RESEARCH ARTICLE OPEN ACCESS

Broad Band Microstrip Patch Antenna Using Foam Gap Substrate for Wi-Fi Band

Ali Esseid Almuzwghi[1], Lail, Brian[2]
1. Department of Computer Eng. and Science, Florida Institute of Technology, Melbourne, FL 32901, USA
2. Department of Computer Eng. and Science, Florida Institute of Technology, Melbourne, FL 32901, USA
Corresponding Author: Ali Esseid Almuzwghi

ABSTRACT
Exclusive today, microstrip patch antenna is widely used in different modern communication systems, where lightweight and low-cost is the main advantages. However, the main disadvantages of microstrip patch antenna it has low gain and narrow bandwidth. In this paper, the bandwidth and the gain of the microstrip patch antenna are increased. This significant value were obtained by inserting a foam gap (FG) layer between the patch and the ground plane-especially with the care of the dimensions of this antenna. The main objective of this paper is to design and simulate microstrip patch antenna that suitable for the 5 GHz (Wi-Fi band) application. The proposed antenna has a maximum gain of 7.922dBi at resonant frequency 4.420 GHz, and 8.910dBi at 5.620GHz with directivity 8.761dBi and 10.160dBi, where 4.420GHz has a bandwidth of 36.84% and 5.620GHz has a bandwidth of 28.93%. The simulation results were obtained by using Microwave office (AWR) version 2018 and Advance Design System (ADS) version 2016 simulator.
***Keywords** - inserting; foam gap; maximum gain; bandwidth*

Date of Submission: 25-02-2019 Date of acceptance: 18-03-2019

I. INTRODUCTION

Antenna is considered the main communication part that used to convert electromagnetic signals into voltage or current and vice versa [1, 2, 3]. Microstrip patch antenna is one such a kind of antenna parts in radar systems, mobile communication systems (Wi-Fi, Wi-MAX, and WPAN), satellite communications, spacecraft, guided missiles, flight control, and navigation systems [4,5].

The microstrip patch antenna usually consists of two or more layers. One of them is the radiating patch, which usually located at the top layer and is made of conducting material such as gold or copper, while the second layer located at the bottom and called the ground plane.

The microstrip patch antenna is commonly used in different modern communication systems due to their small size, eases of fabrication, low cost, ease of conjunction with integrated RF devices, and their circular or linear polarization. However, the major disadvantages and limitations of microstrip antennas are low-gain and very narrow bandwidth [6, 7, 8].

in the past few years, much work has been devoted to increase gains and extend the bandwidth of microstrip patch antennas. They are used many techniques to solve these limitations such as; substrate thickness [9], the slot-loading technique [10], and a slotted ground plane [11]. There is another technique used to improve the gain and the bandwidth by using stacked or multilayer patches, but this technique increases the overall antenna volume [12, 13,14].

Further, several other radiating structures have been reported for the bandwidth enhancement of microstrip antenna. A novel implementation of an electromagnetically coupled patch antenna using air gap filled substrates is conducted to achieve the maximum bandwidth [15]. The comparison of the measured input impedance with the simulated results based on FDTD approves the accuracy of the model. They found that the measured bandwidth of the antenna at 1.36GHz is about 16%, where the broadband behavior is considered the inherent bandwidth limitations in microstrip antennas.

Another work related on creating cuts in the ground and increasing the height of the patch and substrate thickness and decreasing the permittivity of the substrate (the air thickness between the two layers). In these work the percentage of the bandwidth is increased, where the tested two-layer antenna works at 6.1 GHz with a bandwidth (S11 ≤ -10dB) of about 11%, 8-dBi gain [16].

Double U-slots stacked patch antenna with copper plate and air the gap for wireless LAN applications are also used in order to achieve the bandwidth of 119 MHz with the operating frequency range from 2.34 GHz to 2.46 GHz is about 5% and a better gain which is 7.357 dBi at 2.402 GHz [17].

In our work, the adjustable is accomplished by a little change in thickness of Gab of the dielectric substrate, where layer gab have a low permittivity like air or foam. This modifications provide a larger bandwidth, higher gain, higher efficiency, and perfect radiation. In general this technique decreased the value of the dielectric substrate and increase the height of the gap.

