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Demonstrating Antenna Miniaturisation for Radiolocation Applications using Double Elliptical Patches

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ABSTRACT

Double Elliptical Micro-strip Patch Antenna (DEMPA) is developed out of Double Elliptical Patch (DEP) which is a recently proposed shape of patch. The use of DEP results in higher flexibility in design of patch antenna and thus promotes antenna miniaturisation. The present work is an attempt to demonstrate the miniaturisation of radiolocation antenna through the concept of Design Flexibility (DF). In this paper, optimised neural network model for synthesis of DEMPA has been developed for radiolocation applications for which the earmarked frequency band is 8.50 GHz – 10.50 GHz. With the help of synthesis model, for an arbitrary operational frequency of 9.85 GHz, radiolocation antennas with effective patch area ranging from 142 mm^2 to 66 mm^2 were designed by using DEPs. In this case, the percentage reduction in effective patch area was found to be 53.52%. It shows that double elliptical patches can be employed to develop miniaturised radiolocation antennas. One prototype antenna was fabricated and tested to demonstrate the efficacy of the methodology adopted. The fabricated antenna had resonance at 10.15 GHz with a reflection coefficient of -20.73dB and bandwidth of 3.106 GHz (from 7.458 GHz to 10.564 GHz). Its Fractional Bandwidth was 34.469%. Positive and reasonably good gain was maintained over the entire working band. At resonance, the peak gain was 4.22 dB.The measured characteristics of antenna were in close agreement with the simulated results. The methodology presented in this paper can also be applied to frequency bands for other wireless applications.

Keywords: Double elliptical patch; Radiolocation applications; Antenna miniaturisation; Design flexibility

NOMENCLATURE

DEP	Double Elliptical Patch
DEMPA	Double Elliptical Micro-strip Patch Antenna
DEP_{mah}	DEP for which axis of symmetry is horizontal major axis
BPNN	Back Propagated Neural Network
DF	Design Flexibility
RF	Resonant Frequency
a_1	Semi-major axis of left half-ellipse of DEP_{mah}
a_2	Semi-major axis of right half-ellipse of DEP_{mah}
d	Common minor axis of DEP_{mah}
A	Effective patch area
SDEP	Similar Double Elliptical Patch
DDEP	Dissimilar Double Elliptical Patch

1. INTRODUCTION

Double Elliptical Micro-strip Patch Antenna (DEMPA) is a newly proposed family of patch antennas in which the shape of patch is double elliptical. In a Double Elliptical Patch (DEP), only one of the two sets of half-elliptical patches contains identical members unlike in the case of Elliptical Patch (EP). Either the right and left half-elliptical patches or the top and bottom half-elliptical patches will be different. The EP is a special case of DEP, where both the sets of half-elliptical patches are identical. Compared with EP, an additional degree of freedom in design is there for DEP, which provides greater flexibility in design of patch antenna and thus leads to antenna miniaturisation. The definition and constructional details of DEP have been reported in literature[1-2]. Also, the role of DEP in reducing the effective patch area has been discussed in length in those literatures. For a DEMPA with different left and right half-elliptical patches, the percentage reduction in the effective patch area was found to be 8.33%[1] and when the top and bottom half-elliptical patches were different, the percentage reduction was 10.714%[3]. A statistical technique, called Response Surface Methodology (RSM), was employed to predict one of the performance characteristics of DEMPA, its return loss[2]. This is the only parametric study reported so far in the literature with respect to DEMPA.

More studies need to be conducted to understand the parametric relationship between the shape-related input parameters and performance characteristics of DEMPA such as resonance frequency, impedance, gain and radiation pattern. Models for analysis and synthesis of patch antenna were capable of providing much insight into its radiation behavior with respect to the change in input parameters. Soft computing techniques such as Artificial Neural Network (ANN) were helpful to develop analysis and synthesis models of patch antenna. The antenna synthesis is to determine its dimensions and antenna analysis is to find out its resonant frequencies.

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Neural network based analysis-synthesis models could establish the parametric relationship for Circular Fractal micro-strip patch Antenna (CFA), where synthesis was modelled in the forward process and analysis in the reverse process[4]. For single feed circularly polarised square patch antenna with truncated corners, an ANN based synthesis model was developed and the maximum discrepancy observed in its physical dimensions and operation frequency were within 5%[5]. A sizeable number of neural network based design and analysis of rectangular patch antenna such as[6-11] and circular patch antenna like[12-16] was reported in literature. Very few works on elliptical patch antenna also were reported[17-19]. But, so far, an ANN based study on DEMPA has not been reported.

