U-Slot Stacked Patch Antenna Using High and Low Dielectric Constant Material Combinations in S-band

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Abstract

In this paper, a coaxially fed broadband U-slot stacked rectangular microstrip patch antenna in corporating a high and low dielectric material combination is presented. The antenna essentially consists of two commercially available microwave substrates (Rogers TMM3 and Rohacell HF71 foam). Dielectric constants of materials are 3.27 and 1.07 respectively. Foam material doesn't include copper surface thus a third dielectric substrate with thickness of 0.254 mm and dielectric constant of 2.2 is added over the foam material to ease of fabrication. The antenna return loss bandwidth is about 52.94%, centered about 3.4 GHz. The effect of the parameters, such as u slot length and width, on the antenna performance are determined, experimentally verified and discussed.

1. Introduction

Microstrip antennas have the advantage of low cost, thin profile, ligth weight, ease of fabrication, conformable to mounting surface and being integrated in active devices. Also probe fed microstrip antennas provide excellent isolation between the feed network and the radiating elements and yield very good front to back ratios. Because of these advantages microstrip antennas find application in variety of fields like space technology, aircrafts, missiles, tracking, mobile communacition, GPS systems, remote sensing and satellite broadcast. The most important drawback of microstrip antennas is narrow bandwidth. Maximum 8% bandwidts are avaliable with classical microstrip antennas.

To overcome this drawback, several methods have been devised by researchers. These include using parasitic elements on same layer or another layer (stacked) [1]-[2], using various slot shapes such as U-slot [3]-[8], using bending probe and using shorting pin or shorting wall structures [9]. These methods have their own advantages and disadvantages.

In this study, the properties of traditionally stacked patch antenna and U-slot patch antenna are presented. Two examples of these antennas are designed, simulated and measured in Compact Fully Anechoic Chamber in Antenna Test and Reserach Center for effective check on the method. Finally, S band U-slot stacked patch antenna design is presented. Impedance bandwith of 52.94% is obtained. A numerical solution of the antenna is obtained for various values of the slot length and slot width through the effect of these parameters on the return loss and gain of the antenna are studied.

2. Stacked Patch Antenna

Stacked patch antenna is kind of microstrip which consists of two printed antenna. The lower patch is called driven patch and another patch is parasitically coupled to driven patch. To produce broadband responses the selection of the substrate of the first layer is very important. The current distribution on the lower patch has an important role on the bandwidth of the antenna. If the lower dielectric layer has a greater dielectric constant than the upper layer, the magnitude of the first order mode on the lower patch will be greater than on the top patch thus the broadest bandwidths can be achieved.

The thickness of each layer has an important role to obtain broader bandwidth. In the design process the lower patch does not design for minimum return loss in the desired band, rather than the patch should be strongly capacitive over this frequency range. To provide this, feed position of the antenna become near the edge of the

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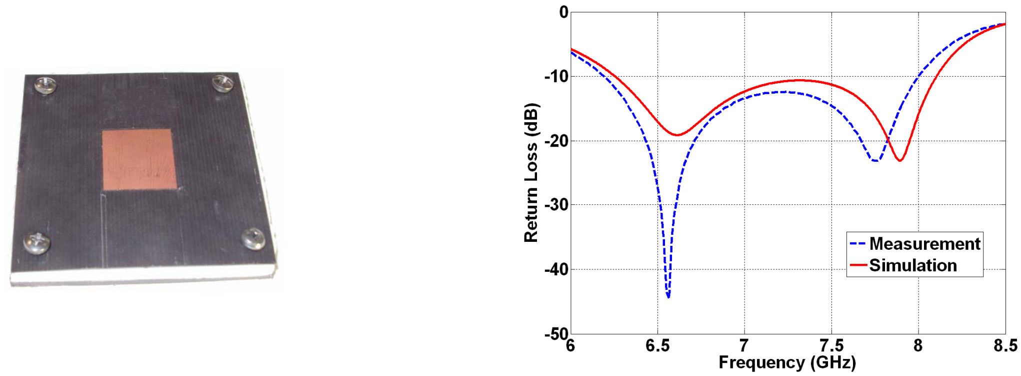
patch. The adding of the second element moves the very capacitive impedance region of the single patch locus to near a matched condition. The bandwidth of the stacked patch antenna is about 25%.

As an example to show above feature of a stacked patch antenna we designed, its return loss parameter is shown in Figure 1. The impedance bandwidth of antenna is about 25% centered about 7 GHz. Simulations were made with CST full wave simulator. Good agreement between simulation and measurement is obtained.