II. ANTENNA DESIGN

The proposed antenna is designed for the resonating frequency of 4.45GHz and 5.65GHZ. The substrate material Rogers_RT_Duroid5870 substrate is designed with thickness 1.6 mm, permittivity (€r) =2.33, and tangent loss is 0.0012 at the bottom layer. The Rogers_RT_Duroid5881 substrate designed with thickness 1.6 mm, permittivity (€r) =2.17, and tangent loss is 0.0009 at the top layer, as shown in figure1.

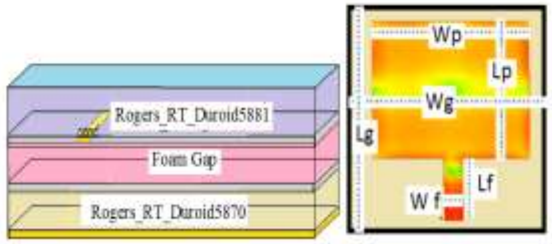

Figure 1: Design of the proposed antenna

Microstrip feed line is considered the main feed in antenna design, because microstrip line feed structure is more suitable compared to probe feeds, and due to ease of fabrication and lower costs. The main advantage of the microstrip line is to applying the adjustable thickness of foam gap method, where coaxially fed patches every time the foam gap width is changed, while the coaxial probe has to be de-soldered and re-soldered to the patch every time changed the thickness.

In this paper, the Microstrip line feeding can be used to radiate the power of the proposed antenna and the strip line can be united with the patch of the antenna. The basic structure of the Microstrip line feeding can be shown in Figure 1, which the purpose of this paper to present the results of our study to increase the bandwidth, gain, impedance matching, and tuning the resonant frequencies by means of an adjustable foam gap for one case. Table 1, shows all the dimensions in millimeters of the patch antenna design.

Table 1: Optimized values of proposed patch antenna parameters.

Parameters	Numerical Values in mm
Patch width =*Wp*	62.5
Patch length =*Lp*	41.5
Substrate height1&2	1.60
Substrate height (Foam Gap)	1.0-4.4
Ground Plane width =*Wg*	80
Ground Plane length= *Lg*	80
Feeding width= *Wf*	3.0
Feeding length =*Lf*	22.5

III. OPTIMIZED ANTENNA DESIGN

The dimensions of the metallic patch were slightly changed in order to improve the antenna performance parameters. A systematic study of the thickness of the substrate foam gap is optimized from 1.0 mm to 4.4 mm in 0.2 mm increment. Finally, the dimension of the ground plane is 80mm x 80mm and the patch reaches the best dimension of 62.5 mm × 41.5 mm.

IV. SIMULATION RESULTS

To get a high gain and wide broad band several experiments were conducted. In order to design and simulate the antenna and to obtain the final results, Microwave office (AWR) version 2018 and Advance Design System (ADS) version 2016 were used. The simulation results are presented graphically and numerically and the discussion is based on the observation of the effective foam gap thickness. The next sections show the major effect of the thickness variation gap on the bandwidth, resonant frequency, gain, directivity, and Return Loss.

IV.1 The effect of Height of the Substrate Foam Gap (FG) on Resonant Frequency

Using the commercial simulation software AWR as well as ADS software the case study has been carried out. The simulation results are obtained as shown in Figures 2 and 3 using eighteen values of the foam gap height. In Figure 2, it is seen that the results from the two software packages show good agreement. As foam gap height varies from 1.0 mm to 4.4 mm, the resonance frequencies increase from 4.373GHz to 4.560 GHz for lower resonance frequency (FR-1), While at higher resonance frequency (FR-2) the value is 5.436GHz to 5.693GHz using ADS software.

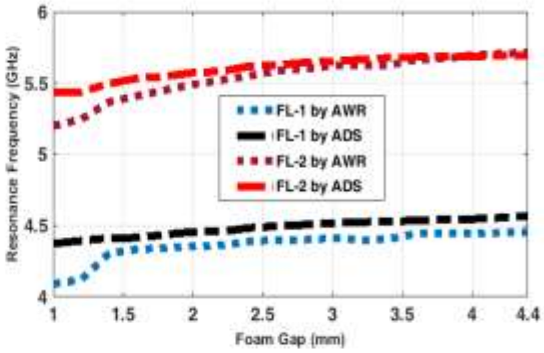

Figure 2: Variation of the resonance frequency with Height of Substrate foam gap

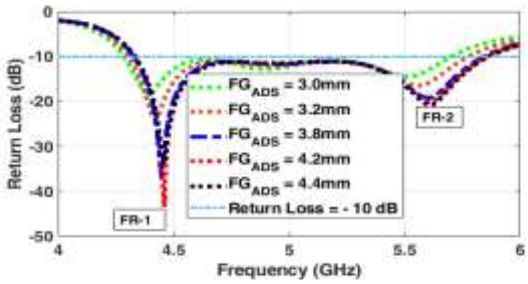

Figure 3: Power reflection coefficient (S11) and resonance frequency for different values of foam gap height.

