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Design and Optimization of Coplanar Capacitive Coupled Probe Fed MSA Using ANFIS

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Abstract In this paper, an optimization method based on adaptive Neuro-Fuzzy inference system (ANFIS) for determining the parameters used in the design of a coplanar capacitive coupled probe fed rectangular microstrip antenna. The antenna was analyzed in the 2-10GHz range to demonstrate universal working of the proposed model. Here, an expert knowledge of fuzzy inference system (FIS) and the learning capability of artificial neural network (ANN) have been embedded (ANFIS). By calculating and optimizing the patch dimensions of a rectangular microstrip antenna with air gap, this paper shows that ANFIS produces good results that are in agreement with the mathematical analysis of the design parameters of antenna. Of the parameters considered for optimization, the error difference (average) between the proposed model and the calculated data is 0.21% for L, 0.41% for W, and 0.2% for air gap which are less than 0.5% and acceptably low.

Keywords: *ANFIS, Patch W, Air gap g, Patch L, Wireless Communication*

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1. Introduction

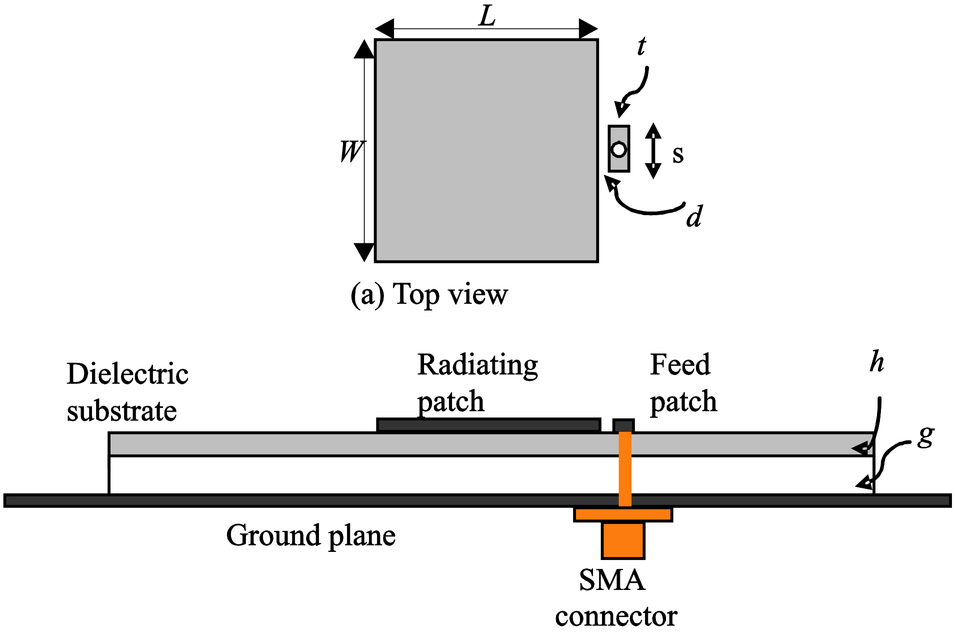
Various wireless electronic systems are improved and also reduced into sizes and weights due to the development of modern integrated circuit technology. In many wireless communication systems, there is a requirement for low profile antennas as these antennas are less obstructive and in addition, snow, rain, or wind has less effect on their performance. Therefore, in many application, Microstrip antennas (MSAs) are used such as high performance aircraft, spacecraft, satellites, and missiles, where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints [1,2,3]. The radiating patch may be square, rectangular, circular, triangular, and any other configuration. In this paper, the rectangular microstrip patch antennas with small capacitive feed are considered [2]. To design microstrip patch antennas, analytical and numerical methods have been used, in the past. The analytical method, based on some fundamental simplifying physical assumptions regarding the radiation mechanism of antennas, which are the most useful for practical designs as well as for providing a good intuitive explanation of the operation of MSAs [2]. However, these methods are not suitable for many structures, in particular, if the thickness of the substrate is significant. The numerical methods are mathematically complex, and still cannot make a practical antenna design feasible within a reasonable period of time. They also, require strong background knowledge, and have time-consuming numerical calculations which need very expensive software packages.