In the present work, Back Propagated Neural Network (BPNN) model for synthesis of DEMPA was developed based on the simulated results from Ansoft HFSS. Resonant Frequency (RF) and effective patch area (A) were the input parameters and length of semi-major axis of left half-ellipse (a_1), length of semi-major axis of right half-ellipse (a_2) and length of the common minor axis (d) were the output parameters. The ranges for geometric parameters selected were such that all the resulting DEMPAs were producing resonance within 8.50 GHz – 10.55 GHz, which was the frequency band allotted to radiolocation applications by the International Telecommunication Union (ITU). It was observed from the synthesis model that for any arbitrary operational frequency within the radiolocation range, a wider range is available for corresponding patch area with which DEMPAs could be made. All these DEMPAs might be used for radiolocation applications, even though the other performance parameters such as gain and return loss may have to be compromised accordingly. However, the proposed methodology of synthesising DEMPA with patch area as one of the input parameters can be used as a powerful tool for antenna miniaturisation since it provides greater flexibility in designing/selecting the geometrical parameters for patch. This paper defines the flexibility during the process of design of patch antenna and demonstrates how the improved design flexibility due to DEP facilitates antenna miniaturisation.

2. DESIGN FLEXIBILITY FOR PATCH ANTENNA

In general, Design Flexibility (DF) improves with increase in the degrees of freedom in design[20-21]. Hence, the DEMPA possesses higher DF than the Elliptical Micro-strip Patch Antenna (EMPA). Here, the DF is defined only as the flexibility during the process of design with respect to a fixed set of requirements and not the flexibility of the product after it was fielded[22]. The fixed set of requirements essentially includes the desired operational frequency of patch antenna. Then the term DF is referred to the extent of scope for varying geometrical parameters for designing the patch. In other words, the higher the flexibility during the design of patch, the larger will be the range of patch area by using which a radiolocation antenna can be developed. Improved DF subsequently facilitates miniaturisation of patch antenna. An antenna with less effective patch area can then be designed in accordance with the other details within the fixed set of requirements.

3. DOUBLE ELLIPTICAL MICRO-STRIP PATCH ANTENNA

The DEMPA is developed out of a DEP and the classification of DEMPA may be carried out based on the type of DEPs. The DEPs may be classified as Similar DEPs (SDEP) and Dissimilar DEPs (DDEP). In SDEP, both the half-elliptical patches must have in common either the minor axis or the major axis. In DDEP, minor axis of one of the half-elliptical patches will be the major axis of other half-elliptical patch. Subsequently, the DEMPAs can be either Similar DEMPA (SDEMPA) or Dissimilar DEMPA (DDEMPA). The SDEP may be defined as the combination of two half-elliptical patches for which either a common major axis and two different semi-minor axes or a common minor axis and two different semi-major axes exist. The DDEP may be defined as the combination of two half-elliptical patches, the common axis of which is minor axis to one of the patches and major axis to the other patch. Both the SDEP and DDEP are envisioned to be having smooth and regular profiles without any abrupt change. The axis of symmetry and its orientation with respect to horizontal helps to characterise any DEP[3]. There are two axes of symmetry for an elliptical patch whereas a DEP has only one axis of symmetry. The axis of symmetry of a DEP may be oriented along horizontal or vertical directions or it may be inclined at any angle to the horizontal. If a DEP has the same common vertical minor axis and different horizontal semi-major axes, then its axis of symmetry will be lying in the direction of major axis. Similarly, the axis of symmetry of a DEP is said to be oriented along the direction of minor axis, if the DEP possesses a common horizontal major axis and different vertical semi-minor axes[3]. The DEP with its axis of symmetry lying on the horizontal major axis may be termed as DEP_{mah} . If the axis of symmetry of a DEP is oriented along its vertical major axis, then it is denoted as DEP_{mav} . More about the nomenclature related to DEP can be obtained from the authors' previous works[1-3]. The Fig. 1 shows the geometric details of $SDEP_{mah}$ and $SDEP_{mav}$ where a_1 and a_2 are the lengths of semi-major axes of left and right half-elliptical patches respectively and d is the length of minor axis.

