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Microstrip Patch Antenna Design Calculator

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Abstract

This paper provides details on how to investigate a new method of teaching microstrip patch antenna design made by Metamaterials using MATLAB. This is achieved by designing a friendly graphical user interface (GUI) for microstrip patch antennas through which antenna parameters and radiation pattern can be determined. Effect of changes in basic parameter microstrip Patch Antenna on its Radiation Patter and other parameters can be determined by using GUI. Understanding the behaviour of the Microstrip Patch Antenna and Design of it for different metamaterial with the use of the Graphical User Interface using MATLAB is better way of Analysis.

1. Introduction

In the recent years the development in communication systems requires the development of low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. The future development of the personal communication devices will aim to provide image, speech and data communications at any time, and anywhere around the world. This indicates that the future communication terminal antennas must meet the requirements of multi-band or wideband operations to sufficiently cover the possible operating bands. The performance of the fabricated antenna was measured and com-pared with simulation results [1]. Moreover, we have also indicated the appropriate choice of particular metamaterial for different specific purposes like antenna size reduction and other mode modification-related applications [2]. The performance of a rectangular patch antenna array on a metamaterial substrate was studied relative to a similar array constructed on a conventional FR4 substrate [3]. In modern wireless communication systems, the microstrip patch antennas are commonly used in the wireless devices. There-fore, the miniaturization of the antenna has become an important issue in reducing the volume of entire communication system [4].

Studying antennas and wave propagation phenomena using interactive graphics and animations becomes nowadays a fundamental tool for describing and understanding electromagnetic concepts. This aspect is strongly related with wave propagation, where the propagation properties of the waves or how to plot the radiation patterns of antennas are not so easy to understand for undergraduate students, due to simple, static, oral explanations. Currently, several products in which computer tools are used have been developed such as Ansoft Ensemble, IE3D, MWO (Microwave Office), SONNET, ADS (Agilent Advance Design System), COMSOL, MATLAB ,HFSS (High Frequency Structure Simulation) etc for modeling and simulation of complicated microwave and RF printed circuit, antennas, and other electronics component. Many of these softwares are commercially available at a very high cost or in the least, are proprietary.

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2. Design of Microstrip Antenna with Metamaterial

Superstrate Microstrip antenna with square patch (5.6mm×5.6mm) on the Roger RT/duroid substrate with permittivity 2.2 and with 40 mm×46 mm dimensions and height 1.575mm is used in the simulation process. The Square patch feed by 50 Ω coaxial probe is positioned 1.25mm off-center. The operation frequency of antenna is 15.23 GHz. Metamaterial superstrate places above the patch of antenna for concentrating of radiation energy normal to itself. Adjustment of first superstrate layer is the most important stage in antenna design and it is about one third of operation wavelength (λ/3) above ground plane which cause to gain increase. The second layer, improve beam shaping and bandwidth. The distance of second layer from first layer is between λ/3 to λ/2. Figure 1a shows configuration of microstrip antenna with S coupled metamaterial superstrate. The first layer is about 9.225mm above the ground plane and the optimized distance of second layer is 11.60mm. Also Configuration of Antenna with Double split ring metamaterial superstrate has been shown in Fig. 1b. The first layer is about 9.225mm above the ground plane and the optimized distance of second layer is 10 mm.

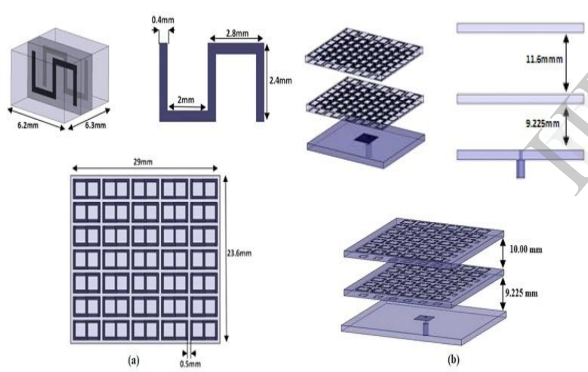

Figure1. Configuration of antenna with metamaterial superstrate
(a) S coupled structure (b) Double split ring structure.

3. Analytical Formulation of the Antenna

Basic Design Equations of Rectangular Microstrip Patch Antenna are as under.
Effective Dielectric Constant can be given by:

$$\varepsilon_{reff} = \left[(\varepsilon_r + 1) / 2\right] + \left[(\varepsilon_r - 1)/2\right]\left[1 + 12\,(h / w)\right]^{-1/2} \quad (1)$$

Where, ε_{reff} = Effective dielectric Constant
ε_r = Dielectric Costant of the Substrate
h = Height of the Dielectric Substrate
w = Width of the Patch

Two slots representation of Microstrip Patch Antenna is as shown in Figure 2.