Recently, many papers have reported various improved methods used in designing of microstrip patch antennas including the use of various forms of artificial intelligence [4-18]. However, none of these consider a capacitive feed in which probe is connected at a distance from the main radiating patch. Therefore, in this paper, a method based on the adaptive neuro-fuzzy inference system (ANFIS) is presented to effectively calculate and optimize the patch dimensions of a rectangular micro strip patch antenna with small capacitive feed. Also, many works that have been written on the same field have concentrated on optimizing only one feature (e.g. resonant frequency, patch length/width, or feed points etc.) in the design of MSA [1]. In this work we proposed a new artificial intelligence based method for calculating and optimizing the three important features in a design of an MSA; the patch length, patch width, and air gap (g). The final results are then validated with the mathematical analysis of the design parameters of antenna. Basic configuration of the antenna geometry considered for optimization is presented in Section 2. Section 3 briefly considers the architecture of adaptive neuro-fuzzy inference system. The proposed model is presented in Section 4. Results and discussions are included in Section 5. Finally, conclusions of the work carried out are included in Section 6.

2. Basic Configuration of MSA with Capacitive Feed

In capacitive feed MSA the air gap separates the substrate, on which rectangular patch is located, and the ground plane. This antenna results in substantially higher bandwidth than the conventional rectangular MSA. The smaller dimension of capacitive feed improves the bandwidth as well as reduces the spurious radiations. Furthermore, this feed approach works well with conventional geometries such as rectangular and triangular patches and offers the impedance bandwidth close to 50% [2]. The ultra-wideband devices are those having a -10dB fractional bandwidth of at least 20 % in the range of 3.1-10.6 GHz. More details (theory, design, analysis, and comparisons) on this geometry can be found in [2,19].

Figure 1 shows the geometry of the suspended RMSA with capacitive feed, where the larger patch works as the radiator and the smaller patch serves as a feed strip which couples the energy to the radiator by capacitive means [2]. In the basic configuration rectangular patch is used for both radiator and feed strip. The antenna substrate is placed above the ground plane at a height equal to air gap. The maximum bandwidth can be obtained with the help of this height. Detailed conventional design procedure and analysis for any frequency of interest for coplanar capacitively coupled probe fed UWB microstrip antenna can be found in [2].



(b) Cross sectional view

Figure 1. Geometry of rectangular patch antenna with capacitive feed [2]

