Effect of Adjustable Antenna Substrate Thickness on Aperture-Coupled Microstrip Antenna

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Abstract: Aperture-coupled microstrip antenna is one type of microstrip antennas. This type of antenna has bandwidth wider than simple microstrip antenna. Herein, we use two substrates, that have the same dielectric constant 2.47 (PTFE-quartz) in which upper substrate is a rectangular patch. The microstrip patch is fed by a microstrip line which is printed on lower substrate, through an aperture or slot in the common ground plane of patch and microstrip feed. This antenna is analyzed by using Finite Difference Time Domain (FDTD) method the specific design frequency 10 GHz and match impedance is 50 ohms. The simulation results of its characteristics are input impedance, return loss, VSWR and radiation patterns respectively.

Keywords: FDTD, VSWR, return loss, resonance frequency

1. INTRODUCTION

It is known that there are many type of antennas can be used for both transmit and receive signals. Microstrip or printed antenna is one type of antennas which is a miniature size, light weight and widely used in wireless and mobile communications.

However, microstrip antenna have a number of useful properties. But one of the serious limitations of microstrip antenna is that it has narrow bandwidth characteristic. Researchers has been engaged in removing this limitation and successful to increase impedance bandwidth. Aperture-coupled microstrip antenna is one of these successful. It was proposed by Pozar in 1985. It is one type of microstrip antenna. It has many advantages over other types. These include shielding of antenna from spurious feed radiation, use of suitable substrates for feed structure and antenna, and use of thick substrate for increasing the antenna bandwidth. Since the features of this antenna is used in a wide variety of applications, and the versatility and flexibility of the basic design have led to an extensive amount of development and design variations by workers throughout the world.

To describe the performance of an antenna, some parameters are necessary. Some of the parameters are interrelated and not all of them must be specified for complete description of the antenna performance. The parameters in characteristics of this antenna are radiation pattern, input impedance, S parameter and VSWR. To achieve these parameters, Finite Difference Time Domain (FDTD) method is used. FDTD method is introduced to solve the complicated problems in electromagnetic field theory. The FDTD method is capable of computing electromagnetic interactions for geometric problems that it is extremely difficult to analyze by other methods.

In this research, we will consider aperture-coupled microstrip antenna with difference substrate thickness H. Analysis an input impedance, return loss, VSWR, and radiation patterns of antennas for observe effect. To have better impedance matching at designed resonant frequency, the real part of input impedance is approached to characteristic impedance of the microstrip line and the imaginary part of the impedance is nearly zero ohm.

2. FDTD METHOD

This antenna was simulated by FDTD analysis. This software is a full wave electromagnetic simulation code for conventional three dimensional (3D) passive structures, particularly planar-oriented microwave circuits and antennas which are based on the FDTD algorithm. FDTD analysis was introduced by Kane Yee. This technique can be treats in transients conditions such as pulse in the time domain, and computational electromagnetic modeling which can predict and analysis of the electromagnetic responses of complex problems.

The analytical space consists of 40x80x100 cells with the cell dimension $\Delta x = 0.1$ mm, $\Delta y = \Delta z = 0.25$ mm. The time step satisfies the following courant condition.

$$\Delta t \le \frac{1}{c}\sqrt{\frac{1}{(\Delta x)^2}+\frac{1}{(\Delta y)^2}+\frac{1}{(\Delta z)^2}} \qquad (1)$$

For FDTD simulation of general three-dimensional microwave structures, it is more effective to use pulsed signal sources for excitation in the circuit. Gaussian pulse has been preferred source signal. The Gaussian pulse is excited at a source plane along the +z direction. The equations of electromagnetic field in FDTD method is analyzed in the boundary condition that calculate by central difference expressions base on Maxwell's equations and can easily derive Yee's famous "leap-frog" algorithm for updating the six electromagnetic field components with respect to a certain type of source excitation [2]. For source excitation of the antenna is input voltage V(t) base on Gaussian pulse and express as

$$V(t) = e^{-\left(\frac{t-t_0}{T}\right)^2} \quad (2)$$

Where t_o is the center of the pulse, T is the pulses width at its 1/e characteristic decay point.

3. ANTENNA STRUCTURE

An exploded view of aperture-coupled microstrip antenna is shown in Fig. 1 Which consists of two substrates. On upper substrate is a rectangular patch of dimensions A x B printed on a substrate of thickness H and dielectric constant ε_{ra}. The microstrip patch is fed by a microstrip line through an aperture or slot in the common ground plane of patch and microstrip feed. The dimensions of aperture is L_a x W_a and width of microstrip line is match with characteristic impedance of transmission line.

