CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter the results of the data analysis are presented. The data were collected by simulation and measurement process. Simulation was done on CST microwave studio and measurement process was taken on vector network analyzer. S_{11} (Return loss), bandwidth, gain of antenna are characteristic of the antenna that will be analyzed. Then the results of simulation and measurement compared.

4.2 Microstrip Patch Antenna

4.2.1 Return Loss of Antenna

Return loss of the antenna or S_{11} parameter is an important parameter of antenna. S_{11} parameter shows the comparison of transmitting wave with reflected wave. To get maximum result of antenna, S_{11} parameter should be under -10 dB value. The minimum value of S_{11} is known as operating frequency or resonant frequency.

Figure 4.1 shows S_{11} for microstrip patch antenna without EBG structure done by simulation using CST microwave studio. The simulated return loss value obtained for single patch without EBG is -22.56 dB at 2.4 GHz.

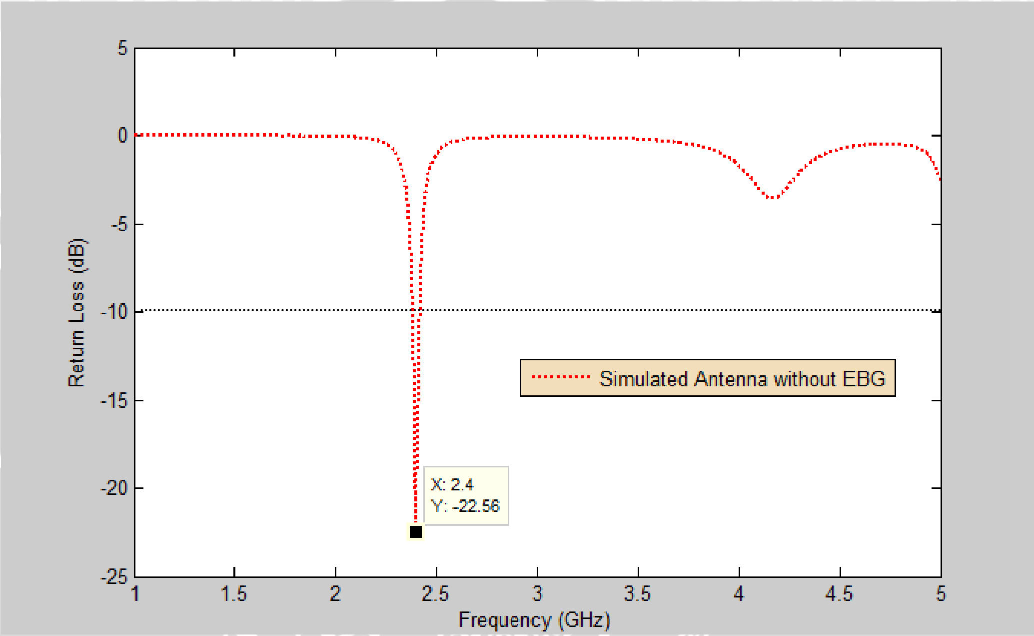


Figure 4.1 simulated S_{11} parameter

4.2.2 Bandwidth

Bandwidth is a frequency range where antenna works well. Bandwidth of antenna determined using S_{11} graph. Upper limit and lower limit of bandwidth are located at -10 dB value. Figure 4.2 shows the relative bandwidth is 13.5 % (from 2.3836 GHz to 2.416 GHz) at 2.4 GHz resonant frequency.

