss < -10 dB) and gain performance (increase from 2 to 5 dB) over the whole frequency range.

K. R. Mahmoud [2010] presented a hybrid approach involving Bacterial Swarm Optimization (BSO) and Nelder-Mead (NM) algorithm. The proposed algorithm is used to design a bow-tie antenna for 2.45 GHz Radio Frequency Identification (RFID) readers. The antenna is analyzed completely using Method of Moments (MoM), and then the MoM code is coupled with the BSO-NM algorithm to optimize the antenna. The BSO-NM algorithm has produced results better than those generated by standalone BFA and BSO. The performance also appears to be slightly better than the BFA-NM algorithm. Finally, it is anticipated that the introduced hybrid approach is very efficient and can be applied to other types of antennas and for adaptive arrays.

Aarti Gehani,et al. [2011]Designed a circularly polarized elliptical patch antenna using artificial neural networks (ANN) and Adaptive Neuro-fuzzy inference system (ANFIS). The resonant frequency and gain are taken as the input while the radius of semi-major axis and heights of the substrate are taken as the outputs. From the numerical results, it is observed that the errors in the output parameters are less in case of an ANFIS model as compared to that of an ANN model. With ANFIS model, a parametric study with different types and numbers of membership functions is also presented. For the present design, '*gauss'* type of membershipfunction gives relatively better results. Also, in case of ANFIS, as the number of membership function increases, the errorreduces. The ANFIS model requires less time and is accuratein prediction. Thus, for antenna problems, ANFIS technique issimple, easy to apply, very useful and efficient once trained.

Abbas Ali Heidari, et al. [2011] Described a method based on combining Adaptive Neuro Fuzzy Inference Systems (ANFISs) and Genetic Algorithm (GA) is applied for design and optimization of a circularly polarized microstrip antenna for L1 frequency band of GPS. In design process, trained ANFISs are used for estimating return loss and axial ratio. In optimization process, a proper objective function is defined and minimized with GA in order to obtain optimum physical parameters. The optimization method is much faster than conventional optimization methods. Both simulation and measurement results confirm the accuracy and efficiency of the method.

K.V. Rop, et al. [2012] has presented an optimization method based on Adaptive Neuro-Fuzzy Inference System (ANFIS) for determining the parameter used in the design of a rectangular microstrip patch antenna. The ANFIS has the advantages of expert knowledge of fuzzy inference system (FIS) and the learning capability of artificial neural network (ANN). By calculating and optimizing the patch dimensions and the feed point of a rectangular microstrip antenna, also shows that ANFIS produces good results that are in agreement with Ansoft HFSS 13.0 simulation results.

Rop, Kimutai Victor [2013] Designed a rectangular microstrip patch antennausing adaptive neuro-fuzzy inference optimization technique. From the simulation results, it was observed that the formulated ANFIS model produces results which are in agreement with simulated data from Antenna Magus Software. The main parameters that influence the antenna design are the dielectric constant of the dielectric substrate, the feed location, patch length, and patch width. A comparison of the ANFIS model simulation with the Antenna Magus simulation and the theoretical results shows that there is a minimal difference of about 3% in the patch dimensions with ANFIS model producing an improved simulated gain. Simulating an antenna using HFSS took a significant time (about twenty eight minutes) with incidences of memory overload. These simulations were carried out on a computer with a processor of 2.2GHz core2duo and RAM of 2GB. Simulation using ANFIS took a significantly less time (6 minutes) as compared to HFSS (28 minutes) thus has the advantage of less computer time and memory usage. This demonstrated that ANFIS being fast and accurate design methodology can be used to effectively design MPAs with complex structures and other related work.

Serene Bhaskaran, et al. [2013] Presented the problem of locating feed point of an inset fed microstrip patch antenna designed for wireless communication is dealt with. The optimization is done using three techniques: Genetic Optimization (GA), Particle Swarm Optimization (PSO) and Accelerated Particle Swarm Optimization (APSO). Results obtained using all these techniques are in good agreement and are compared using convergence graphs.

The convergence graph clearly shows that APSO needs very less no of iterations to compute the same task and thus outperforms others. This is due to the fact that acceleration constants are also updated in APSO in addition to the position and velocity constants as in PSO. This reduces the time of computation and hence is faster than PSO. Thus results encourage the use of APSO for optimal design.
Joshua Madhukar Singh, et al. [2013] Presented the state of work includes the design procedure of microstrip patch antenna using PSO which shows the improved bandwidth then the conventional results, the gain is high and the s parameters graphical results shows the increase in the efficiency and wide radiation patterns detailed experimental studies can be taken up at a later stage to find out a design procedure for balanced amplifying antennas. This PSO technique gave more easy calculationin the design of microstrip patch antenna and analysis theeffect of various design parameter like dimensions (L & W)and substrate of antenna.
Vishal Davara, et al. [2014] described the different computing techniques for the design of Microstrip patch antenna. The performance of antenna is greatly influenced by the choice of technique used to design antenna. In this paper three different soft computing techniques are presented and compared. The most recently used techniques Artificial Neural Networks (ANNs), Fuzzy Logic (FL) and Adaptive Neuro-Fuzzy Inference System (ANFIS) are described. Antenna design is simulated for all three techniques and result is compared with each other. ANFIS is the most efficient technique to use. As far as number of training data set is concern ANFIS requires small data set and hence ANFIS provides optimization too.
ArkadeepJoardar, et al. [2015] have proposed a technique to design and optimize a bow-tie patch antenna with the help ofvarious soft computation techniques such as Adaptive NeuroFuzzy Inference System (ANFIS), Genetic Algorithm(GA) and a hybrid technique consisting of both ANFIS and GA. The codes for the different soft computationtechniquesare developed using the MATLAB software. All results of the antenna are tested on software platform. Thesoftware used is IE3D (Integral Equation in Three Dimension) software of Mentor Graphics. The aim of this work is tostudy and observe resonant frequency, directivity, gain and efficiency obtained by designing the bow-tie patch antennawith the help of the different optimization techniques and to determine which technique gives the most effectiveantenna. After that it has also been observed that all thesoft computation techniques give good results in terms ofthe output parameters. While the ANFIS technique gives the most directive antenna, more gain is obtained using thegenetic algorithm technique. However, the hybrid modelconsisting of both genetic algorithm and ANFIS gives the most efficient antenna. So, the soft computation techniquescan be chosen by the designer according to his need.

IV. CONCLUSION

The various ways and approaches used for designing of antenna during the last decades are surveyed in this research paper. This paper is also focussed on different soft computing techniques and use of these in Antenna design problems. This work proposes a model for applying Soft Computing techniques mainly neural networks or fuzzy set theory or Genetic Algorithms or their combinations for Antenna Design problem. After the reviewed previous work deeply, ANFIS, PSO and A hybrid technique consisting both ANFIS and Genetic Algorithm (ANFIS-GA) techniques is the most efficient technique to use. But As far as number of training data set is concern ANFIS requires small data set and the ANFIS model requires less time and is accuratein prediction. Thus, for Bow-Tie antenna problems, ANFIS technique issimple, easy to apply, very useful and efficient once trained. Hence ANFIS provides optimization too.

V. FUTURE WORK

My future work is mainlyto design & optimization of Bow-Tie antenna using Adaptive Neuro Fuzzy Inference System (ANFIS)with improved Bandwidth & Gain then the conventional results.

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