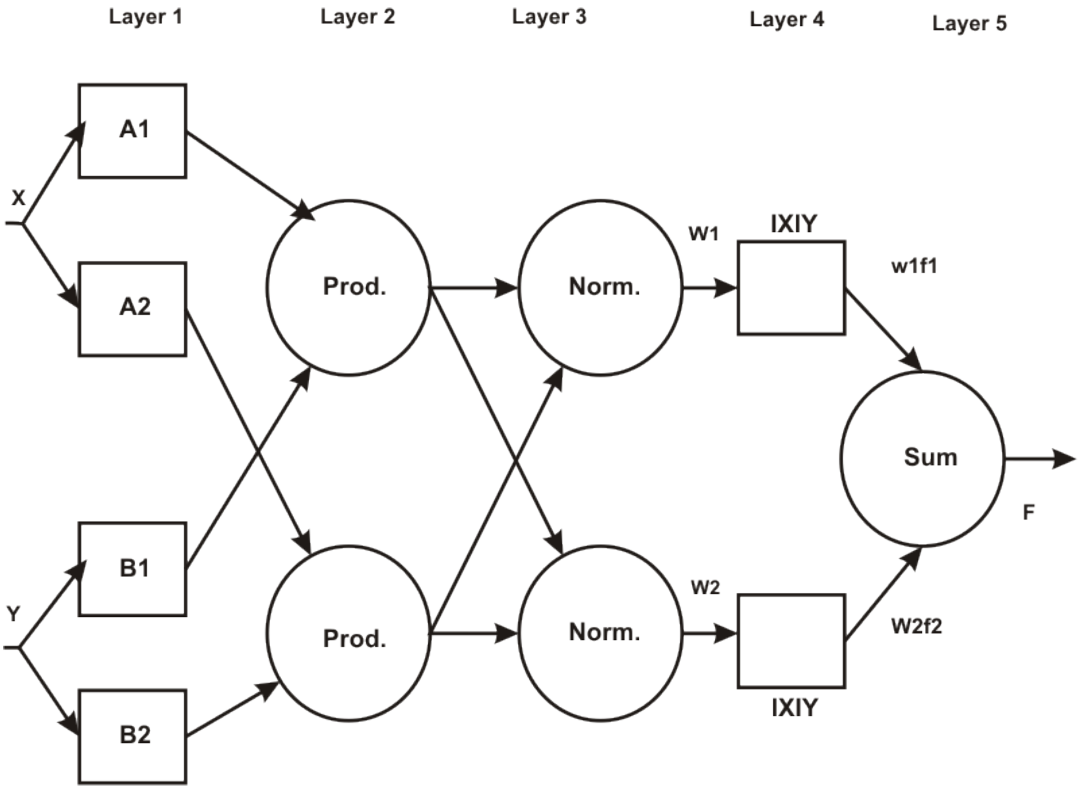


Figure 2. Architecture of ANFIS

3. Architecture of Adaptive Neuro-Fuzzy Interference System (ANFIS)

ANFIS network is organized into two parts like fuzzy systems. The first part is the antecedent and the second part is the conclusion, and the two are connected together by rules to form a network. The ANFIS architecture consists of five layers namely; fuzzy layer, product layer, normalized layer, de-fuzzy layer, and summation (total output) layer as shown in Figure 2. In the figure, a circle indicates a fixed node, whereas a square indicates an adaptive node. Assuming that the fuzzy inference system under consideration has two inputs x and y, and one output z. Based on a first-order Sugeno model [3], a typical rule set with two fuzzy if-then rules can be expressed as;

Rule 1: If x is A_1 and y is B_1, then $f_1 = p_1x + q_1y + r_1$ (11)

Rule 2: If x is A_2 and y is B_2, then $f_2 = p_2x + q_2y + r_2$ (12).

Where, A_1, B_1, A_2 and B_2 are fuzzy sets, p_i, q_i and r_i (i = 1, 2) are the coefficients of the first-order polynomial linear functions. More details on all five layers of ANFIS can be found in [3,8,9,14].

4. Application of ANFIS in the Design

It is well known that ANFIS uses a set of data for training of its network. There are two types of data generators (measurements and simulations) for antenna applications. The selection of a data generator depends on the application and the availability of the data generator. In this work, the ANFIS model shown in Figure 3 with the inputs: substrate height (h), resonant frequency (f_r), and dielectric constant (ε_r), and the outputs: patch width (W_t), patch length (L_t), and the feed point along the width and length (Y_f, X_f) respectively.