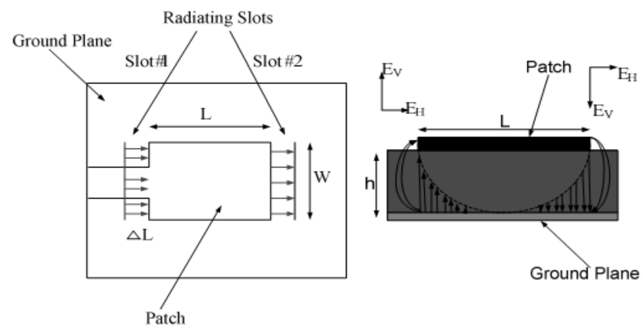

Figure 2. Top view and side view of Rectangular Microstrip Patch Antenna

As shown in Figure slots are separated by distance L, when, the width of the structure has a maximum voltage and minimum current, then, it acts as an open ended circuit.
It is seen from Figure 2, if we consider direction of the field opponents at edges then, they are opposite directions and thus out of phase, hence they cancel each other.
If the tangential components are in phase then the resulting fields combine to give maximum radiated field normal to the surface of the structure.
The fringing fields can behave like as radiating slots and electrically the patch of the Microstrip antenna. The Extended length of patch ΔL, is given empirically by [3] as:

$$\Delta L = 0.412\,h \frac{\left[(\varepsilon reff + 0.3)\left(\left(\frac{w}{h}\right) + 0.264\right)\right]}{\left[(\varepsilon reff - 0.258)\left(\left(\frac{w}{h}\right) + 0.8\right)\right]} \quad (2)$$

The actual length L of the patch is given as

$$L = \frac{\lambda_0}{2} - 2\Delta L \quad (3)$$

The Effective Length of the Patch Leff now Becomes

$$L_{eff} = L + 2\Delta L \quad (4)$$

For the Given resonant frequency f0, the effective length is given as

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}} \quad (5)$$

For the effective radiation width of the patch W is given as

$$W = \frac{c}{\left[2 f_r \sqrt{\frac{[\varepsilon_r + 1]}{2}}\right]} \qquad (6)$$

To determine the fields radiated by each slot, the total field is the sum of the two-element array with each element representing one of the slots.

For the microstrip antenna, the x-y plane (θ=90◦, 0◦ ≤ ϕ ≤ 90◦ and 270◦≤ ϕ ≤ 360◦) is the principal E-plane. For this plane, the expressions for the radiated fields is given by

$$E_\phi^t = +j\frac{k_0 h W V_0 e^{-jk_0 r}}{\pi r}\left\{\frac{\sin\left(\frac{k_0 h}{2}\cos\phi\right)}{\left(\frac{k_0 h}{2}\cos\phi\right)}\right\}\cos\left(\frac{k_0 L_{eff}}{2}\sin\phi\right) \qquad (7)$$

The principal H-plane of the microstrip antenna is the x-z plane (Ø = 0˚, 0˚ ≤ θ ≤180˚), and the expressions for the radiated fields is given by

$$E_\phi^t = +j\frac{k_0 h W E_0 e^{-jk_0 r}}{\pi r}\left\{\sin\theta\frac{\sin\left(\frac{k_0 h}{2}\sin\theta\right)}{\left(\frac{k_0 h}{2}\sin\theta\right)}\frac{\sin\left(\frac{k_0 W}{2}\cos\theta\right)}{\left(\frac{k_0 W}{2}\cos\theta\right)}\right\} \qquad (8)$$

The gain of the antenna is the quantity which describes the performance of the antenna or the capability to concentrate energy through a direction to give better picture of the radiation performance. it is given as

$$G = \eta \times D \qquad (9)$$

Where, η = efficiency of the antenna,
D = Directivity

4. Antenna GUI Design using MATLAB

In this paper utilization of the design equation of rectangular patch antenna and circular patch antenna is done for the preparation of the Graphical User Interface in MATLAB.GUI for the Rectangular patch antenna is as shown below.

In GUI resonant frequency (Fr), Input Impedance, Dielectric Thickness, Dielectric Constant are taken as a input parameter.

As shown in Figure 3, antenna parameters are calculated using this GUI as well as the radiation pattern for given input is plotted on GUI.

As mention in title of paper this GUI includes the "Help" option for the user, by which user can get the basic information related to the Microstrip Antenna like, What is Antenna?, What is Microstrip Patch Antenna?, What is Advantages of Microstrip Patch Antenna? , What is Disadvantages of Microstrip patch Antenna?, What is Metamaterials?

5. Results

Table 1. Comparing the Different Feed Techniques

Input Parameter	**Patch Material**			
	Silicon	**RT/Duroid**	**GaAs**	**Indium**
Resonant Frequency (MHz)	2.1	2.1	2.1	2.1
Input Impedance (Ohm)	50	50	50	50
Dielectric thickness (h) Mm	1.5	1.5	1.5	1.5
Dielectric Constant (E_r)	11.8	2.2	12.9	12.4

Output Parameter	**Rectangular Patch Material**			
	Silicon	**RT/Duroid**	**GaAs**	**Indium**
Length Of Microstrip (mm)	20.76	48.11	19.85	20.25
Width Of Microstrip (mm)	28.23	56.46	27.09	27.59
Effective Length (mm)	2.07	4.81	1.98	2.02
Width Of Feed Line (mm)	0.0005	0.0031	0.0005	0.005
Inset Feed Point Y_0 (mm)	3.06	3.2868	3.02	3.04

