Synthesis of Multiband Dielectric Resonator Antennas using Transmission Line Model

Dr. Sunita Kumari[1] & Dr. K. B. Singh[2]

[1]Department of Physics, L N M U Darbhanga, Bihar, India.
Email: sunitakumariguddi2006@gmail.com
[2]Department of Physics, Samastipur College, Samastipur,
L N M U Darbhanga, Bihar, India.

Abstract:*In this paper we studied about the synthesis of multiband dielectric resonator antennas using transmission line model.Low loss in the antenna is also crucial for the operation of such a networks. High energy efficiency is a key for obtaining higher signal strengths and increasing the capacity of existing networks. Now a days, patch antennas have varieties of applications in communication equipment's because of its compact size but this type of antennas have also some drawbacks, such as conduction losses due to the skin effect and narrow operating frequency bandwidth.*

Keywords:**Patch antenna, Transmission Line, Resonator, Multiband.**

1. Introduction

The use of mobile communication is increasing very rapidly, because its applications for communication are being launched commercially. This development has put more demand for compact size and low every consumption for the equipment's related to communication systems. Base stations powered by solar cells are a reality, for example. Such analyses help in the physical understanding for the performance of the antenna and in determining optimal usage of the antenna. Many studies have concentrated on the cylindrical DRA structures, for which the TM and quasi-TM modes may be excited by having the dielectric disk situated on a ground plane. Little attention has been given to cylindrical DRA structures excited in the TE and quasi-TE modes, however, because these modes cannot be excited when the circular base of a cylindrical DRA is placed on a ground plane. We have studied some of the characteristics of the DRA's related to the $HEM_{11\delta}$ and the $HEM_{12\delta}$ Modes compared to the more commonly studied TM mode and the $TE_{01\delta}$ mode. Some basis regarding their excitation mechanism are described, and empirical expressions are given to compute accurately the resonant frequency and the radiation Q-factor for the ideal case of an isolated, source-free DRA. To permit excitation of the $HEM_{12\delta}$ modes for a resonator situated on a ground plane. The $HEM_{11\delta}$mode can also be excited in this configuration. Results are presented showing a broadband performance of the DRA excited in single mode operation, which reaches about 35%. Also, in some cases it is possible to have a dual band performance with the proper excitation of the DRA. The dielectric resonator antennas (DRAs) have attracted the attention of several investigators due to their high radiation efficiency, flexible feed arrangement, simple geometry, structure, small size low profile, light weight, low cost, a wide range of material dielectric constant, case of excitation and easily controlled characteristics. DRAs are available in various basic classical shapes such as rectangular, cylindrical, spherical and hemispherical geometries. Rectangular DRAs can be designed with greater flexibility since two for the three of its dimensioins can be varied independently for a fixed resonant frequency and known dielectric constant of the material. The techniques used to improve the bandwidth of the DRAs include changing the aspect ratio of DRA, employing multi segments and stacked DRAs and by varying the dielectric constant of DRA material.

2. Materials and Methods

Depending on the application of the dielectric resonator, different requirements are specified for the material to be used. The dielectric properties depend on the material, crystal structure, porosity and imperfections in the crystal lattice as well as on the preparation conditions. Dielectric resonators generally consist of a puck-formed cylinder of ceramic material of high permittivity and low dissipation factor. Traditional passive devices have been desired to have a high Q-factor (Up to 20,000 between 2 and 20 GHz, high permittivity and near zero temperature coefficients for the resonant frequency which has been difficult to achieve simultaneously.

The objective of this research paper is to simulate the dielectric resonator antennas which could resonate in multi frequency bands. The radiation parameters of the DRA will also be studied over the multi bands of operation. In this research project two or more than two dielectric resonator antennas will be coupled. Their composite radiation parameters will be studied. A single DRA will be proposed to have its geometry shape and size such that its radiation parameters are identical to that of the composite antennas in this way the validity of the multiband DRA will be tested. All these works will be performed on computer programs. The HFSS software's will be used for simulation works and analysis. In this way the investigation on enhancement of bandwidth of DRA will be done for multiband applications. This is a study of the possibilities and limitations with dielectric resonator antennas. It is intended as a guideline, the main objective is a proof of concept and the evaluation of a manufactured physical antenna is highly desired. The radiation parameters of DRA of suitable shape and size will also be studied. The variation in parameters of staked DRA will be allowed keeping in view improving the performance of radiation patterns. The optimization of condition will be shorted out to increase the radiation amplitude and enhance the band width. The synthesis of DRA and study of its performance will be done by simulation technique using suitable program.

