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Designing of E-shaped Microstrip Antenna and Parameters Estimation using ANN

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ABSTRACT: **The microstrip antenna finds its place in varied and upcoming technologies because it offers low profile, narrow bandwidth, high gain, and compact antenna element. The biggest disadvantage of microstrip antenna is its narrow bandwidth and poor impedance matching capacity. To make microstrip antenna compatible with commercial applications, the bandwidth enhancement and impedance matching of such antennas has to be done. In order to improve the bandwidth - L probe and U slot techniques should be utilized, as they are efficient to enhance the bandwidth. In this research, Microstrip patch antenna is integrated with coaxial feed technique. The impedance matching of antenna depends upon type and position of the feed because impedance matching of source at the feeding point of antenna is very important for efficient operation of antenna. But it is not an easy as it looks, it's fairly difficult to be achieved for a simple microstrip patch antenna. To solve the problem an Artificial Neural Network (ANN) model has been proposed in this research. Artificial Neural Network is highly simplified model of biological neural network to calculate the parameters by estimation.**

Keywords: Microstrip Patch Antenna; Microstrip Line feed; Coaxial Probe feed; NN tool; IE3D; ANN.

I. INTRODUCTION

Due to their many attractive features, microstrip antenna has drawn the attention of researchers over the past work [1-3]. Microstrip antennas are used in an increasing number of applications, ranging from biomedical diagnosis to wireless communications [4].

Microstrip patch antennas were first developed by Munson in the early 1970's, when he worked on low profile antennas to be mounted on missiles for the US military. However at that point of time microstrip antennas were not popular due to the major drawback that these antennas were low in efficiency, low power, high Q, poor polarization purity, poor scan performance and very narrow frequency bandwidth (less than 5%). With the evolution of design techniques on microstrip technology, current microstrip antenna can achieve a bandwidth of 30% or more. That's the reason why these antennas are more popular in this modern world. These are used in high performance and sized constrained applications. These are mechanically robust when mounted on rigid surfaces and very versatile in terms of resonant frequency, polarization, pattern and impedance match.

Research on microstrip antenna in the 21st century aims to size reduction, increasing gain, wide bandwidth, multiple functionality and impedance matching. Significant research work has been reported on increasing the gain and bandwidth of patch antennas. Many techniques have been suggested for achieving wide bandwidth [5-6]. There are numerous and well-known methods to increase the gain of antennas, including decrease of the substrate thickness, feeding techniques and with the use of different optimization techniques [7-8].

Microstrip Antenna

Generally, patch of microstrip antenna thickness is very thin in the range of t<< λ 0(λ 0 is free space wave length) and the height h of dielectric material is between 0.003 λ 0 < h< 0.05λ0. For a rectangular path, the length L of the element is usually λ0 /3 < L<λ0/2. There are numerous substrate that can be used for the design of Microstrip antenna, and their dielectric constants are usually in the range of 2.2<Ɛr< 12, where Ɛr is relative dielectric constant. The substrate whose size is thick and dielectric constant is in the range of lower end provides better efficiency and bandwidth; but it expenses large element size.

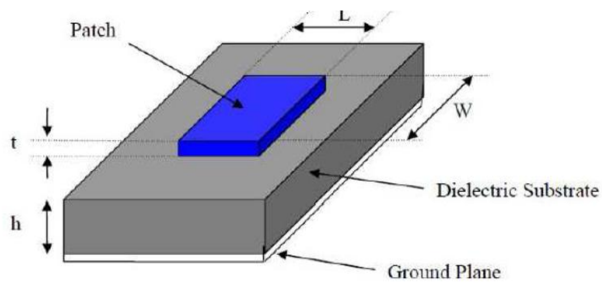


Fig 1 Rectangular Microstrip patch antenna

Need and Significance of Research

The microstrip antenna finds its place in latest upcoming technology. But due to some lateral drawbacks the following techniques are required, which are used to improve the performance of the antenna. The bandwidth of microstrip patch antenna can be enhanced by increasing substrate height, parasitic elements, better techniques such as U slot and L probe feed is used [14].