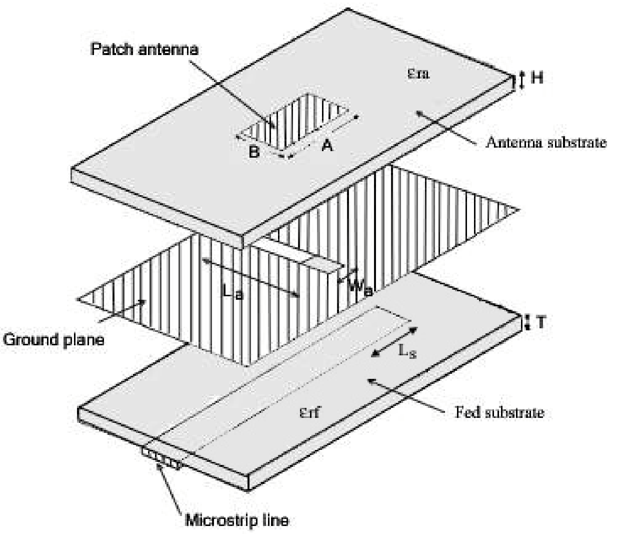


Fig. 1 Aperture-coupled microstrip antenna structure

The first step in designing an antenna is chose with an appropriate substrate. The dielectric material substrate has dielectric constant which may affect the electrical performance of an antenna, circuits and transmission line. In this paper, we use two substrates that have the same dielectric constant 2.47 (PTFE-quartz). After that, we define thickness H and T. Later, we adjust A, B, L_a, W_a that effect to resonance frequency. Adjusting stub length (L_s) will effect to matching impedance. Moreover, we also study the behavior of the designed microstrip antenna by changing thickness H of substrate ε_{ra} and fixed T at 0.7 mm.

4. SIMULATION RESULTS

4.1 Return loss and characteristic of input impedance

The return loss or reflected loss set as S_{11} parameter is given as follows.

$$S_{11} = \frac{\Im\left[V_{ref}(t)\right]}{\Im\left[V_{inc}(t)\right]} e^{2\gamma L} \quad (3)$$

Where $\Im$ shows a Fourier Transform and L is the length between observing point and a reference point. The propagation constant γ can be defined by

$$\gamma=\alpha+j\beta \quad (4)$$

Where γ and β are attenuation and phase constants, respectively.

The input impedance is the complex number. To find out the input impedance can be done by using an parameter S11 and characteristic impedance Z_o of a microstrip line :

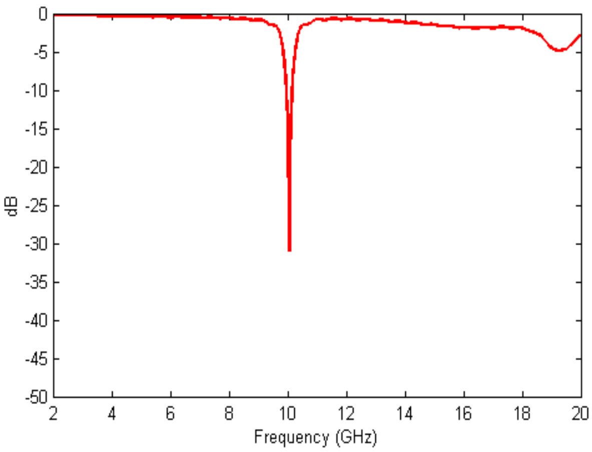
$$Z_{in} = \left[\frac{(1+S_{11})}{(1-S_{11})}\right] Z_o \quad (5)$$

The observation point will be nearly the reference point when analysis by FDTD method. By adjusting technique, real part and imaginary part of Z_{in} are nearly 50 ohms and 0 ohm, respectively.

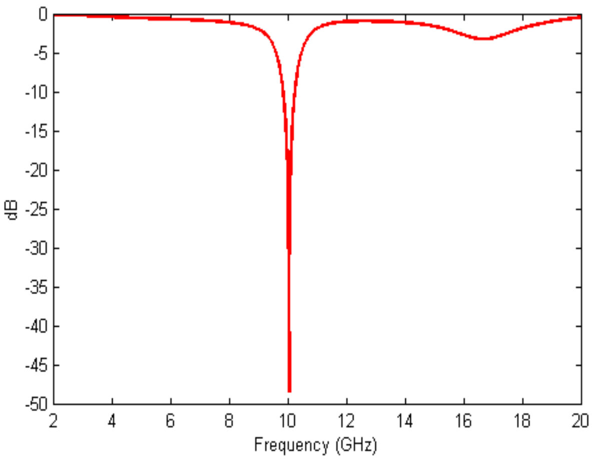
Table 1. Simulation Result of aperture-coupled antennas with difference substrate thickness H by fixed T = 0.7 mm.