The most popular models for the analysis of Micro strip patch antennas are the transmission line model (which include primarily integral equations/Moment Method).The transmission line model is the simplest of all and it gives good physical insight but it is less accurate. The cavity model is more accurate and gives good physical insight but is complex in nature. The full wave models are extremely accurate, versatile and can treat elements, finite and infinite arrays, stacked elements, arbitrary, shaped elements and coupling. These give less insight as compared to the two models mentioned above and are far more complex in nature.

3. Transmission Line Model

This model represents the micro strip antenna by two slots of width W and height h, separated by a transmission line of length L. The ratio strip is essentially a nonhomogenous line of two dielectrics, typically the substrate and air.

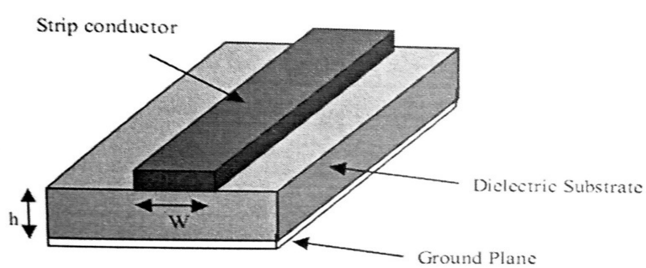

Figure 1: Microstrip Line

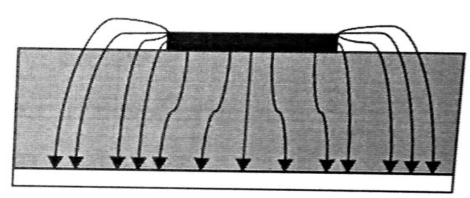
Figure 2: Electric Field Lines

Hence, as seen from figure 1, most of the electric field lines reside in the substrate and parts of some lines in air. As as results, this transmission line cannot support pure transverse electric-magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε_{reff} is slightly less than ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in figure 2 above. The expression for ε_{reff} is given as:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{½} \quad 1$$

Where ε_{reff}= Effective dielectric constant
ε_r = Dielectric constant of substrate
h = Height of dielectric substrate
w= Width of the patch

Consider figure 2 below, which shows a rectangular micro strip patch antenna of length L, width W resting on a substrate of height h. The co-ordinate axis is selected such that the length is along the x direction, width is along the y direction and the height is along the z direction.

In order to operate in the fundamental TM10 mode, the length of the patch must be slightly less than $\lambda/2$ where λ is the wavelength in the dielectric medium and is equal to $\lambda_0/\sqrt{\varepsilon_{reff}}$ where λ_0 is the free space wavelength. The mode implies that the field varies one $\lambda/2$ cycles along the length, and there is no variation along the width of the patch.

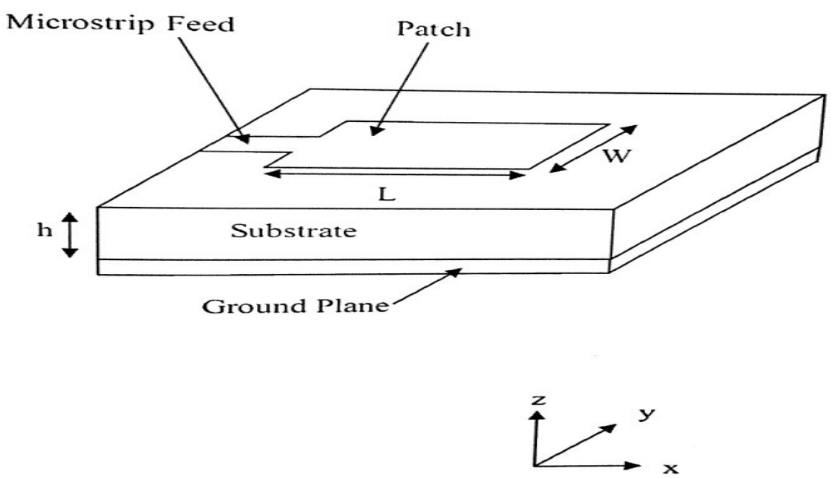

Figure 2: Microstrip Patch Antenna

In the figure 3 shown below, the micro strip patch antenna is represented by two slots, separated by a transmission line of length L and open circuited at both the ends. Along the width of the patch, the voltage is maximum and current is minimum due to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane.

It is seen from figure 4 that the normal components of the electric field at the two edges long the width are in opposite directions and thus out of phase since the patch is $\lambda/2$ long and hence they cancel each other in the broadside direction.