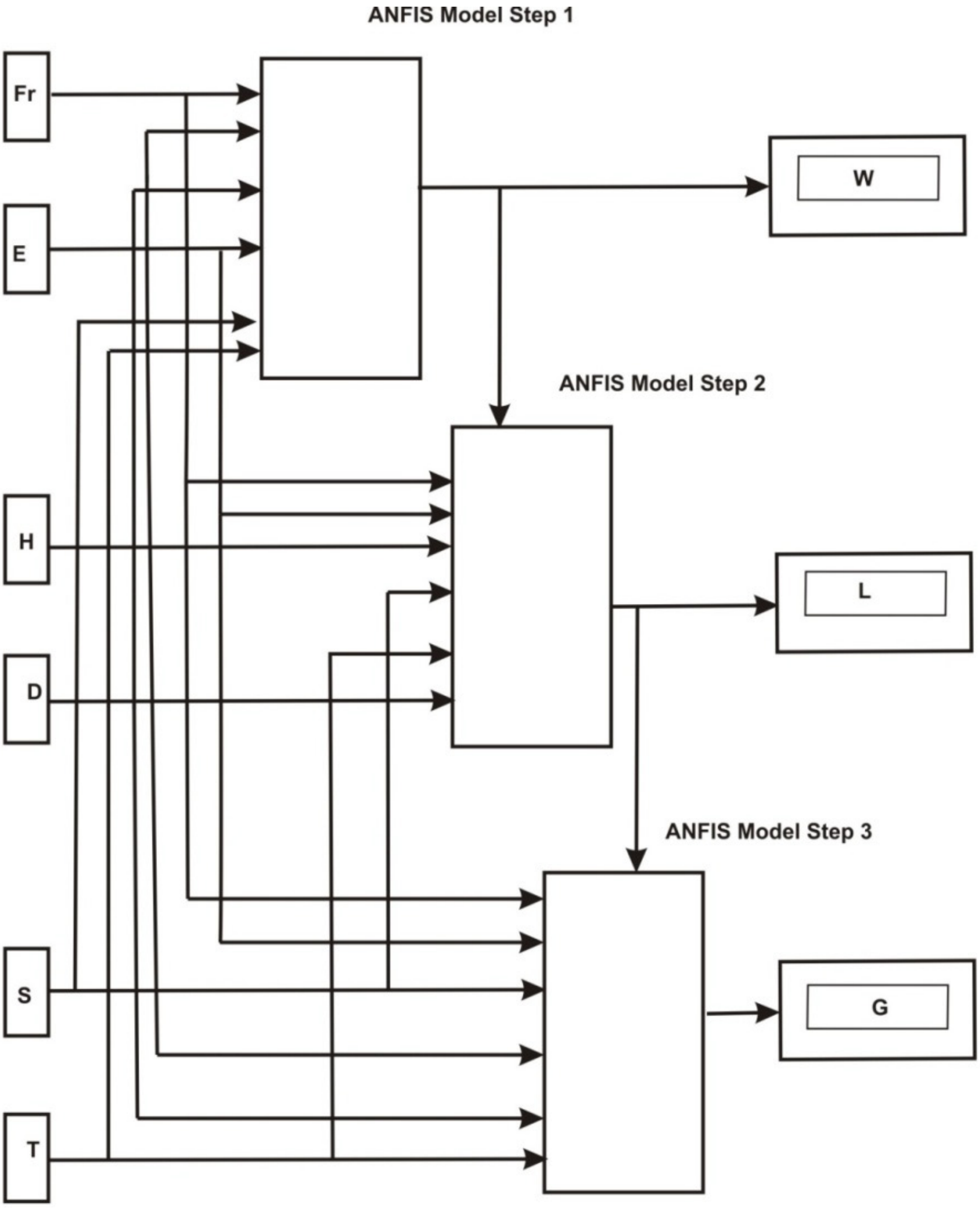


Figure 3. ANFIS model for design of rectangular MSA with air gap

The ANFIS can simulate and analyze the mapping relation between the input and output data through a learning algorithm so as to optimize the parameters used in design of microstrip antennas. The training and test data sets used in this work have been obtained from both simulations and previous experimental works which are already reported in literature [2].

As shown in Figure 3, the ANFIS model used in this work is having four stages. In the first stage, resonant frequency, dielectric constant, and substrate height are used in optimizing the patch width (*W*) of the antenna. A total of 90 and 18 data sets were used for training and testing respectively. The membership functions (MFs) for the input variables f_r, ε_r, and *h* are 4, 3, and 3, respectively. The number of rules is then 36 (4x3x3) and the number of epochs is specified as 700. In the second stage, the antenna patch length (*L*) is optimized. The three input variables used in first stage are maintained with the addition of the optimized patch width (W_t) as an input variable, and therefore, variables f_r, ε, *r* , *h*, and W_t were used as inputs with *L* as the output variable to be optimized. As stated earlier a total of 90 training data sets and 16 testing data sets were used in this stage.