In the present work, an EMPA proposed for UWB applications[23] has been used as the referral antenna for developing the $DEMPA_{mah}$. For this referral antenna, the major axis was horizontal and the lengths of semi-major axis and semi-minor axis were 9.0 mm and 7.0 mm respectively. In order

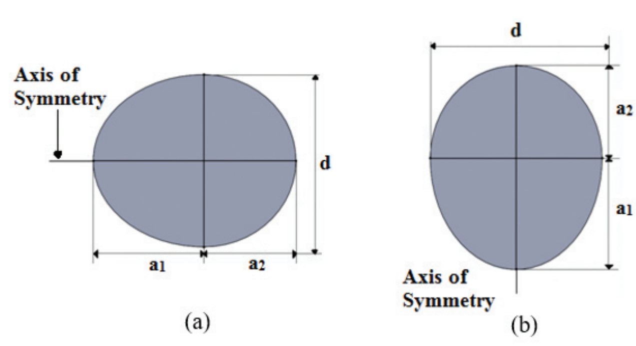


Figure 1. Geometric details of Similar DEPs (a) $SDEP_{mah}$ and (b) $SDEP_{mav}$ [3].

to maintain a common ground for performance comparison, all the design particulars of the referral antenna have been adopted for the present design, except the shape and size of its patch.

The design matrix was created by varying the geometrical parameters of $DEMPA_{mah}$ one-at-a-time. The geometrical parameters a_1, a_2 and d were varied within the ranges of 4 mm -9 mm, 4 mm - 9 mm and 7 mm - 14 mm respectively. These ranges were determined after conducting an extensive pilot study in which it was observed that the resulting DEMPAs could produce resonance within the frequency band for radiolocation applications. All these DEPs were smaller than referral elliptical patch as our effort was towards miniaturisation. A total of 138 sets of data were generated out of which 130 were used to develop BPNN model and 8 were utilised to test the model. The above numbers of training data sets and testing data sets were determined according to literature[24-25]. The effective patch area of DEP (A) was calculated by using the Eqn (1).

$$A = \frac{\pi}{2}\left(\frac{d}{2}\right)(a_1 + a_2) \quad (1)$$

Optimised neural network model was developed using Neural Network Toolbox in MATLAB. The High Frequency Structure Simulator (HFSS) from Ansoft was used to model and simulate the DEMPAs. Resonant Frequency of maximum return loss within the band of 8.50 GHz -10.55 GHz was noted down for each model. The substrate material used for the design of antenna was FR-4, with a relative dielectric constant $\varepsilon_r = 4.4$ and thickness, h=1.0 mm. The length (L) and width (W) of FR-4 substrate were 40.0 mm and 38.0 mm respectively. The micro-strip feed was provided to the DEP at the side of its common minor axis. The length of micro-strip feed line was 20.7 mm and its width was 1.6 mm. The DEP and the ground plane were designed with the same metallic material and the dimensions of ground plane were 38.0 mm and 20.0 mm respectively. Similar to the referral antenna, partial ground plane has been used here also. Except the patch shape and size, all the design details were the same as that of referral antenna[23].

4. DEVELOPING SYNTHESIS MODEL

The Fig. 2 shows the schematic of the synthesis model and Table 1 gives the corresponding training data set. A large number of combinations of number of hidden layers, number of neurons in each layer and type of transfer functions for neurons in hidden layer and output layer were systematically tried and the most appropriate network architecture among them was selected based on the criterion of possessing the minimum Mean Square Error (MSE) value. The model was optimised so as to get the highest value for the overall R. The Levenberg-Marquardt (LM) supervised learning algorithm was chosen to train the data. The architecture of optimised BPNN model for synthesis was 2-15-15-3 with transfer functions of LOGSIG-TANSIG-PURELIN in their first hidden layer, second hidden layer and output layer respectively. The training function was TRAINLM, adaption learning function was LEARNGDM and the performance function was MSE. Out of the 130 sets of data given, 60% was used for training, 20% for testing and remaining 20% for validation by the NN Toolbox[26]. The R values of training, testing and validation were 0.96701, 0.9501 and 0.97293 respectively. The Fig. 3 gives the MSE curve and Regression plot for the optimised BPNN model. The best validation performance was 0.24291 at epoch 4 and the overall R was 0.96543. The BPNN model was tested with fresh data of 8 sets and the predicted results were compared with the actual data as shown in Table 2.

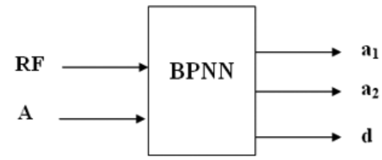


Figure 2. Schematic of BPNN model for Synthesis of DEMPA.