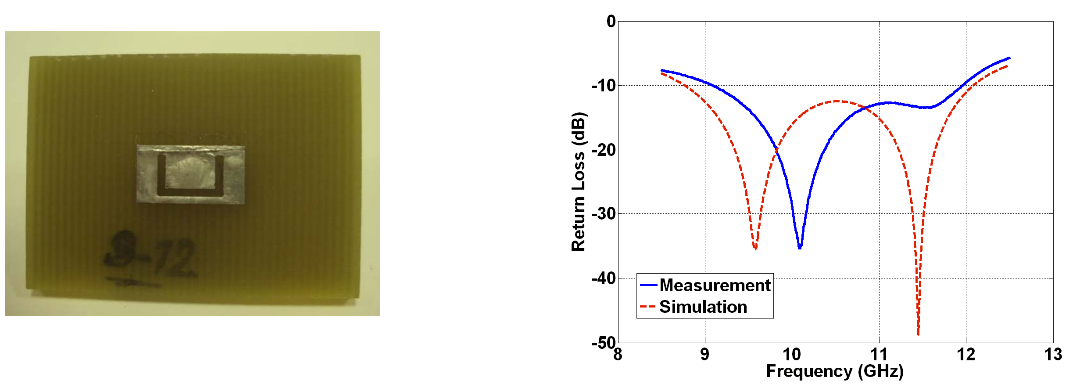


(a) (b)

Figure 1. (a) Stacked patch antenna, (b) Return Loss of the stacked patch antenna.

3. U Slot Patch Antenna

Impedance bandwith of about 30% can be obtained by cutting a U-shape slot on the patch. U slot behaves as a serial capacitor thus the inductive behaviour of probe feed can be compensated and impedance matching can be optained. The main advantages of U-slot patch antenna is that it produces broad band characteristics with a single and simple topology. The variations of U-slot patch antenna paramaters such as slot widht, slot lenght, height and size of the patch, probe location and substrate permitivity can dramatically change the antenna's behaviour. Analytical procedures have not been develop to design U-slot patch antenna. Dimensional invariance and resonance frequency approaches are well known empirical design procedures in literature. These approaches are useful for initial designs and desired antenna behaviour can be obtained after some optimizing and tuning process.



(a) (b)

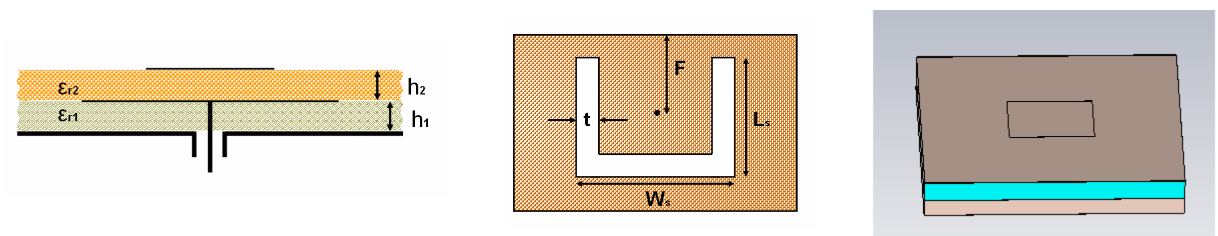
Figure 2. (a) U-Slot patch antenna, (b) Return Loss of the U-Slot patch antenna.

The strenght of dimensional invariance method is that it converges optimized design quickly, if desired frequency lies in the range in which the design equations are reliable. The weakness of this method is that the design equations were developed for specific values of substrate permittivity and thickness. Resonance frequency approach assumes the existence of four distinct frequencies. Third resonance frequeny is selected to the center freqency and the second resonance frequency is selected to lower end of frequency range. In this method only low permitivity substrates were studied and this approach may generate physically unfeasible designs.

As an example a u slot patch antenna and its return loss parameter are shown in Figure 2. The impedance bandwidth of antenna is about 27.77% centered about 10.5 GHz. Simulations were made with CST full wave simulator. Good agreement between simulation and measurement is obtained. There is a bit shift between the measurements and simulation results in the first resonance of the antenna. We think that this difference originated from the uncertainties of FR-4 material at high frequencies.

