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Modeling the mutual coupling of circular DRA MIMO array using Artificial Neural Networks

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Abstract: A circular Dielectric Resonator Antenna (DRA), operating at the resonant frequencies 7.4GHz and 8GHz is developed for a two element Multiple Input Multiple Output (MIMO) system. The proposed antenna gives an impedance bandwidth of 20%, which is suitable for UWB applications. The mutual coupling between the two antennas is modelled by using the computational tool, Artificial Neural Networks. The neural structure is trained by using different ANN algorithms and a comparative study is made between them. It is shown that, Quasi Newton and Quasi Newton MLP algorithms are better in terms of training, testing errors and correlation coefficient. The mutual coupling is shown to reduce as the separation between the two antennas is increased. The neural network generated data and EM simulator data are compared for a separation of 10mm and a small variation of 1 dB in the mutual coupling is observed.

Keywords: DRAs, MIMO systems, Artificial Neural Networks, mutual coupling, impedance bandwidth.

I. INTRODUCTION

The Multiple input multiple output **(**MIMO) technology is the latest paradigm for achieving very high bandwidth efficiencies and larger data rates in modern wireless communications. The MIMO technology was first proposed by the pioneer Foschini [1]. In MIMO technology multiple antennas are placed at the transmitting and receiving side of a communication system to improve the data rates.

In a MIMO system, mutual coupling between the antennas is the major area of interest for research. This mutual coupling arises when the antennas are closely spaced in the MIMO system, which deteriorates the performance of the system. When the antennas are spaced at smaller distances, the electromagnetic waves of nearby antennas interfere with each other resulting in signal loss. The mutual coupling is one of the important parameters that describe the amount of interference between the elements of the array, and the main goal of any antenna design for a MIMO system is to reduce this mutual coupling. The affect of mutual coupling on the channel capacity of MIMO channels is studied in [2]. The main sources of this mutual coupling are studied in [3] and [4].

Dielectric Resonator Antennas (DRA) are the modern antennas used in many wireless applications [5]. In these antennas a dielectric material of high dielectric permittivity is used for radiation purpose. The main advantage of these antennas is their higher impedance bandwidth and lower mutual coupling compared to the traditional microstrip antennas. Hence, in the present study these dielectric antennas are taken for analysing the mutual coupling between them.

The Mutual Coupling between the elements of a dielectric resonator antenna (DRAs) has been studied previously by some researchers [6-7].

Artificial Neural Networks (ANNs) are the latest computational tools, which process the information with their design inspired by the ability of the human brain to learn from observations, experience and to generalize by abstraction [8]. The neural networks can be trained to learn any nonlinear input–output relationships from corresponding data, which resulted their use in a number of areas such as speech processing, control, biomedical engineering, pattern recognition, etc. The beauty of ANNs is their versatile use in RF and microwave Computer-Aided Design (CAD) problems [9]. A neural network model for microwave device/circuit can be developed from measured/simulated or calculated microwave data, through a process called training. Once the ANN model is fully developed, the computation time is usually negligible and much faster than any single full-wave EM simulator. Though a considerable effort is required in developing an ANN model, it is worthy doing so if repeated design analysis and optimization is required. This is the main reason for selecting the ANN tool to analyze the mutual coupling in circular DRA MIMO array.

In the present paper, a circular DRA MIMO array, resonating at 7.4GHz and 8 GHz frequencies is developed. The proposed system is shown to give an impedance bandwidth of 20%. The mutual coupling developed between the two antennas is studied for various separations using

Artificial Neural Networks. The ANNs are trained with different training algorithms and it is shown that, Quasi Newton and Quasi Newton MLP algorithms are better in terms of testing error and correlation coefficient.

II. ANTENNA ARRAY DESIGN

Two identical circular DRAs with each antenna radius 8.3 mm and a height of 6.8 mm were modelled using FEKO simulator. The separation between the two antennas is initially taken as 10 mm, as shown in the Fig.1. The two antennas were fed at the centre with a coaxial probe of impedance 50Ω. Both the antennas are placed on a finite conducting plane, which acts as the ground.