Table 1. Training data set for synthesis model

Training Data Set for synthesis model					
No.	Input parameters		Patch dimensions		
	RF (GHz)	A (mm^2)	a_1 (mm)	a_2 (mm)	d (mm)
1	9.988	86.54625	4	6.5	10.5
2	10	88.19475	4.2	6.5	10.5
3	10.1502	89.84325	4.4	6.5	10.5
4	10.1802	91.49175	4.6	6.5	10.5
5	10.1922	93.14025	4.8	6.5	10.5
6	10.1862	94.78875	5	6.5	10.5
7	10.2162	96.43725	5.2	6.5	10.5
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
125	10.1201	94.39625	6.5	6.5	9.25
126	10.0781	96.9475	6.5	6.5	9.5
127	10.03	99.49875	6.5	6.5	9.75
128	10.0961	104.60125	6.5	6.5	10.25
129	10.036	109.70375	6.5	6.5	10.75
130	10.0781	114.80625	6.5	6.5	11.25

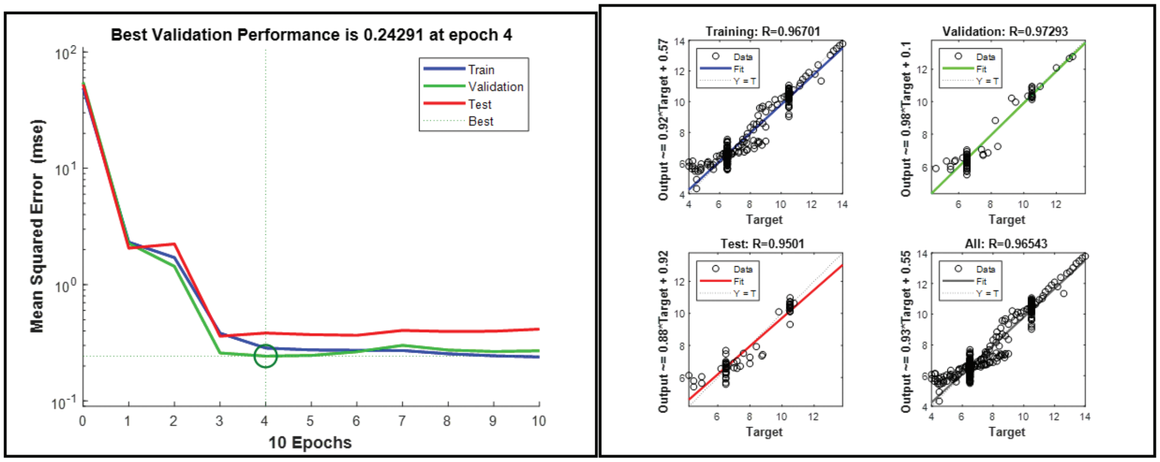
The percentage error for each data set was calculated by using the Eqn (2).

$$\%Error = \frac{\text{the target response} - \text{the predicted response}}{\text{the target response}} \times 100 \quad (2)$$

The Average Absolute Percentage Error (AAPE) for predicted values gives us an idea about the spread of error in prediction by BPNN model. The AAPE for each response was calculated as the average of absolute values of errors with respect to each set of data as per the Eqn (3) given below.

$$AAPE = \frac{\sum_1^8 |\text{Percentage error}|}{8} \quad (3)$$

In this case, the AAPE was found to be 1.7008, 3.0472 and 1.1195 for a_1, a_2 and d respectively.



(a) (b)

Figure 3. (a) MSE curve (b) Regression curve for the BPNN model for synthesis of DEMPA.

Table 2. Testing of synthesis model with fresh data set

Sl. NO.	Test Data set for synthesis model (from HFSS)					Predicted responses by BPNN model			% Absolute error between predicted and actual responses		
	Input parameters		Responses								
	RF (GHz)	A (mm^2)	a_1 (mm)	a_2 (mm)	d (mm)	a_1 (mm)	a_2 (mm)	d (mm)	a_1	a_2	d
1	10.1431	98.91	5.5	6.5	10.5	5.8407	6.2393	10.3419	6.1948	4.0099	1.5048
2	10.043	108.801	6.7	6.5	10.5	6.6057	6.6706	10.5943	1.4063	2.6246	0.8986
3	10.012	137.7675	6.5	6.5	13.5	6.6682	6.3696	13.4157	2.5890	2.0047	0.6243
4	9.988	140.3188	6.5	6.5	13.75	6.5725	6.4483	13.6613	1.1156	0.7947	0.6449
5	10.028	103.856	6.5	6.1	10.5	6.5539	6.5478	10.1915	0.8300	7.3414	2.9379
6	9.963	108.801	6.5	6.7	10.5	6.4796	6.7834	10.3217	0.3134	1.2460	1.6972
7	9.973	113.747	6.5	7.3	10.5	6.6692	6.8327	10.6638	2.6039	6.4003	1.5599
8	10.042	127.5625	6.5	6.5	12.5	6.5397	6.4605	12.2966	0.6115	0.6076	1.6272
Average Absolute Percentage Error, AAPE (%)									**1.7008**	**3.0472**	**1.1195**