The input impedance matching of microstrip patch antenna actually depends on type and location of feed because impedance matching of source at the feeding point of antenna is very important for its efficient operation. But as mentioned earlier it's not a cake walk for a simple microstrip antenna. To solve this problem we are proposing "The Artificial Neural Network(ANN)" model in this research. The architecture consists of interconnected processing units. The model is prepared using feed forward multilayer perceptron neural network Levenberg Marquarat back propagation algorithm. The multilayer perceptron (MLP) model with input, hidden and output three layer structure is used.
Also one really worthy advantage of coaxial probe feed is that it has the flexibility to place the feed anywhere on the patch in order to match the input impedance. This gives an easy fabrication and has low spurious radiation. Finding the best feed position is not an easy task, now which is made easy and achievable by Artificial Neural Network (ANN). In this research, the proposed ANN model is used to estimate the parameters: Return loss (S11), resonant frequency (fr) and resistance (Rin) in lesser time than IE3D simulation software with good agreement results.

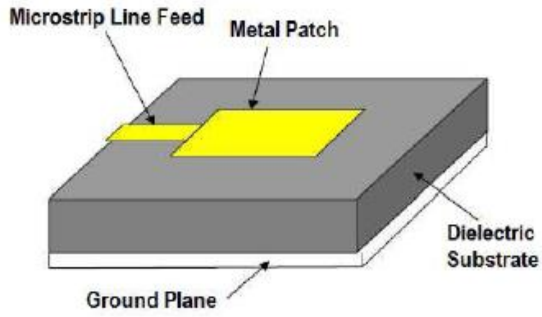
II. FEEDING METHODS (ANALYSIS TO IMPROVE IMPEDANCE MATCHING)

There are several techniques available to feed or transmit electromagnetic energy to a microstrip patch antenna which effects positively to match the impedance with source. But first two are mostly used.

a) Microstrip line feeding.
b) Coaxial cable or probe feeding.
c) Aperture Coupled Feed.
d) Proximity coupling Feed.

a) Microstrip Line Feeding

In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch as shown in Figure 2.1 (a). The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. However as the thickness of the dielectric substrate being used increases, the surface waves and spurious feed radiation also goes up, which hampers bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation.



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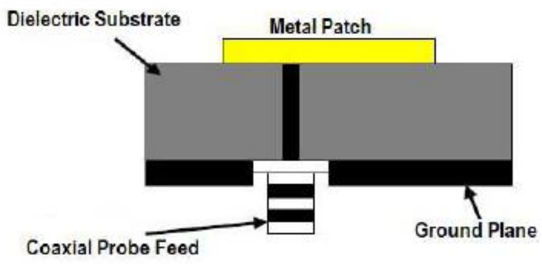

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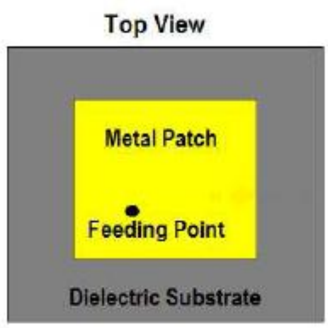

(c)

Fig 2.1 Rectangular Microstrip patch antenna with (a) Inset Line Feeding, (b) Coaxial Probe Feeding.(c) top view

b) Coaxial Cable or Probe Feeding

The Coaxial feed or probe feed is a very common technique used for feeding microstrip patch antennas. As seen from Figure 2.1 (b), the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor

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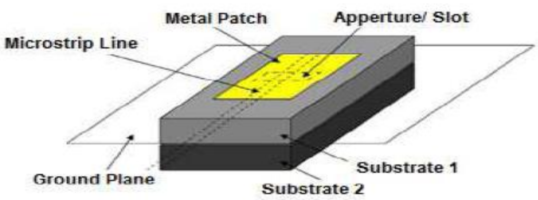
is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location on the patch in order to match with its input impedance. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ($h > 0.02\lambda o$).Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leads to matching problems. The main aim to use probe feeding is enhancing the gain, narrow bandwidth and impedance matching.