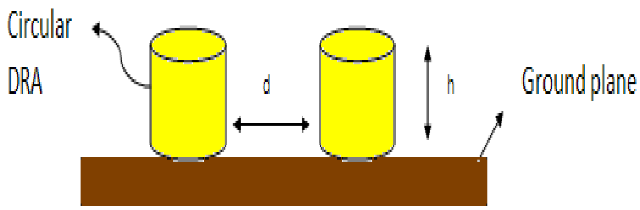

Figure.1. Circular DRA MIMO array

The simulated return loss and mutual coupling are shown in the Fig.2. The proposed MIMO array resonates at a dual frequency of 7.4 GHz and 8 GHz, giving an impedance bandwidth of 20%. The average mutual coupling for a separation of 10mm is observed as -15 dB at the operating frequency 7 to 9 GHz. The obtained bandwidth and isolation are adequate for many of the Wi-max applications. In the following section, the mutual coupling is analysed for various separations between the two antennas using the Artificial Neural Networks and a comparative analysis is made between different ANN algorithm approaches.

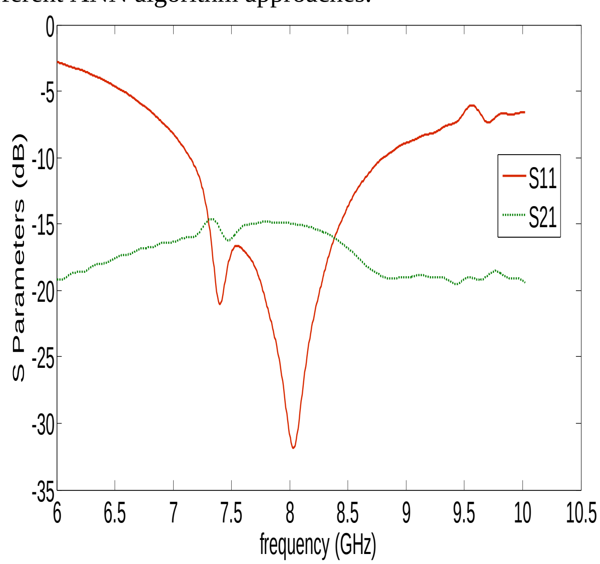

Figure.2. S parameters of the proposed DRA MIMO array

III. ANN MODEL FOR ANALYSING THE MUTUAL COUPLING BETWEEN TWO ANTENNAS

The neural model shown in Fig.3 is used for calculating the mutual coupling between the antennas. The distance'd' between the two antennas and the operating frequency 'f' are given as the inputs to the neural network structure. The S parameters S_{11} and S_{21} are taken as the outputs. The parameters S_{11} represents the return loss of the antenna system and S_{21}represents the mutual coupling between the two antennas.

ANN models are a kind of black box models and their accuracy depends on the amount of data presented to it during training. A well-distributed, sufficient, and accurately simulated or measured data is the basic requirement to obtain an accurate model. For microwave applications, the data can be obtained either by simulations or measurements.

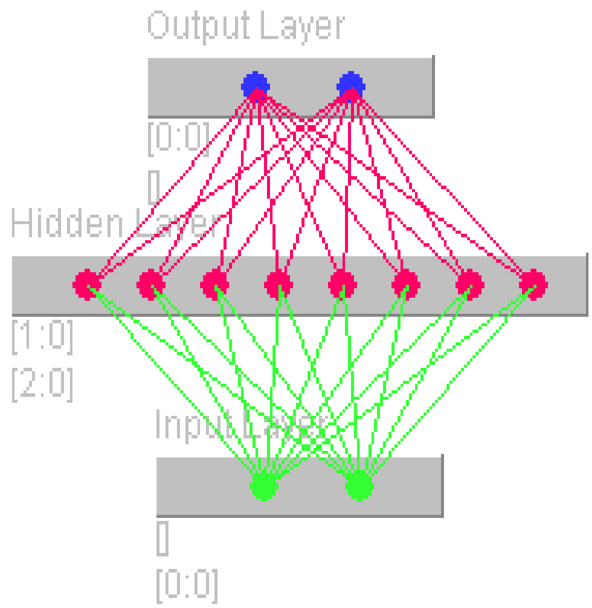

Figure.3. Neural Network structure

The data sets used in this paper were obtained from the simulation software FEKO and contain 3500 samples. For training, 2500 samples are used and for testing 1000 samples are used. The NN's are trained with a learning rate of 0.25 for 1000 epochs. The main aim of the training process is to minimize the error between the target output and the actual output of the ANN. Selection of training parameters and the entire training process mostly depend on experience besides the type of problem at hand. After several trials, it was found that the above mentioned three layered network achieved the task in high accuracy

The neural model for the modeling of mutual coupling is trained with nine learning algorithms namely, Back Propagation (BP), Sparse Training (ST) , Conjugate Gradient (CG), Adaptive Back Propagation (ABP), Quasi-Newton MLP (QN-MLP), Quasi-Newton(QN), Huber-Quasi-Newton (HQN), Auto Pilot (MLP3) and Simplex Method (SM).