The MFs for the input variables f_r, ε *r* , *h*, and W_t are 4, 2, 2, and 4 respectively thus, the number of rules is 64 (4x2x2x4) with the number of iterations specified as 700. The third stage in the ANFIS model is used for optimizing the feed point (Y_f) along the patch width. In this stage, the number of epochs is specified as 600 with 90 testing data sets and 15 testing data sets used.

The variables f_r, W_t, and L_t are used as inputs with the MFs as 3, 4, and 4, respectively. With 50 testing data sets, the number of iterations was specified as 500. As stated in earlier paragraphs, the input variables f_r, W_t, and L_t were allocated each with the MFs values as 3, 4, and 4 respectively, making the number of rules as 48 (3x4x4). The geometry parameters variations such as patch length (*L*), patch width (*W*), and airgap (*g*) versus frequency are indicated in Figure 4. As expected these parameters keep on decreasing with respect to increase in the frequency.

5. Results and Discussions

Training and testing of data sets was carried out by using ANFIS implemented in MATLAB platform. Also, the values of various MSA parameters namely patch width, patch length, and air gap are calculated by mathematical formulas. Finally, ANFIS optimized data were validated with previously reported works [2]. Table 1 shows a representative of the data sets obtained by using both ANFIS (MATLAB) and calculations. All data indicated in the table indicate that ANFIS calculates and optimizes the parameters effectively and agree with the calculated results. The error difference between the ANFIS and calculated results for the patch width is equal to 0.41% (average). Similarly, for patch length and airgap these values are 0.21%, and 0.2% which clearly demonstrate that overall error percentage is less than 0.5% and acceptably low and also demonstrates how effective ANFIS is in producing results close to calculated data.

6. Conclusions

This paper presented the procedure of optimization of parameters of coplanar capacitive coupled probe fed rectangular MSA with air gap. The average error difference between the ANFIS and calculated results for the patch width is found to be 0.41%. Similarly, for patch length and airgap these values are 0.21% and 0.2% respectively, and which clearly demonstrate that overall error percentage is less than 0.5% for all the cases considered. On comparing these data with calculated ones, it is clear that the ANFIS produces results which are in good agreement with the values reported in earlier works. As the traditional method of analyzing design parameter is complex and hence the optimization with ANFIS provides great simplified method for obtaining design parameters. Also, use of ANFIS in determining the design parameters are the fast and accurate than that of traditional methods.

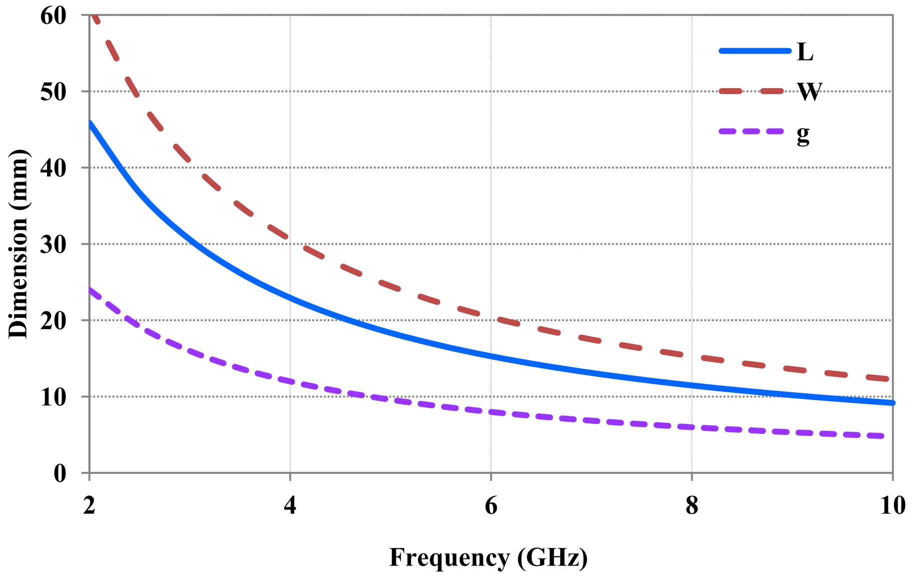


Figure 4. Geometry parameters variations vs. frequency

Table 1. A representative of input variables, ANFIS output, and calculated output data