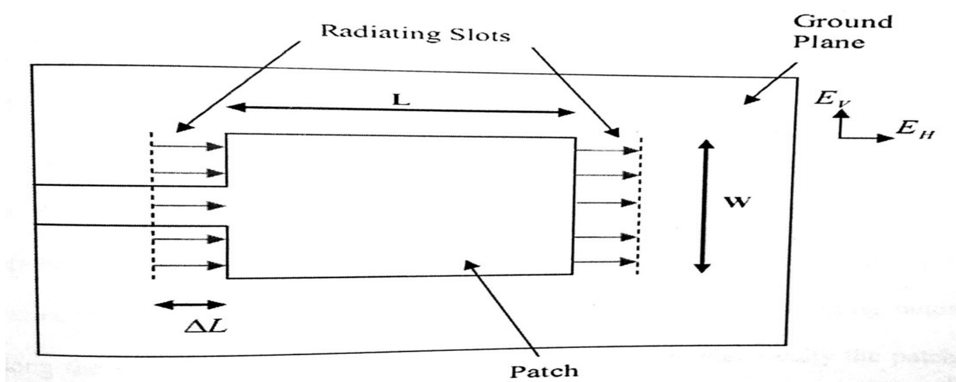

Figure 3: Top View of Antenna

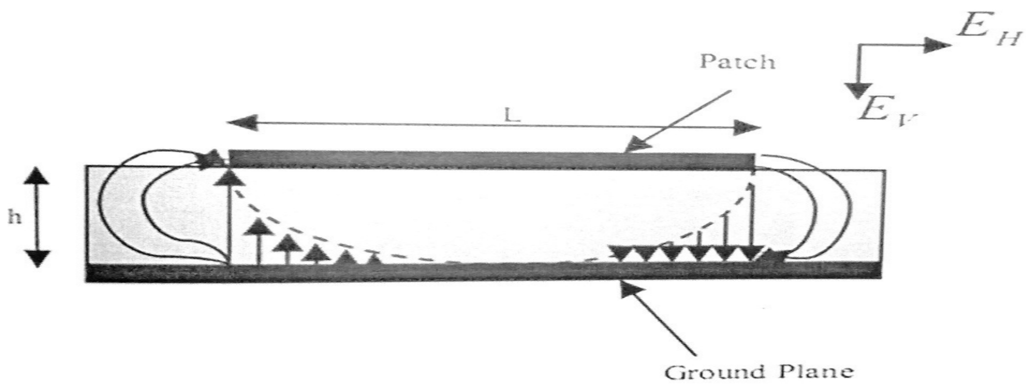

Figure 4: Side view of Antenna

The tangential components (seen in Figure 4), which are in phase, means that the resulting fields combine to give maximum radiated field normal to the surface of the structure. Hence the edges along the width can be represented as two radiating slots, which are λ/2 apart and excited in phase and radiating in the half space above the ground plane.

The fringing fields along the width can be modeled as radiating slots and electrically the patch of the micro strip antenna looks greater than its physical dimensions. The dimension of the patch along its length has now been extended on each end by a distance ΔL, which is given empirically as:

$$\Delta L = 0.412h \frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad 2$$

The effective length of the patch L_{eff} now becomes:

$$L_{eff} = L + 2\Delta L \quad 3$$

For given resonance frequency f_0, the effective length is given as:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad 4$$

For a rectangular Micro strip patch antenna, the resonance frequency for any TMmn mode is given as:

$$f_0 = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{1/2} \quad 5$$

where m and n are modes along L and W respectively. For efficient radiation, the width W is given by

$$w = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad 6$$

4. Conclusion

In this paper, an introduction to the micro strip patch antenna is followed by its advantages and disadvantages. Next, transmission linemodelingtechnique is discussed. Finally, a detailed explanation of micro strip patch antenna analysis and its theory are discussed, and also the working mechanism is explained.

References

1. Constantine A. Blains; Antenna Theory, Analysis and Design, John Wiley & Sons Inc. 2nd edition 1997.
2. Y.T. Lo. and S.W. Lee, editors, Antenna Handbook Theory, Applications and Design, Van Nostrand Reinhold Company, New York 1988.
3. Stutzman Warren L. and Thiele Antennas and Propagations Magazine, vol. 52, Feb. 2010.
4. BraodbandMicrostrip Antennas, Girish Kumar and K.P.Ray, Artech House, 2002.
5. Daniel H.Schaubert, "A review of Some Microstrip Antenna Characteristics" Microstrip Antennas - The Analysis and Design of Microstrip Antennas and Arrays, Edited by David M. Pozar, Daniel H. Schaubert, John Wiley & Sons. Inc., 1995, ISBN 0-7803-1078-0.
6. A Derneryd, "Linearly Polarized Microstrip Antennas", IEEE Trans. Antennas and Propagation, AP-24, pp. 846-851, 1976.
7. D.M.Pozar Microwave Engineering, 3rd ed. New York, John Wiley & Sons, 1998.
8. J.A. Kong, Electromagnetic wave theory. EMW Publishing, 2008, P. 268.