H (mm)		0.3	0.7	1.5
A (mm)		7.5	7.5	7.5
B (mm)		11.5	7	5.5
L_a (mm)		5.5	5.5	5.5
W_a (mm)		0.5	0.5	0.5
L_s (mm)		7.75	7	3.5
Bandwidth		2.4%	4.4%	12.1%
Return Loss	GHz	10.03	10.02	9.91
	dB	-30.87	-48.43	-31.40
Input Impedance	Real (Ω)	52.10	49.84	47.54
	Imag (Ω)	2.02	-0.34	0.92

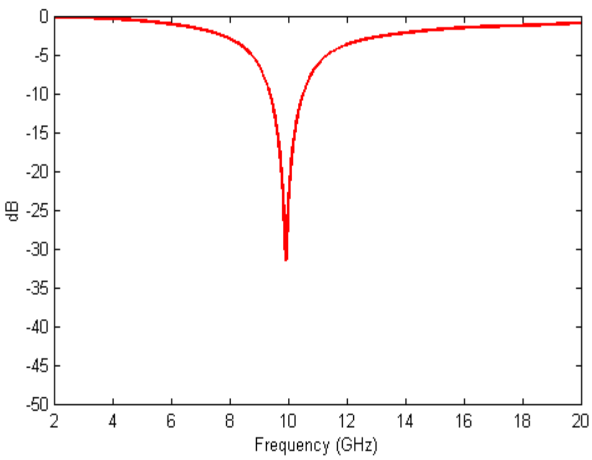
On table 1, by using three different thickness H and fix the thickness T, the adjusting technique in this simulation will be done for get the good matching impedance at resonant frequency 10 GHz. The characteristics of return loss, input impedance as shown in Fig. 2 and 3.



a) T= 0.7 mm, H= 0.3 mm

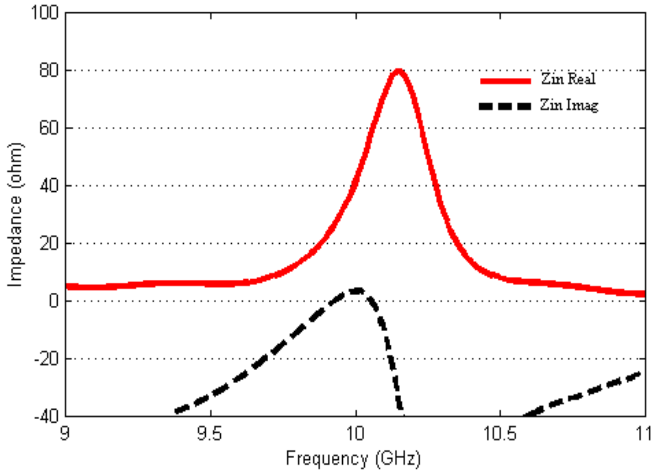


b) T = H = 0.7 mm

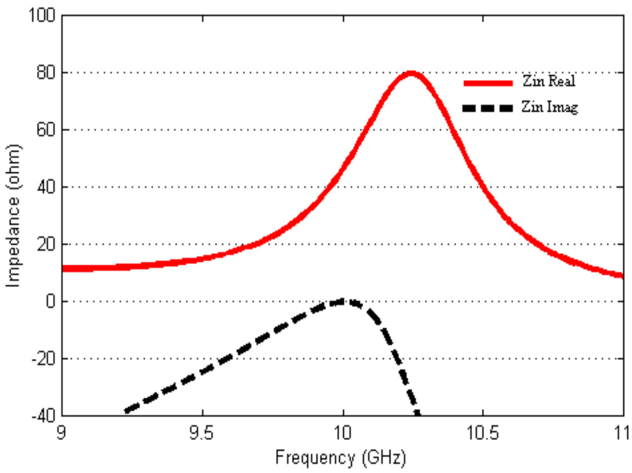


c) T=0.7 mm, H= 1.5 mm

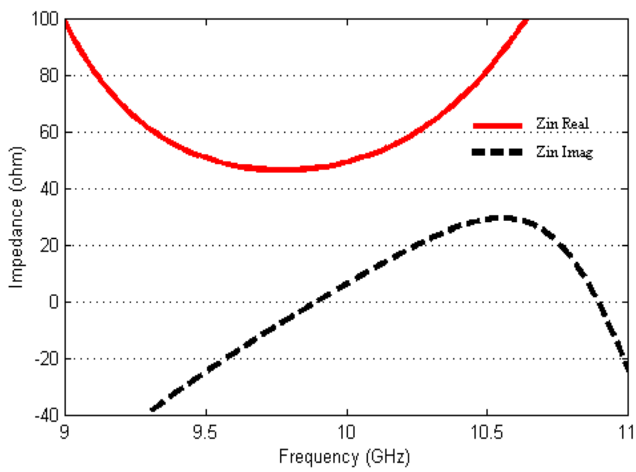
Fig. 2 Shown return loss of antennas at difference thickness H