Radiation Power (mm)	5.43	1.58	7.08	6.32
Directivity (DB)	52.82	52.76	52.96	52.92
Characteristics Impedance (Ohm)	59.27	91.73	57.43	58.25
VSWR	0.843	0.54	0.87	0.85

6. Discussion with Future Scope

From the Equation of the Rectangular Microstrip patch Antenna manual calculation of all parameter is complex. By the use of the GUI this can be easy to calculate it. The Effect of the Changes in input parameter on radiation pattern can be easily analyzed by the use of GUI. As mentioned in results by changes in the material of the patch physical parameter of the Microstrip Patch is changes, this will be help designer to determine the antenna performance and make necessary adjustment before fabrication. As the same way all the parameter of circular microstrip patch antenna can be possible to analyze.

7. Conclusion

This work was aimed at designing a effective GUI for Rectangular Microstrip Patch Antenna. Alongside this, various properties of Metamaterials & parameters of antenna viz actual and effective length, width, radiation power, directivity, VSWR, which dictate the ultimate performance of the antenna were determined by simulation using a GUI developed in MATLAB.

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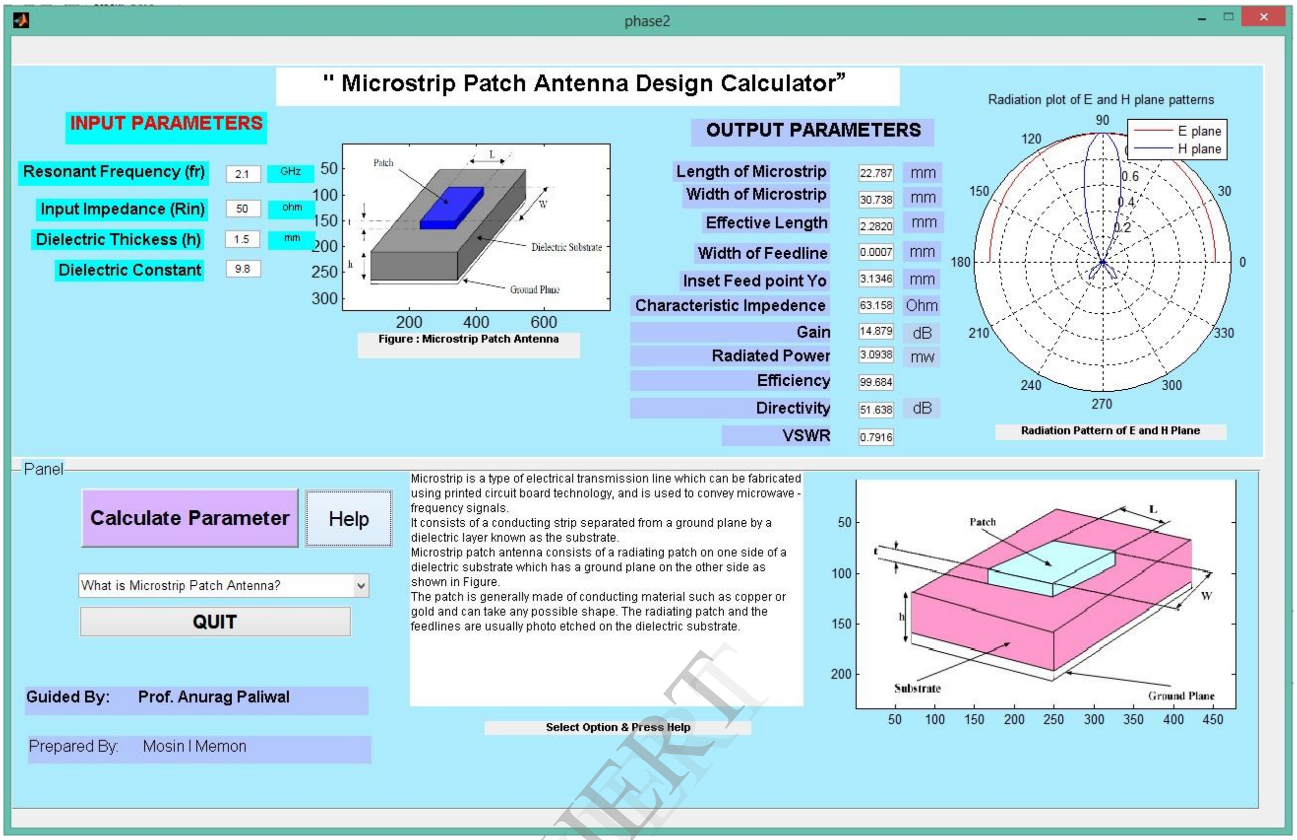

Figure 3. GUI front end for rectangular patch antenna

(Input fr = 2.1 Ghz, Input Impedance 50 Ω, Dielectric Thickness 1.5 mm, Dielectric Constant 9.8)