c) Aperture Coupled Feed



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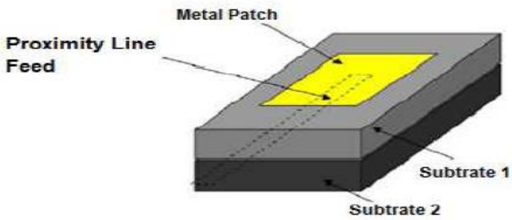


(b)

Fig 2.3 Rectangular Microstrip patch antenna with (a) Aperture coupled, (b) Proximity coupled Feeding.

This feeding technique consist of two substrate separated by a ground plane. Microstrip feed line is connected below bottom substrate whereby electromagnetic energy is coupled with the radiating patch through the aperture slot as shown in fig 2.3 (a). Matching is done by adjusting the width of feed line and the slot's length.

d) Proximity Coupled Feed

It is non-conducting coupling technique which offers the opportunity to reduce the feed line radiation and provides very high bandwidth (as high as 13%). while maintaining a relatively thick substrate for the radiating patch as shown in fig 2.3 (b).

III. METHODS TO IMPROVE BANDWIDTH

Some of the techniques that have been successfully developed are illustrated as:-

a) Bandwidth Enhancement by L probe feed

If we want to improve the bandwidth, the inductance must be tuned out by a capacitor. One approach is to connect the end of coaxial feed probe in series to a tab that does not directly contact the patch element, which is equivalent to a series capacitor that can be controlled by the size of the tab and distance from the patch.
Effectively, the probe inductance is cancelled by a series capacitor, which is formed by the horizontal portion of the L-probe with its length less than a quarter wavelength. This design provides a bandwidth of 40%.

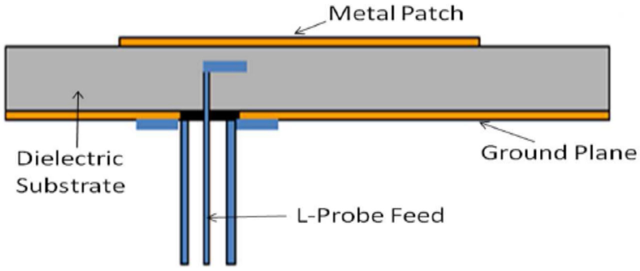
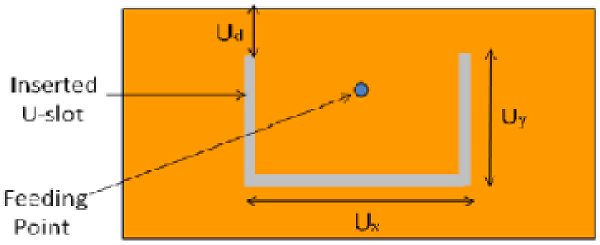


Fig 3.1 Rectangular Microstrip patch antenna with L-probe Feed.

b) Bandwidth Enhancement by U-slot

The U-slot is optimized in 3 phased manners. First the Uy (slot length along Y-axis) can be varied. In the second phase Ux (slot length along X-axis) can be varied. In the third phase Ud (U slot distance from top edge of patch) can be varied. Using U-slot technique, the bandwidth of around 26% can be achieved with 90% efficiency. With the movement in a direction of outside from U-slot.