Inputs						ANFIS Output [This work]			Calculated Output [2,19]		
f	e	h	d	s	t	W	L	g	W	L	g
2.16	2.1	1.67	0.5	6.2	1.8	55.32	42.29	22.07	55.7405	42.5276	22.2044
2.18	2.1	1.67	0.5	6.2	1.8	54.87	41.96	21.9	55.2292	42.1375	22.007
2.23	3.2	1.78	0.5	6.2	1.8	46.64	41.66	21.44	46.3849	41.794	21.5066
2.27	3.8	2.48	0.5	6.2	1.8	42.61	41.41	21.16	42.6245	41.3305	21.2259
2.92	3.5	1.89	0.5	6.2	1.8	34.07	31.89	16.35	34.2229	32.0267	16.4234
2.92	3.7	2.32	0.5	6.2	1.8	33.42	32.07	16.4	33.4868	32.0961	16.4225
3.17	2.4	1.87	0.5	6.2	1.8	36.19	28.88	15.03	36.2666	29.1028	15.1286
3.17	2.6	1.98	0.5	6.2	1.8	35.22	29.02	15.05	35.2448	29.1818	15.1283
3.17	2.8	2.23	0.5	6.2	1.8	34.35	29.23	15.11	34.3048	29.2574	15.1277
3.28	3.4	2.45	0.5	6.2	1.8	30.73	28.31	14.53	30.811	28.4794	14.6195
3.28	3.6	2.36	0.5	6.2	1.8	29.99	28.4	14.54	30.1337	28.5425	14.6195
3.69	3.2	1.68	0.5	6.2	1.8	27.87	25.18	12.95	28.032	25.2573	12.9961
3.92	2.2	1.77	0.5	6.2	1.8	30.16	23.37	12.19	30.2305	23.4677	12.2338
4.24	2.2	1.56	0.5	6.2	1.8	28.18	21.85	11.39	27.9489	21.6966	11.3106
4.24	2.4	1.68	0.5	6.2	1.8	27.33	21.87	11.37	27.1144	21.7583	11.3103
4.42	3.3	1.76	0.5	6.2	1.8	23.42	21.26	10.93	23.1286	21.1101	10.849
4.58	3.9	1.85	0.5	6.2	1.8	21.13	20.62	10.53	20.9094	20.5057	10.4694
4.75	3.4	2.42	0.5	6.2	1.8	21.54	19.74	10.13	21.2758	19.6654	10.0938
4.78	3.6	2.48	0.5	6.2	1.8	20.9	19.61	10.04	20.6775	19.5851	10.0302
4.86	2.3	2.24	0.5	6.2	1.8	24.19	19.04	9.912	24.0111	18.9555	9.8663
5.08	2.5	2.47	0.5	6.2	1.8	22.42	18.09	9.398	22.3053	18.1848	9.4384
5.08	2.4	1.57	0.5	6.2	1.8	22.86	18.32	9.532	22.6309	18.1598	9.4383
5.32	2.3	1.83	0.5	6.2	1.8	21.94	17.25	8.984	21.935	17.3166	9.0135
5.53	2.5	1.66	0.5	6.2	1.8	20.56	16.7	8.677	20.4902	16.7054	8.6713
5.68	3.1	1.71	0.5	6.2	1.8	18.59	16.51	8.505	18.4317	16.3886	8.4418
5.68	3.2	1.78	0.5	6.2	1.8	18.36	16.52	8.498	18.211	16.408	8.4417
5.86	3.5	1.81	0.5	6.2	1.8	17.2	16.09	8.347	17.053	15.9582	8.1821