IV.2 THE EFFECT OF THE HEIGHT OF THE SUBSTRATE FOAM GAP ON REFLECTION COEFFICIENT (S11)

Moving towards a higher height of the substrate the more volume to the fringing effects occurred, and this leads to a better return loss. The two best results are shown in Figure 4, Figure 5, and Figure6.

As shown in Figure 4, using the foam gap equal 3.0 mm, the return loses RL-1= −28.97dB and RL-2=-39.96dB, which obtained by (AWR software), and RL-1=-18.32dB, and RL-2=-14.32dB obtained by (ADS software). Using the foam gap equal 3.2 mm, the return loss parameter (S11) is RL-1=−40.64 dB, RL-2=-35.73dB by using (AWR software), and RL-1=-23.60dB, and RL-2= -16.30dB using (ADS software).

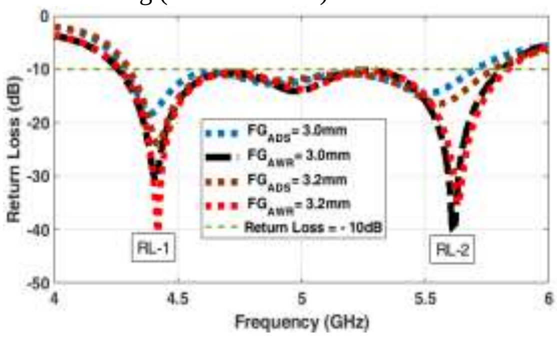

Figure4: Better of Power reflection coefficient (S11) for two different values of foam gap height

As shown in figure 5, the foam gap gives the great or more than average values of impedance matching with better return loss values when it maintains a gap between 3.0mm and 3.6mm for two resonant frequencies also at the gap is 4.2mm.

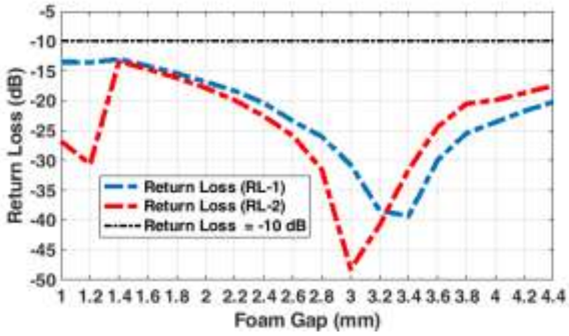

Figure 5: Variation of the Reflection Coefficient (S11) with Height of Substrate foam gap (AWR)

In Figure 6, it is observed that return loss (RL-1AWR) is a small increase when the height of the foam gap is increasing from 1.0mm to 3.0mm. Then again 3.0mm 3.4 mm viewing foam gap increase the rapid increase of return loss (RL-1 AWR) increases the exceptional and excellent from -30.75dB to - 39.39dB. While increasing the foam gap is increasing from 3.4mm to 4.4 mm had rapid return loss (RL-1 AWR) decrease from- 39.39dB to - 20.18dB. Whereas that return loss (RL-1ASD) is a small increase when the height of the foam gap is increasing from 1.0mm to 3.4mm, and it decreases between 3.4mm to 3.8mm. Then again 3.8mm 4.0 mm viewing foam gap increase the rapid increase of return loss (RL-1ADS) increases the exceptional and excellent from -25.43dB to - 50.62dB and it decreases again when foam gap is 4.2mm, also it is increasing where foam gap is 4.4mm.

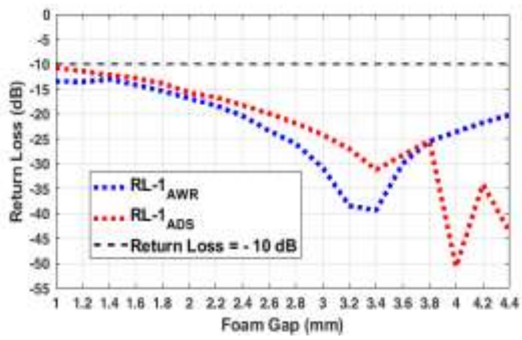

Figure 6: Variation of the Reflection Coefficient (S11) with Height of Substrate foam gap (AWR& ADS).