5. RESULTS AND DISCUSSIONS

It is clear from the Table 2 that the AAPE for the predicted responses are well within the acceptable limits for neural network models and hence the generalisation capability is ascertained for this BPNN model.

5.1 Demonstrating Antenna Miniaturisation Through Design Flexibility

At the beginning, a design engineer will always have a fixed/desired set of requirements with respect to the patch antenna. This set of requirements consists of the operational frequency, desired level of peak gain, expected minimum value of return loss etc. Flexibility during the design can be practiced only within the boundaries laid down by these requirements. In order to demonstrate the antenna miniaturisation through DF for radiolocation antenna due to adopting a double elliptical patch, an arbitrary operational frequency of 9.85 GHz was chosen from the frequency band for radiolocation, 8.50 GHz-10.55 GHz. The BPNN model for antenna synthesis was simulated with several data sets in which the RF value was constant at 9.85 GHz and the *A* value was varied between lower and upper values of its range given in the Table 2. It was observed that for *A* values below 66 mm^2 and above 142 mm^2, the values of a_1, a_2 and d were out of their respective ranges defined. For *A* values between 66 mm^2 to 142 mm^2, the patch dimensions were well within their limits. In other words, a radiolocation antenna designed to work at 9.85 GHz can be made with effective patch area ranging from 66 mm^2 to 142 mm^2, which may be designated as design range. Hence, the design engineer can choose any patch area within the design range to develop a DEMPA which will be operating at the radiolocation frequency of 9.85 GHz . Here, the percentage reduction in effective patch area was found to be 53.52%. The design engineer can exercise this flexibility during the process of design because of the regular, easy to create, continuous and smooth profile of DEP along with its higher degrees of freedom. Selection of appropriate *A* from within the design range may be finalised depending upon the other details within the fixed set of requirements, such as antenna gain, return loss etc. Numerical models of DEMPA with patch areas of 140 mm^2, 120 mm^2, 100 mm^2, 80 mm^2 and 66 mm^2 and with operational frequency at 9.85 GHz were developed and simulated to demonstrate the Design Flexibility. The Table 3 below shows the performance details of these DEMPAs.

For DEMPAs with different patch areas spanning across its design range, the resonant frequencies obtained from numerical models in HFSS are very close to the desired operational frequency of 9.84 GHz and there are variations for the corresponding reflection coefficient and peak gain values, as evident from the Table 3. This uncovers a good opportunity for miniaturisation and the design engineer can choose a suitable set of dimensions for the patch so that it may satisfy the desired performance levels of antenna in terms of reflection coefficient, peak gain, etc. For example, a radiolocation antenna can be made with A=66 mm^2, if the engineer is satisfied with Reflection Coefficient, S_{11}= -20.8204 dB and peak gain of 2.9630 dB. Otherwise, he will have to think of DEMPA with higher patch area. This methodology can be applied for producing a radiolocation antenna with a certain specific patch area so as to conveniently position it in any compact space. This methodology will also work well with frequency bands for other applications.