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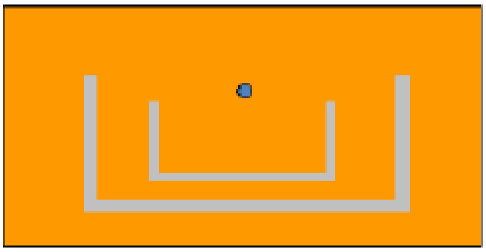

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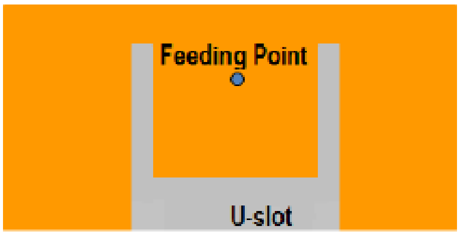


(c)

Fige 3.2 The introduction of a (a) U-slot can give a significant bandwidth of (10%-40%), (b) Double U-slot can give a significant bandwidth of 44%, (c) Modification of a U-slot as E-patch gives a bandwidth of 34%.

IV. DESIGN OF ANTENNA BY IE3D SOFTWARE

The ZelandInc (ZelandInc, 2008) provides such software package to design, analyze, simulate, optimize and save results for microstrip patch antenna named as "IE3D". IE3D is a full wave, method of moment (MoM) based on electromagnetic tool for the design of general 3D and planar structures. It solves Maxwell's equations in integral form and its solutions include the wave effects, discontinuity effects, coupling effects and radiation effects. The simulation results include S, Y, Z parameters, VSWR, RLC equivalent circuits and current distribution, near field, radiation patterns, directivity, efficiency and RCS. It is an extremely powerful tool in the design of MMIC, RFIC, RF PCB, Microstrip Antenna, Wire Antenna, RFID Antenna and other RF antennas. The IE3D has become the most versatile, easy to use, efficient, accurate electromagnetic simulation tool. It is able to provide following results:-

1-Radiation pattern and pattern lobes.
2-Directivity.
3-Antenna gain (dB).
4-Antenna efficiency (%).
5-VSWR (voltage standing wave ratio).
6-Return loss or S11 parameter (dB).
7-Input impedance (Zin).
8-Resonant frequency (fr).
9-Bandwidth (BW).
10-Polarization (Horizontal, vertical, circular, elliptical etc).

Design procedure of Microstrip Patch Antenna

The following steps require basic requirements beforehand like dielectric constant (Ɛr), resonant frequency (fr) and height of the substrate (h).

Step 1:- Specify the values of Ɛr, fr, and h as required.

Step 2:- Determine Practical width that leads to good radiation efficiency.

$$W = \frac{C}{2f_r}\left(\frac{\varepsilon_r+1}{2}\right)^{-1/2} \quad (1)$$

Where C = free space velocity.

Step 3:- Determine the effective dielectric constant of microstrip patch antenna.

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+\frac{12h}{W}\right]^{-1/2} \quad (2)$$

Step 4:- Determine the extension in length

$$\Delta l = 0.412h\left(\frac{\varepsilon_{eff}+0.3}{\varepsilon_{eff}-0.258}\right)\left(\frac{W/h+0.264}{W/h+0.8}\right) \quad (3)$$

Step 5:- Determine the length of the patch antenna

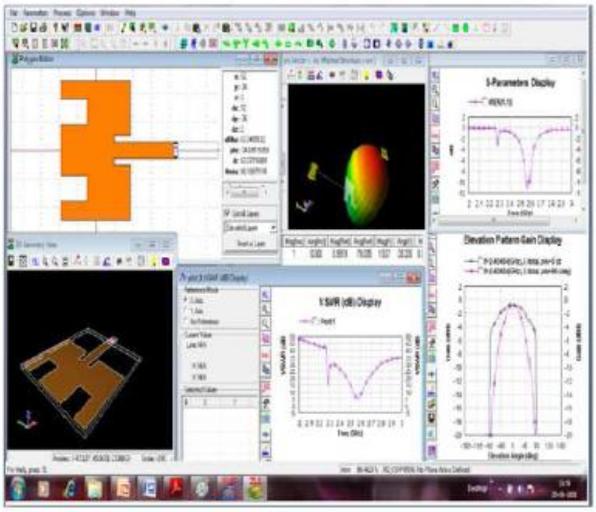
$$L = \frac{C}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta l \quad (4)$$

Using the above equations (1) to (4), we calculate the basic dimensions of microstrip patch antenna and then design and simulate the geometry on IE3D software as shown in Fig 5 (a).