The training and testing errors obtained in modeling the mutual coupling of the given circular MIMO DRA array are given Table I. From the results, it is evident that QN (Quasi Newton) and QNMLP (Quasi Newton Multi Layer Perceptron) algorithms yield better results compared to the other algorithms. Both the algorithms are shown to give minimum training and testing errors and maximum correlation coefficients. The correlation coefficient describes the amount of correlation between the trained and tested data.

As the QN algorithms are giving better results, these are used for modeling the mutual coupling between the two antennas by varying the distance between them. The range of the distance'd' between the two antennas is selected in the range 5 to 10mm and the results are obtained using neural network structure as shown in Fig. 4. From the results, it is evident that the mutual coupling between the antennas is reduced as the distance between them is increased. This is obvious, as the distance between the antennas is increased, the interaction of the EM fields between the antennas reduces thus reducing the mutual coupling. The plot of mutual coupling for different frequencies is shown in Fig. 5.

Table I. Comparison of training and testing errors with various algorithms

Learning Algorithms	Training Error
ABP	0.0311457
AP	0.02509138
BPMLP3	0.03386
CG	0.03113
HQN	0.02509
QN	**0.02645**
QNMLP	**0.02645**
SM	0.02657
ST	0.03128

Learning Algorithms	Testing		
	Avg. Error	Worst Case Error	Correlation Coefficient
ABP	3.0302	52.38	0.9947
AP	2.45518	50.99	0.9950
BP	3.3224	53.09	0.9946
CG	3.0302	52.38	0.9947
HQN	2.4451	50.99	0.9950
QN	**2.5482**	**48.88**	**0.9956**
QNMLP	**2.5482**	**48.88**	**0.9956**
SM	2.5801	50.06	0.9955
ST	3.0465	52.18	0.9947

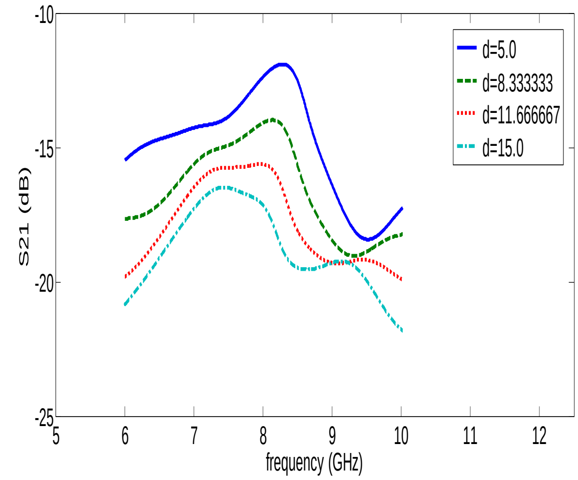

Figure. 4. Mutual coupling generated by the neural network for different values of d

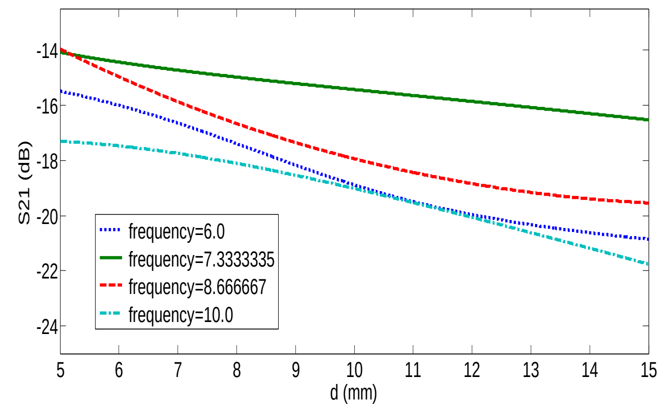

Figure. 5. Mutual coupling generated by the neural network for different frequencies

In order to validate the performance of the given neural network structure, a comparison is made between the neural network generated and EM simulated mutual coupling for d= 10mm as shown in Fig.6. From the figure, it is evident that the neural network generated data almost traces the EM generated data except at the sudden peaks, giving a variation of around 1 dB, which is tolerable for all practical purposes.