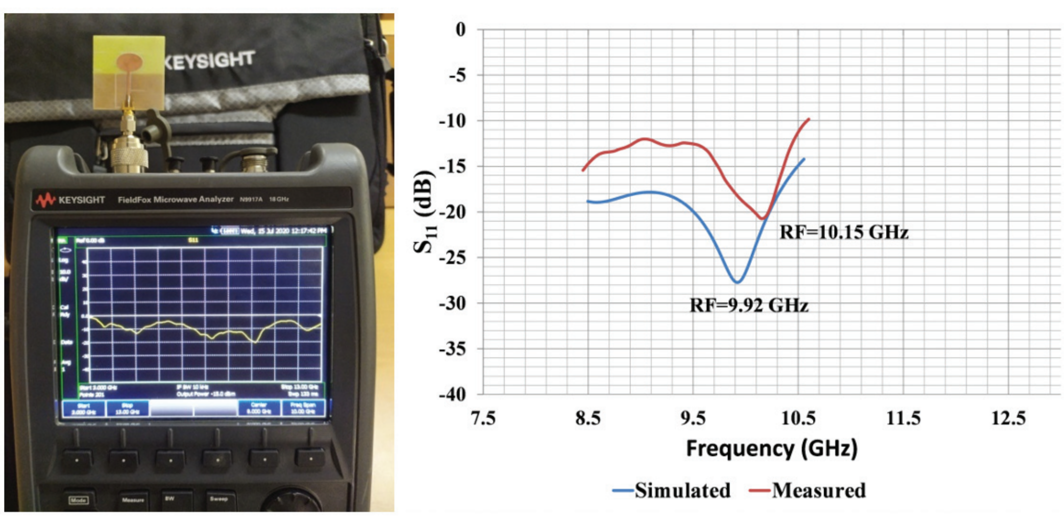
5.2 Fabrication and Testing of DEMPA

Out of the five numerically synthesised DEMPAs given above, one having its reflection coefficient as the median value has been fabricated and tested to validate the findings of the corresponding numerical model and to establish the usefulness of the proposed methodology. The selected DEMPA for fabrication was of 120 mm^2 patch area. This DEMPA was fabricated through a chemical etching process which removed the undesirable regions of metal from the metallic layer of substrate. The prototype of DEMPA was fed with the help of an SMA connector with a characteristic impedance of 50Ω. This connector was joined to the FR-4 substrate by soldering. The micro-strip feed line was of width 1.6 mm and length 20.7 mm. The reflection coefficient and VSWR measurements were taken at a lossless laboratory using the KEYSIGHT FieldFox Microwave Analyser N9917A. The Fig. 4 (a) shows the top view of the fabricated DEMPA during testing.

The radiation and gain measurements were carried out with the help of anechoic chamber. The co-polarisation and cross-polarisation characteristics of DEMPA at E-plane and

Table 3. Demonstration of antenna miniaturisation through Design Flexibility of DEMPA for radiolocation applications

Sl. No.	Patch dimensions predicted through BPNN model for different areas within the design range at RF = 9.85 GHz				Values of performance measures obtained from numerical models in HFSS		
	Patch Area (A) in mm^2	a_1 (mm)	a_2 (mm)	d (mm)	RF (GHz)	Reflection Coefficient (S_{11}) in dB	Peak Gain (dB)
1	66	6.4448	6.5295	7.1741	10.058	-20.8204	2.9630
2	80	6.5760	6.8081	7.5549	10.04	-20.73	3.6914
3	100	5.6735	7.1515	9.7953	10.1141	-32.2158	3.7286
4	120	6.7932	7.63	10.1435	9.9179	-27.7327	4.1212
5	140	6.4541	7.2092	13.1271	9.9079	-34.8476	4.3591



(a) (b)

Figure 4. (a) The top view of fabricated DEMPA of area 120 mm^2 during testing (b) Comparison of reflection coefficient curves from simulation and measurement.

H-plane were measured. The Fig. 4 (b) is the comparison of S_{11} curves obtained from simulation and fabrication of synthesised DEMPA within the frequency band for radiolocation applications and these two curves are found to be close to each other. The simulated and measured resonant frequencies were 9.92 GHz and 10.15 GHz respectively and the corresponding reflection coefficient values were -27.73 dB and -20.73 dB. Fig. 5 (a) shows comparison of VSWR curves and Fig. 5 (b) shows the comparison of simulated and measured peak gain curves. Within the radiolocation range, the gain is positive and good. For the fabricated antenna, the peak gain at resonance was 4.22 dB. The Fig. 6 (a) and (b) shows the comparison between simulated and measured co-polarisation and cross-polarisation patterns of DEMPA at E-plane and H-plane respectively at the resonant frequency of 9.92 GHz. The antenna under radiation test in the anechoic chamber is shown in Fig. 6 (c). The simulated and measured performance values are slightly different and it may be because of the inherent limitations and practices related to experimentation such as the tolerance level during the fabrication of antenna, ground plane effect and SMA connector effect. These aspects are neglected during simulation. Also, the dielectric loss tangent of substrate was kept constant during the simulations even if it was really a function of frequency. The cross-polarisation level at E-plane is found acceptable and its level at H-plane is somewhat high as per the Fig. 6. This may be because of the excitation of hybrid current distribution on the antenna radiator at such a high frequency[27]. The unsymmetrical shape of the patch gives rise to a hybrid structure and that might be contributing towards the hybrid current distribution.