V. PARAMETER ESTIMATION BY ANNMODEL

An ANN model for finding the resonating frequency, return loss and gain for particular feed location has been designed. The input to the ANN model is feed locations in terms of Xi and Yi coordinates.

The network considered is multilayer perceptron (MLP) model with three layers: - input layer, hidden layer and output layer. The input layer has 2 neurons and output layer has 3 neurons. The no. of neurons in hidden layer is 50. For parameter estimation purpose, a neural network tool, known as NNTOOL will be used which is a Graphical User Interface (GUI) based ANN learning tool capable of learning input data according to desired target data as shown in fig 4 (b).



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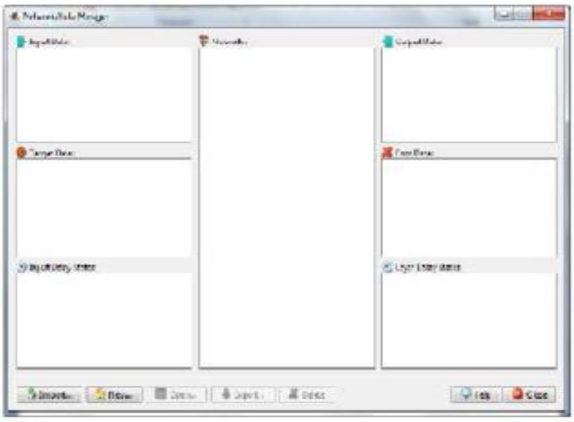

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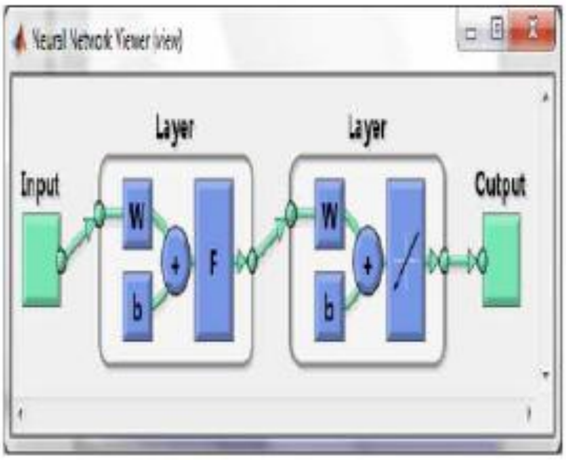

(c)

Fig 5.1 (a) Design and Simulation overview of antenna, (b) NN tool in MATLAB, (c) Neural Network created by NNTOOL.

In this tool, a training pair consisting of input data and target data is provided from ‘New’ option. It can also be imported from workspace of MATLAB or can be loaded from the disk file. A neural network will be created from new option after choosing specific Network Type as shown in Fig 5 (c).

After training the next step is to test its performance. The results from tested ANN model are compared with IE3D simulation results for the same input, here unknown input combinations means the input combinations are not considered for the training of model.

VI. CONCLUSION

In this research our approach was to design a microstrip patch antenna, simulated with Coaxial feeding technique andthen Artificial Neural Network was proposed to be designed to estimate parameters. We discussed as how to analyze the impedance matching and bandwidth enhancement techniques. We also talked of analyzing the different feeding techniques to give better outcome in terms of impedance matching and suggested as how the U-slot is an efficient technique to improve the bandwidth. Then we talked about preparation of the data set of simulated results for different coaxial feed positions, which is used for training of ANN. After training, we test its performance by providing the inputs with unknown outputs and then we compare the results (estimated parameters) with IE3D simulated results (actual parameters). At the last our approach is to reduce the aggregated error by efficient training of ANN model.

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