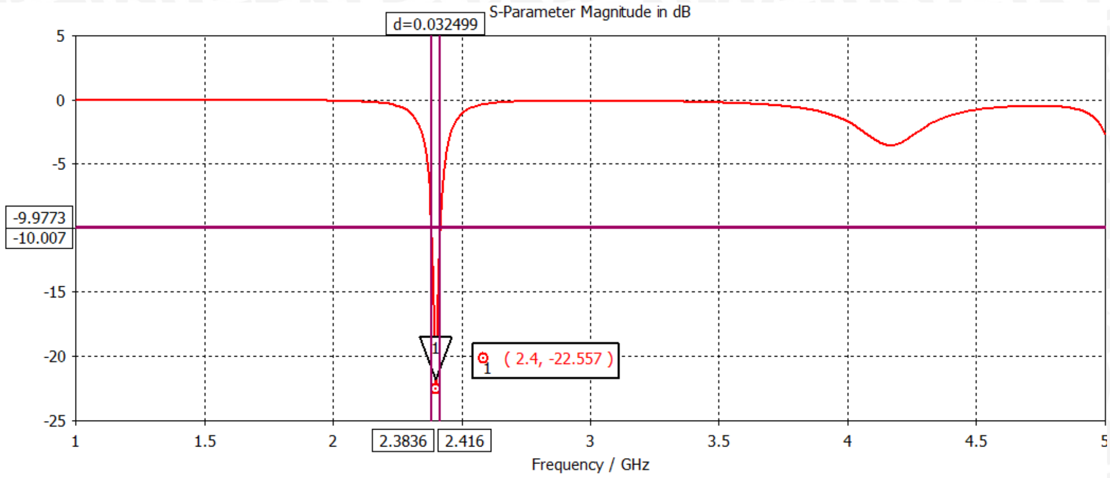


Figure 4.2 simulated bandwidth of microstrip patch antenna

4.3 Electromagnetic Band Gap (EBG) Structure

The electromagnetic bandgap (EBG) structures exhibit a bandstop behavior over a certain frequency range, in which the propagation of electromagnetic waves is prohibited. to get frequency range of EBG, EBG is analyzed using suspended microstrip line method (Figure 3.4) to get the parameter of EBG. Figure 4.3 shows S_{21} parameter of 1x3 array EBG.

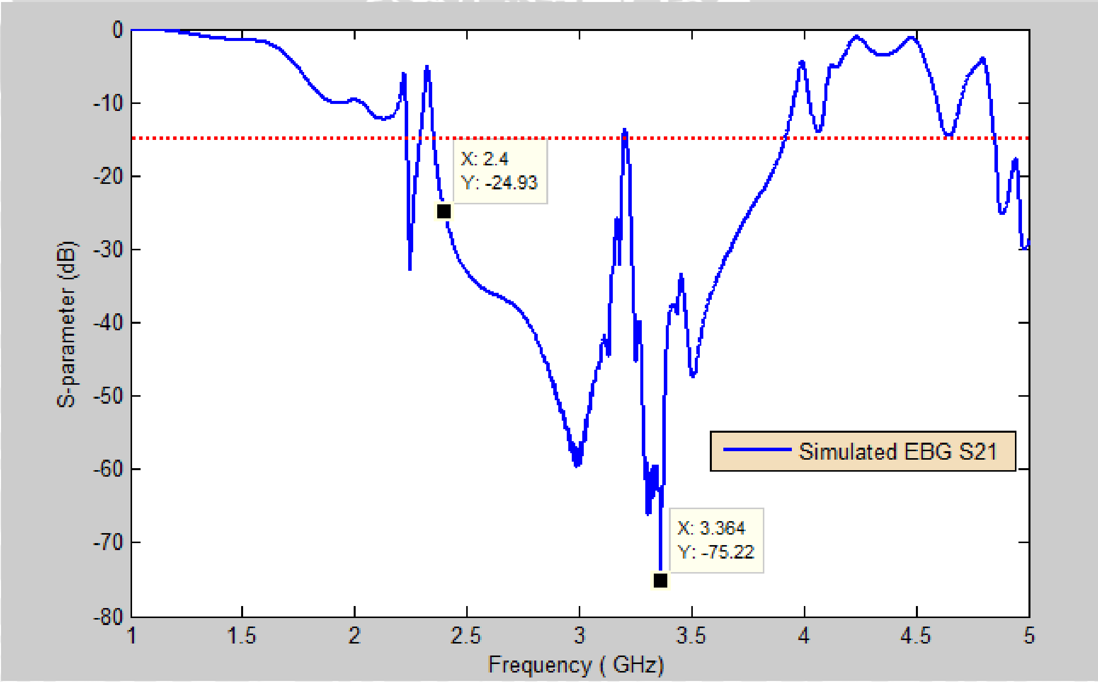


Figure 4.3 simulated 1 x 3 EBG S_{21} parameter

4.4 Microstrip Patch Antenna with EBG

4.4.1 Return Loss, S_{11}

Fig. 4.4 depicts the simulated return loss (dB) value of microstrip antenna with EBG structures. For microstrip antenna with EBG structures, the return loss is obtained as -18.46 dB in simulation, at the resonant frequency of 2.392 GHz.