The Upper Cut-off Frequency (UCF) and Lower Cut-off Frequency (LCF) for the fabricated DEMPA were found to be 10.564 GHz and 7.458 GHz respectively. Hence, it is clear that the antenna covers the entire frequency band for radiolocation applications. The Fractional Bandwidth (FB) of antenna is given as

$$FB = \left(\frac{UCF - LCF}{Centre\ Frequency} \right) \times 100\% \tag{4}$$

where,

$$\text{Centre Frequency} = \left(\frac{UCF + LCF}{2} \right) \tag{5}$$

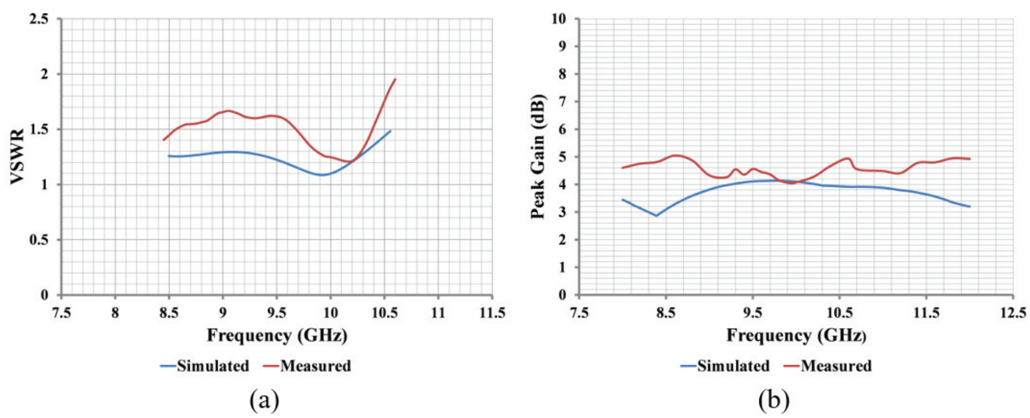


Figure 5. (a) Comparison of VSWR curves from simulation and measurement (b) Comparison of simulated and measured peak gain curves.