6.07	3.8	2.12	0.5	6.2	1.8	16.11	15.56	7.947	15.9403	15.4557	7.8981
6.19	2.7	1.69	0.5	6.2	1.8	18	15.1	7.815	17.8039	14.9637	7.7463
6.33	2.9	1.72	0.5	6.2	1.8	17.23	14.89	7.686	16.9578	14.6699	7.5748
6.33	3.1	1.84	0.5	6.2	1.8	16.83	14.94	7.69	16.539	14.7056	7.5745
6.58	3.4	2.14	0.5	6.2	1.8	15.72	14.41	7.395	15.3587	14.1959	7.2858
6.69	3.9	2.32	0.5	6.2	1.8	14.54	14.15	7.226	14.3147	14.0377	7.1653
6.97	3.8	2.33	0.5	6.2	1.8	14.11	13.56	6.93	13.882	13.4597	6.8774
7.12	2.2	2.41	0.5	6.2	1.8	16.74	13.01	6.778	16.6437	12.9197	6.7333
7.32	2.6	2.39	0.5	6.2	1.8	15.45	12.71	6.59	15.2631	12.6366	6.549
7.32	3.3	1.37	0.5	6.2	1.8	14.18	12.86	6.605	13.9656	12.7466	6.5504
7.54	3.7	1.57	0.5	6.2	1.8	13.05	12.47	6.381	12.9684	12.4294	6.3586
7.54	3.6	1.75	0.5	6.2	1.8	13.18	12.45	6.375	13.1086	12.4159	6.3583
7.77	2.4	1.83	0.5	6.2	1.8	14.81	11.86	6.162	14.796	11.8728	6.1705
7.93	2.3	1.53	0.5	6.2	1.8	14.71	11.59	6.035	14.7155	11.617	6.0465
8.17	2.7	1.63	0.5	6.2	1.8	13.56	11.32	5.864	13.4891	11.337	5.8684
8.43	2.8	1.74	0.5	6.2	1.8	13	10.98	5.68	12.8999	11.0014	5.6871
8.43	2.9	1.79	0.5	6.2	1.8	12.83	10.99	5.678	12.7334	11.0152	5.687
8.68	3.2	1.85	0.5	6.2	1.8	12.03	10.73	5.524	11.9168	10.7366	5.5228
8.89	3.5	1.95	0.5	6.2	1.8	11.35	10.54	5.404	11.2408	10.5187	5.3919
8.89	3.7	2.41	0.5	6.2	1.8	11.03	10.54	5.388	10.999	10.5413	5.391
9.17	3.1	2.34	0.5	6.2	1.8	11.56	10.16	5.234	11.4168	10.1506	5.2267
9.17	3.3	2.24	0.5	6.2	1.8	11.29	10.19	5.238	11.1481	10.1744	5.2268
9.48	3.8	2.38	0.5	6.2	1.8	10.25	9.924	5.069	10.2065	9.8956	5.0551
9.68	3.6	2.28	0.5	6.2	1.8	10.22	9.692	4.96	10.2106	9.6706	4.9509
9.88	3.7	2.31	0.5	6.2	1.8	9.78	9.491	4.849	9.8969	9.485	4.8505
9.88	3.9	2.43	0.5	6.2	1.8	9.552	9.52	4.853	9.6928	9.5048	4.8501
9.98	3.1	2.47	0.5	6.2	1.8	10.33	9.345	4.808	10.4902	9.3266	4.8019
9.99	3.2	2.37	0.5	6.2	1.8	10.19	9.33	4.793	10.3542	9.3283	4.7972
9.99	3.8	2.49	0.5	6.2	1.8	9.459	9.405	4.798	9.6854	9.3903	4.7966