a) T= 0.7 mm, H= 0.3 mm



b) T = H = 0.7 mm



c) T=0.7 mm, H= 1.5 mm

Fig. 3 Shown input impedance of antennas at difference thickness H

4.2 VSWR

VSWR is a characteristic for show the performance of antenna which relate to reflected wave. The VSWR can be calculated from any of several bits of knowledge. Therefore, it is possible to determine value of VSWR by the ratio of the reflected voltage to incident voltage along the microstrip line. In a properly designed system for impedance matching the value of VSWR will nearly 1.

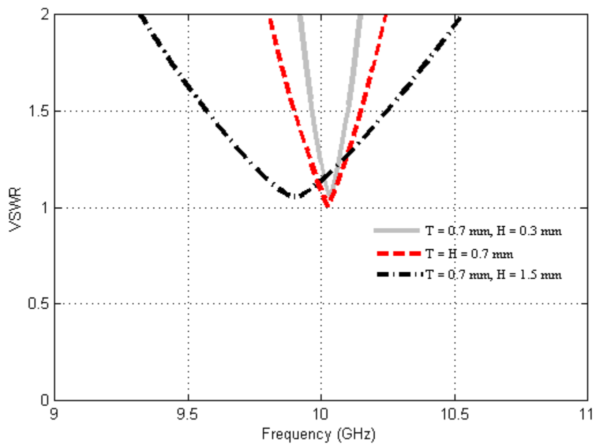


Fig. 4 VSWR of aperture-coupled microstrip antennas in three difference thickness H

4.3 Far Field Patterns

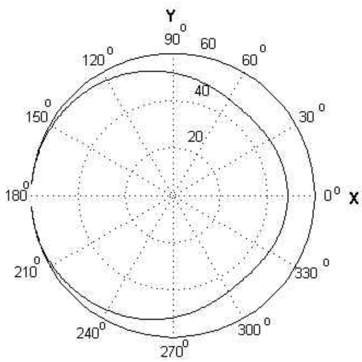


Fig. 5 Far field pattern on the xy-plane

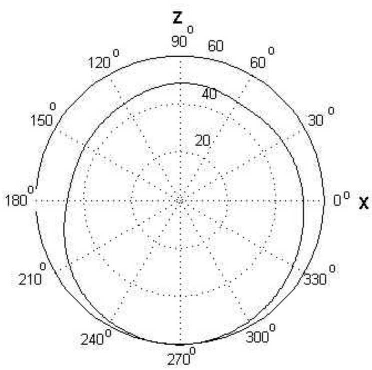


Fig. 6 Far field pattern on the xz-plane

To achieve far field patterns, FDTD method can transform near field to far field by discrete Fourier Transform to carry out for the equivalent electric and magnetic current densities during the FDTD iteration. From simulated by FDTD, we found that total far field patterns of this antenna in three different thickness H will be similar.

5. CONCLUSION

Microstrip antennas have various useful properties. But one of the serious limitations is that it has narrow bandwidth characteristic. To overcome this limitation, aperture-coupled microstrip antenna used the thickness of substrate to increase the antenna bandwidth.

From simulated results by FDTD method, it is shown that changing thickness H will effect the bandwidth of antenna. Furthermore, when thickness H is adjusted. The size of patch, L_a, W_a and stub length (L_s) have to be adjusted for good matching impedance at specific resonance frequency 10 GHz.

REFERENCES

[1] David M. Pozar, "A review of Aperture Coupled Microstrip Antenna: History Operation, Development and Applications".

[2] Yongxi Qian and Tatsuo Itoh, *FDTD Analysis and Design of Microwave Circuits and Antennas Software and Applications*, Realize Inc., 1999.

[3] Ramesh Grag, Prakash Bhartia, *Microstrip Antenna Design Handbook*, Artech House 2001.

[4] Kai Fong Lee and Wei Chen, *Advances in Microstrip and Printed Antennas*, John Wiley & Sons, Inc., 1997.

[5] Pamela R. Haddad and David M. Pozar, "Analysis of Aperture Coupled Microstrip Patch antenna with a thick ground plane," *Antennas and Propagation Society International Symposium*, Volume: 2, Page(s): 932-935, 20-24 June 1994.

[6] K. Williams, D.B. Davidson and H.C. Reader, "FDTD MODELLING OF AN APERTURE COUPLED PATCH ANTENNA FOR USE IN AN ACTIVE ARRAY," *10th International Conference on Antennas and Propagation*, 14-17 April 1997.