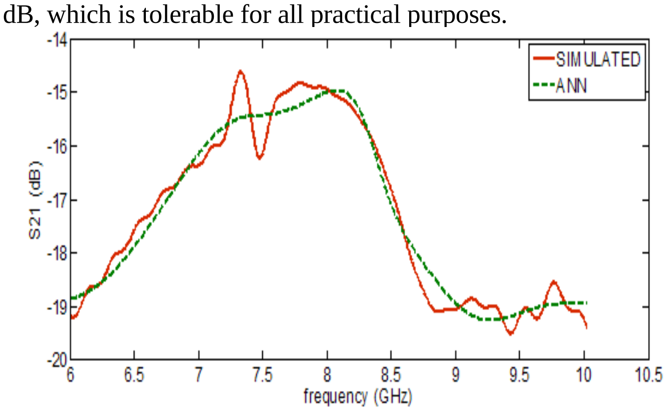

Figure.6. Comparison of mutual coupling for a separation of 10mm using ANN generated and EM simulated data.

IV. CONCLUSIONS

A circular MIMO DRA array resonating at the frequencies 7.4 GHz and 8 GHz is developed. The proposed antenna gives an impedance bandwidth of 20%. The mutual coupling between the antennas is studied by using Artificial Neural Network structure with varying the distance between the antennas. The neural structure is trained with different training algorithms and the better results in terms of training, testing error and correlation coefficient are obtained with Quasi Newton and Quasi Newton MLP algorithms. Hence, these algorithms are used for modeling the mutual coupling between the antennas. The system performance is validated by comparing the neural network generated data and EM simulated data.

V. REFERENCES

[1] Foschini, G. J. and M. J. Gans, "On limits of wireless communications in a fading environment when using multiple antennas," Wirel. Pers. Commun., Vol. 6, 3, 311– 335, 1998

[2] Abouda, A. A. and S. G. H¨ aggman, "Effect of mutual coupling capacity of MIMO wireless channels in high SNR scenario," Progress In Electromagnetics Research, PIER 65, 27–40, 2006.

[3] D. E. J. Humphrey and V. F. Fusco, "A mutual coupling model for microstrip patch antenna pairs with arbitrary orientation,"Microwave Opt. Technol. Lett., vol. 18, no. 3, pp. 230– 233, Jun. 20, 1998.

[4] M. M. Nikolic, A. R. Djordevic, and A. Nehorai, "Microstrip antennas with suppressed radiation in horizontal directions and reduced coupling," IEEE Trans. Antennas Propag., vol. 53, no. 11 pp. 3469–3476, Nov. 2005 .

[5] .Aldo Petosa and Apisak Ittipiboon, "Dielectric Resonator Antennas: A Historical Review and the Current State of the Art" , IEEE Antennas and Propagation magazine , vol.52. No. 5, Oct' 2010

[6] Dorris,R.J.,R.T.Long,S.A.Long,M.A.A.Khayat,and J. T. A. Williams "Mutual coupling between cylindrical probe fed dielectric resonator antennas," IEEE Antennas and Wireless Propagation Letters, Vol. 1, 8–9, 2002

[7] Chair, R., A. A. Kishk, and L. Kai-Fong, "Comparative study on the mutual coupling between different sized cylindrical dielectric resonators antennas and circular microstrip patch antennas," IEEE Transactions on Antennas and Propagation, Vol. 53, 1011–1019, 2005

[8] Q.J. Zhang , K. C. Gupta and Vijay K Devabhaktuni, "Artificial Neural Networks for RF and Microwave Design- from theory to Practice" , IEEE Trans. Microwave Theory Tech., vol. 51, pp 1339-1350, April 2003.

[9] J.Lakshmi Narayana, Dr.K.Sri Rama Krishna and Dr.L.Pratap Reddy, "Modeling of Capacitive Membrane Shunt Switch Using ANN " International Journal of Computational Intelligence and Information Security, June 2011