References

[1] K.V. Rop, D. B. Konditi, H.A. Ouma, and S.M. Musyoki, “Parameter optimization in drsign of rectangular microstip patch antenna using ANFIS technique,” *International Journal on “Technical and Physical Problems of Engineering*, vol. 12, no. 3, Sep. 2012.

[2] V. G. Kasabegoudar, D. S. Upadhyay, and K. J. Vinoy, “Design studies of ultra-wideband microstrip antennas with a small capacitive feed,” *International Journal of Antennas and Propagation*, vol. 2007, pp. 1-8, 2007.

[3] I. Singh et. al., “Microstrip patch antenna and its applications: a survey,” *Int. J. Comp. Tech. Appl.*, vol.2, pp. 1595-1599, 2011.

[4] K. Guney and N. Sirikaya, “Adaptive neuro-fuzzy inference system for computing of the resonant frequency of circular microstrip antennas,” *ACES Journal*, vol. 19, no. 3, pp. 188-197, 2004.

[5] N. Turker, F. Gunes, and T. Yildirim, “Artificial neural design of microstrip antennas,” *Turk J. Elec Engin, Tubitak*, vol. 14, no. 3, pp. 445-453, 2006.

[6] C. A. Balanis, *Antenna Theory-Analysis and Design*, John Wiley & Sons Inc., 2nd Edition, 1997.

[7] R.A. Saeed and K. Sabira, “Design of microstrip antenna for WLAN,” *Journal of Applied Sciences*, vol. 5, no. 1, pp. 47-51, 2005.

[8] B. Milovanovic, M. Milijic, A. Atanaskovic, and Z. Stankovic, “Modeling of patch antennas using neural networks,” *Int. Conf. on Telecommunications in Modern Satellite, Cable and Broadcasting Services (TELSIKS)*, pp. 386-388, 2005.

[9] K. Guney and N. Sarikaya, “Adaptive neuro-fuzzy inference systems for computation of the bandwidth of electrically thin and thick rectangular microstrip antennas,” *Electrical Engineering Journal*, vol. 88, pp. 201-210, 2004.

[10] N.K. Kasabov, *Foundations of Neural Networks, Fuzzy Systems, and Knowledge Engineering*, The MIT Press Cambridge, Massachusetts London, England, 1996.

[11] J. S. R. Jang, “ANFIS: adaptive-network-based fuzzy inference system,” *IEEE Transactions on Systems, MAN, and Cybernetics*, vol. 23, no.3, pp. 665-685, 1993.

[12] S. N. Sivanandam, S. Sumathi, and S. N. Deepa, *Introduction to Fuzzy Logic Using MATLAB*, Springer-Verlag Berlin Heidelberg, 2007.

[13] Z. I. Dafalla, W.T.Y. Kuan, A.M. Abdel Rahman, and S.C. Shudakar, “Design of a rectangular microstrip patch antenna at 1GHz,” *RF and Microwave Conference, Subang, Selangor, Malaysia*, pp. 145-149, 2004.

[14] A.B. Mutiara, R. Refianti, and Rachmansyah, “Design of microstrip antenna for wireless communication at 2.4 GHz,” *Journal of Theoretical and Applied Information Technology*, vol. 33 no.2, pp.184-192, 30th Nov., 2011.

[15] M. Aneesh, Jamshed A. Ansari, Ashish Singh, Kamakshi, and Saiyed S. Sayeed, “Analysis of Microstrip line feed slot loaded patch antenna using artificial neural network,” *Progress in Electromagnetic Research M*, vol.58, pp. 35-46, 2014.

[16] V. V. Thakare and P. K. Singhal, “Bandwidth analysis by introducing slots in microstrip antenna design using ANN,” *Progress in Electromagnetic Research M*, vol. 9, pp. 107-122, 2009.

[17] L. H. Manh, F. Grimaccia, M. Mussetta, and R. E. Zich, “Optimization of a dual ring antenna by means of artificial neural network,” *Progress in Electromagnetics Research B*, vol. 58, pp. 59-69, 2014.

[18] J. S. Sivia, A. P. S. Pharwaha, and T. S. Kamal, “Analysis and design of circular fractal antenna using artificial neural networks,” *Progress in Electromagnetics Research B*, vol. 56, pp. 251-267, 2013.

[19] V.G. Kasabegoudar and K.J. Vinoy, “Coplanar capacitively coupled probe fed microstrip antennas for wideband applications,” *IEEE Trans. Antennas Propagat.*, vol. 58, no. 10, pp. 3131-3138, 2010.