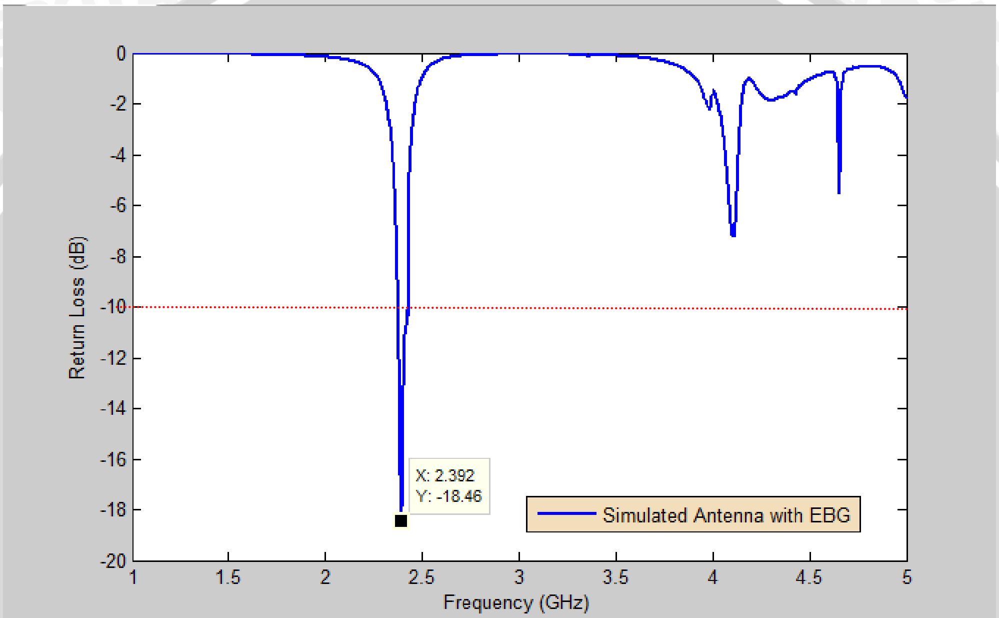


Figure 4.4 Simulated Antenna with EBG structure

4.4.2 Bandwidth

To achieve good performance in bandwidth is the goal of the designed microstrip patch antenna with EBG structure. Application of EBG structures at the optimal distance from the patch improves the bandwidth, which has been demonstrated by simulated results. Figure 4.5 shows the bandwidth is 1.6 % (2.374 GHz - 2.4109 GHz) at 2.4 GHz resonant frequency.