IV.3 THE EFFECT OF THE HEIGHT OF THE SUBSTRATE ON GAIN AND DIRECTIVITY.

Figure7 shows a graph of gain and directivity Vs thicknesses of the foam gap substrate. It can be seen that the gain increases (Gain-1(G-1)) from 6.25dBi to 8.05dBi and Gain-2(G-2) from 7.66dBi to 8.81dBi with the increase in substrate height whereas, directivity (Directivity-1(D-1)) from 7.36dBi to 8.98dBi and Directivity-2(D-2) from8 .56dBi to 10.21dBi.

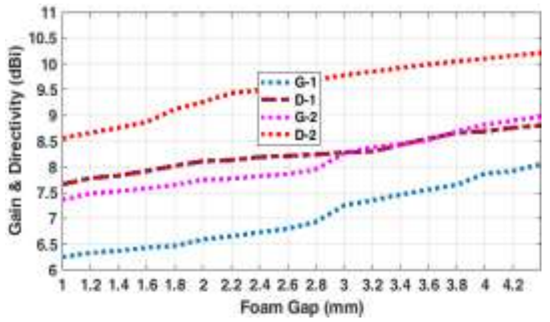

Figure 7: Variation Gain and Directivity with Height of Substrate foam gap.

IV.4 THE EFFECT OF THE HEIGHT OF THE SUBSTRATE ON BANDWIDTH

As shown in figure 8, from a height varying from 1.0 mm to 1.4 mm, there is very little variation in the absolute value of the bandwidth (BW-1) but the bandwidth (BW-2) at 1.0mm to 1.6mm. The bandwidth (BW-1) has a rapid increase where foam gap increases from 1.4mm to 1.8mm whereas; the bandwidth (BW-2) has a rapid increase at 1.6mm to 1.8mm. A significant bandwidth is observed at height of the substrate beyond from 1.8 mm to 4.4mm, it is appreciable extent. In these points of observation, the bandwidths are close to 1.628GHz or 36.17% and 28.43%.

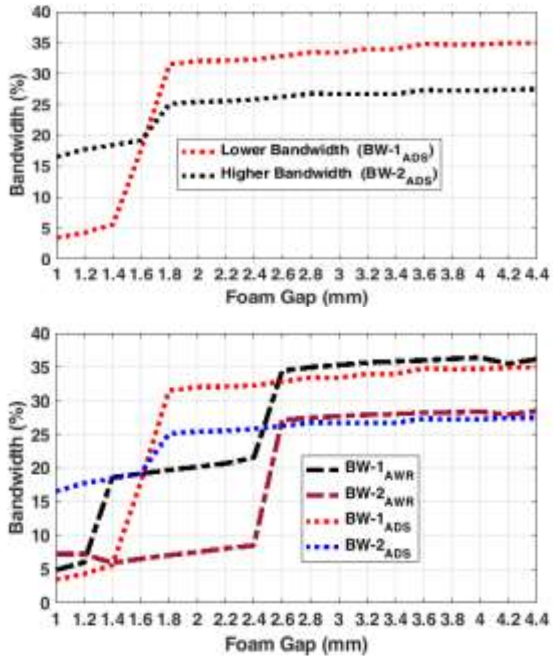

Figure 8: Variation Bandwidth with Height of Substrate foam gap.

V. CONCLUSION

It is seen from sections IV that all parameters of patch microstrip antenna such as directivity, gain, and bandwidth of a patch antenna depend on the height of the foam gap substrate. From the simulation results presented in section IV, it can be concluded that the foam gap substrate thickness of a patch antenna impacts the directivity, gain, and bandwidth of a patch antenna. The simulated results further show that a linear relationship exists between the thickness of the foam gap substrate and patch antenna performance parameters such as directivity, gain, and bandwidth.

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Ali Esseid Almuzwghi" Broad Band Microstrip Patch Antenna Using Foam Gap Substrate for Wi-Fi Band" International Journal of Engineering Research and Applications (IJERA), Vol. 09, No.03, 2019, pp. 48-52