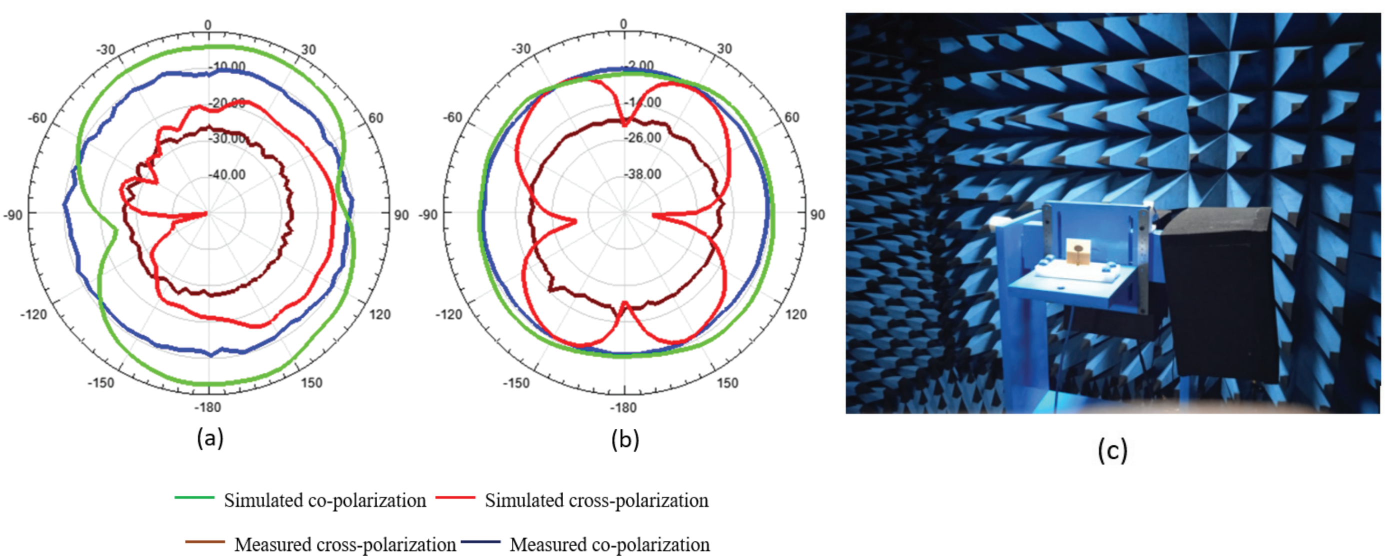


Figure 6. Simulated and measured Co-polarisation and Cross-polarisation patterns of synthesised DEMPA of area 120 mm² (a) E-plane (X-Z) (b) H-plane (Y-Z) at resonant frequency of 9.92 GHz and(c) Antenna under radiation test in anechoic chamber.

Table 4. Comparison of effective patch area of the proposed DEMPA with that of various patch antennas from literature

Reference	Published year	Antenna size details (mm)	Antenna design details	Effective patch area (mm^2)	Resonance at (GHz)
28	2018	R=22.4	Logo type slot in circular patch	1280 (approx.)	8.78, 10.33
29	2018	L=14.5; W=15; r_1=1; r_2=1.1; r_3=2.5; r_4=1.9;	Rectangular patch with four circular cuts at corners	208.025	10.04
30	2019	W=20.37; L=23.5; t=2.5	E-shaped patch	358.695	9.18
31	2019	W=20; L=16; l=31; w=1;	E-shaped slot in rectangular patch	289	8.9,10.4
32	2019	L=21.5; W=16.50	Rectangular patch structure loaded multi-slotted forked antenna	230	10.31
33	2020	L=29.8; W=39.8	Modified Hilbert Curve Fractal from rectangular patch	739.38	9.5, 10.0
Fabricated DEMPA	______	a_1=6.7932; a_2=7.63; d=10.1435	Double elliptical patch	120	10.15

Where, L- length of rectangle; W- width of rectangle; l - length of slot; w - width of slot; R - radius of circle; t - notch thickness; a_1- semi-major axis of left half-ellipse of DEMPA; a_2- semi-major axis of right half-ellipse of DEMPA; d - common minor axis of DEMPA; r - radius of circular arc.

The FB is calculated as 34.469%. It implies that the fabricated DEMPA covers the bandwidth of 34.469% from 7.458 GHz to 10.564 GHz for $|S_{11}|$<-10dB.

A radiolocation antenna which can be tuned at a frequency of 9.85 GHz can be realised with as minimum a patch area as that of 66 mm^2. However, the fabricated DEMPA was of A=120 mm^2 which ensured an average performance in terms of reflection coefficient and gain. The effective patch area of the fabricated DEMPA has been compared with that of other patch antenna reported in literature and the details are given in Table 4. The fabricated antenna with the resonant frequency of 10.15 GHz can be used for radiolocation applications, more specifically, for amateur radio operations as the Radio Regulations of the ITU has allocated the band 10.00 GHz – 10.45 GHz to this. It also serves the military requirements for land, airborne and naval radars. It can also be used for medical applications, such as breast cancer detection and patient monitoring in cancer treatments[34] as the X band (8.0 GHz – 12.00 GHz) is popular in medical field. Unlike the lower frequency radiations, the higher frequency radiations in X band provide less penetration to skin and better range resolution. The X band radiations do not penetrate beyond the skin level and do not harm the muscles[35-36].

6. CONCLUSION

The Back Propagated Neural Network model for synthesis of DEMPA was developed for radiolocation applications. Training and testing data for BPNN were collected by simulating numerical models of DEMPA in HFSS. The methodology of producing miniaturised radiolocation antenna through improving its Design Flexibility by using DEP was described. This synthesis model was employed to design double elliptical radiolocation antennas of patch area ranging from 142 mm^2 to 66 mm^2 for an arbitrary operational frequency of 9.85 GHz. A percentage patch area reduction of 53.52% was thus achieved by using DEPs. This methodology may be applied to miniaturising antenna in other frequency ranges also and is particularly helpful while designing a patch antenna with limitations on its size such as in the case of mobile phones. A prototype antenna was fabricated and tested. It has resonance at 10.15 GHz and bandwidth of 3.106 GHz (from 7.458 GHz to 10.564 GHz). A good and reasonable gain is maintained over the entire working band. This antenna can be used for amateur radio operations and medical applications such as detecting cancer and patient monitoring in cancer treatments.

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