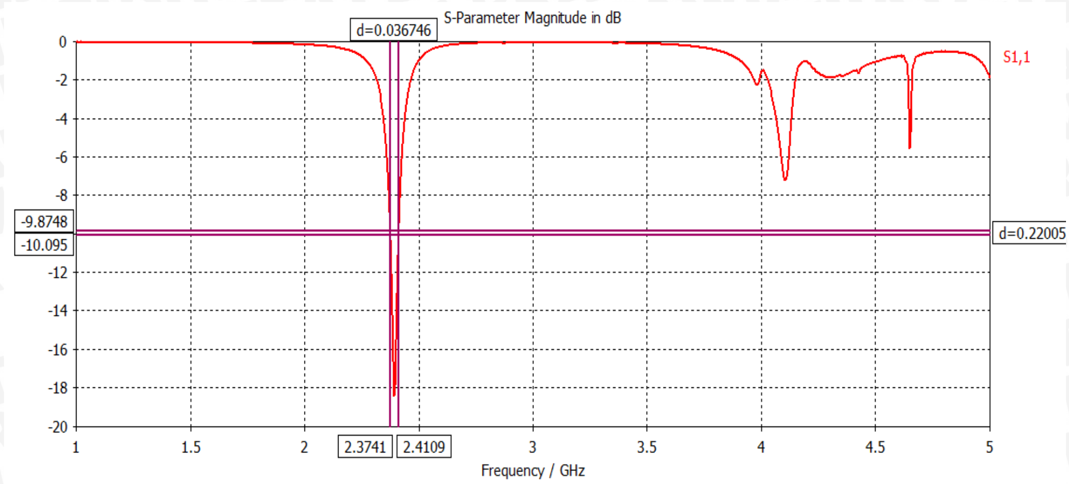
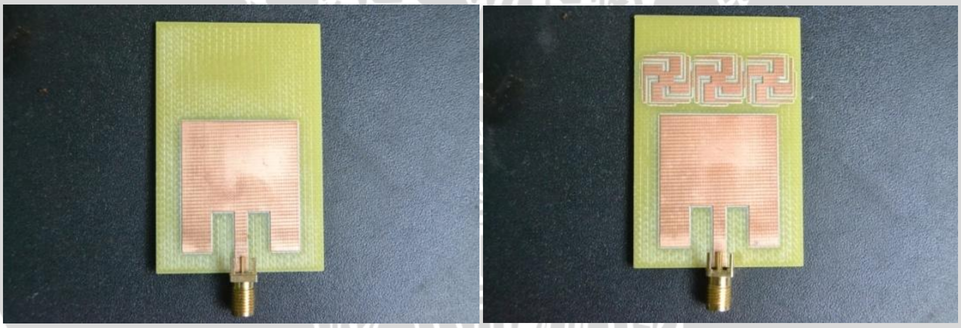


Figure 4.5 Bandwidth of microstrip patch antenna with EBG

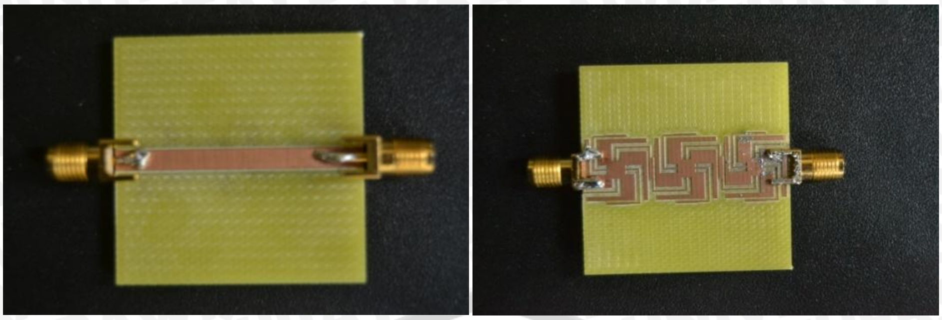
4.5 The Prototype

After simulation done and the best result is obtained, next step is fabrication process. Figure 4.6 shows front side of antenna with and without EBG structure.



(a) (b)

Figure 4.6 Front side of fabricated microstrip patch antenna (a) without EBG (b) with EBG.



(a) (b)

Figure 4.7 Fabricated proposed EBG (a) top view (b) bottom view

Figure 4.7 shows (a) front side of EBG structure (b) bottom side front side of EBG structure. Suspended transmision line method is used to analyze the performance of EBG.

4.6 Data Comparison

4.6.1 Comparison of Simulated Microstrip Antenna with and without EBG

Figure 4.8 depicts the simulated return loss S_{11} (dB) value of microstrip patch antenna with and without EBG structures. For microstrip patch antenna without EBG structures, the return loss is obtained as -22.56 dB at 2.4 GHz, meanwhile for microstrip patch antenna with EBG structures the return loss is obtained as -18.48 dB at 2.392 GHz. Resonant frequency is shifted after the EBG is applied with the microstrip patch antenna. This discrepancy is due to the application of EBG cause different matching condition in the simulation process.