4. U Slot Stacked Patch Antenna

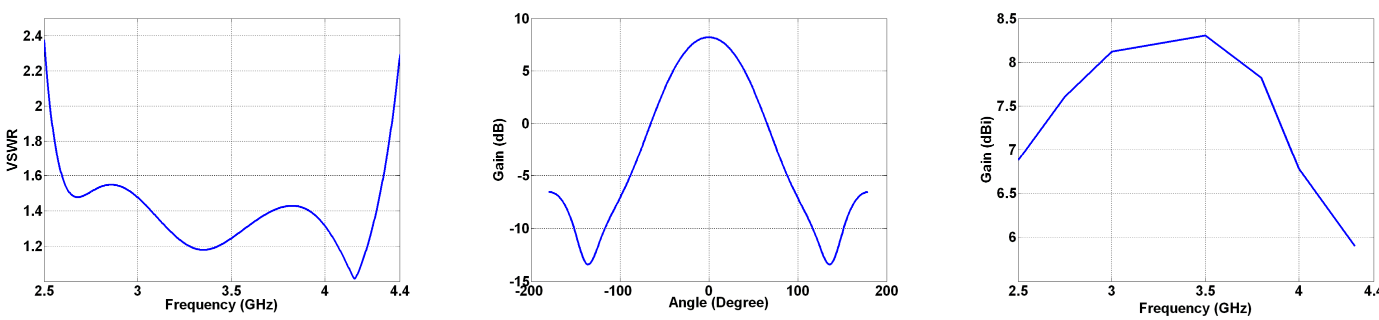
U-slot stacked patch antenna structure combines two broadbanding methods thus wider bandwidths can be obtained. Normally classical U-slot patch antenna’s pattern bandwidth is smaller than impedance bandwidth but by using a stacked configuration this drawback can be overcomed. The geometry of the antenna is given in Figure 3. The height of the first layer is determined like in classical U-slot patch antenna. Appropriate $h\sqrt{\varepsilon_r}/\lambda$ value can be chosen in literature [10] for dielectric constant of the material. The height of the second layer must be higher than the height of the first layer like in classical stacked patch antenna.



(a) (b) (c)

Figure 3. (a) Side view of the antenna, (b) Top view of the first layer patch, (c) CST view of the antenna.

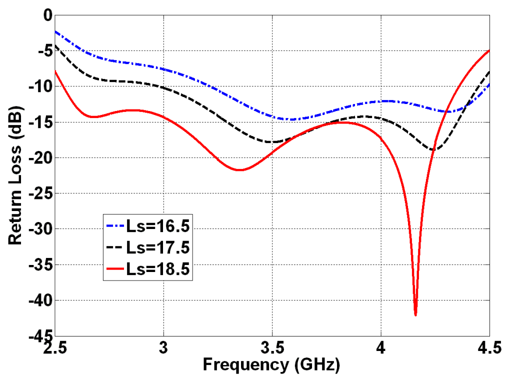
In this study Rogers TMM3 material is used instead of foam material for the first layer thus the fabrication process is much easier. Although using higher dielectric constant (3.27) for he first layer, wider bandwidth is obtained. Rohacell HF71 foam material is used for the second layer thus the combination of the high and low dielectric constant material 52.94% impedance bandwidth is achieved. The return loss, pattern and gain characteristics of the antenna are given in Figure 4.



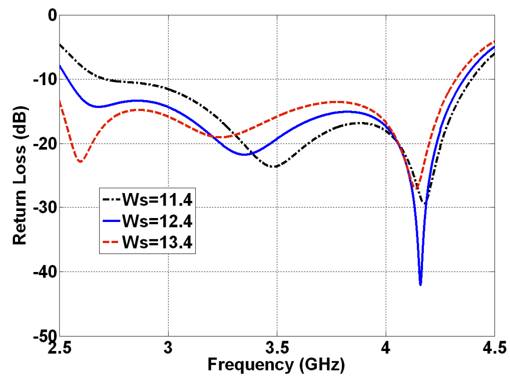
(a) (b) (b)

Figure 4. (a) VSWR of the U-slot stacked patch antenna, (b) Pattern of the U-slot stacked patch (c) Gain of the U-slot stacked patch antenna.

U-slot stacked patch antenna has a large number of paramaters that effect the impedance behaviour of the antenna thus wider bandwidts can be obtain by changing these parameters appropriately. The effects of slot width and length of the antenna impedance characteristic is given in Figure 5. Slot width and lenght effect the lower frequency of the antenna because the present of the slot restricts the patch currents, at its lower resonance frequencies, between the slot arm and patch vertical edge thus increasing the slot widht or lenght increases the path length and lowers its resonance frequency.



(a)



(b)

Figure 5. (a) Effect of slot lenght on the return loss, (b) Effect of slot widht on the return loss.

5. Conclusion

In this study, properties of the U-slot stacked patch antenna were investigated. The antenna consists of high and low dielectric constant material combinations thus the fabrication process of the antenna is much easier and much larger bandwidth of about 52.94% was achieved. The pattern of the antenna was stable over the entire bandwidth. The effects of some parameters on the return loss were investigated. Properties of the classical stacked and classical U-slot patch antenna were also examined.

6. References

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