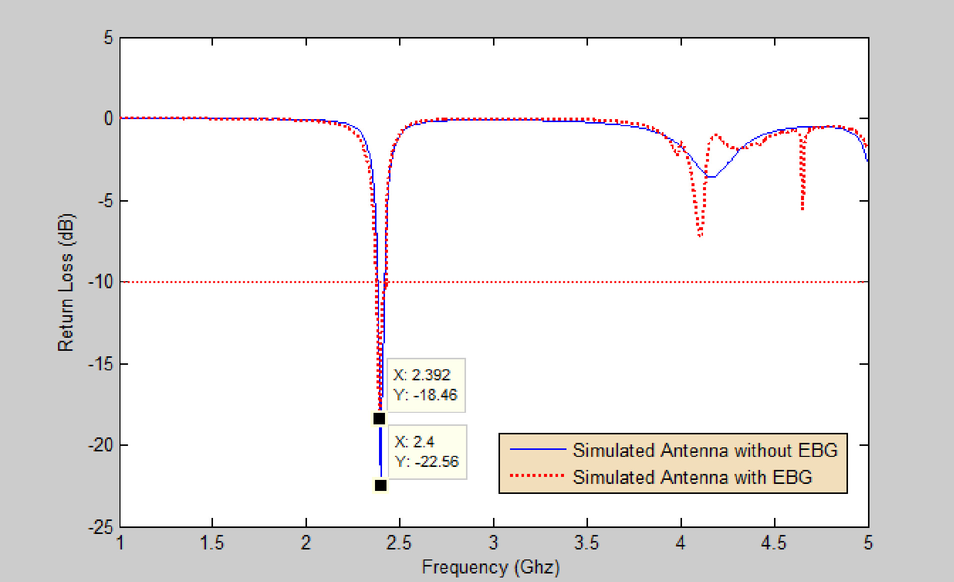


Figure 4.8 Return loss comparison of simulated microstrip antenna with and without EBG

Figure 4.9 shows the bandwidth comparison of simulated antenna without EBG and simulated antenna with EBG. With the criteria of S_{11} less than -10 dB, the antenna without EBG obtained 32.5 MHz bandwidth and the antenna with EBG obtained 36.7 MHz bandwidth. The bandwidth increases about 4.2 MHz.

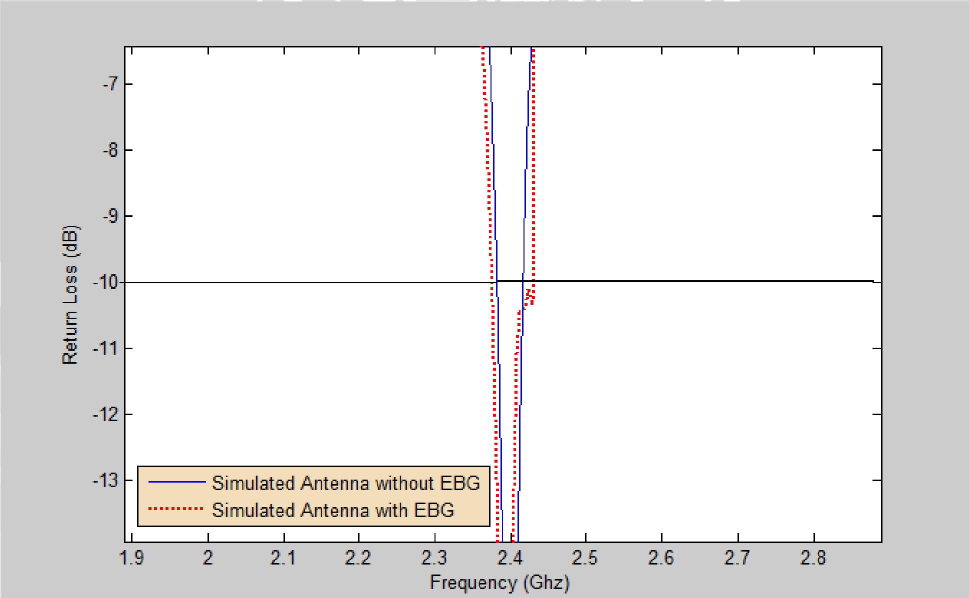


Figure 4.9 Bandwidth Comparison of Simulated microstrip antenna with and without EBG

4.6.2 Comparison of Measured Antenna with and without EBG

Figure 4.10 depicts the measured return loss (dB) value of microstrip patch antenna with and without EBG structures. For microstrip patch antenna without EBG structures the return loss is obtained as -15.19 dB at 2.42 Ghz, meanwhile For microstrip patch antenna with EBG structures the return loss is obtained as -15.09 dB at 2.42 Ghz.

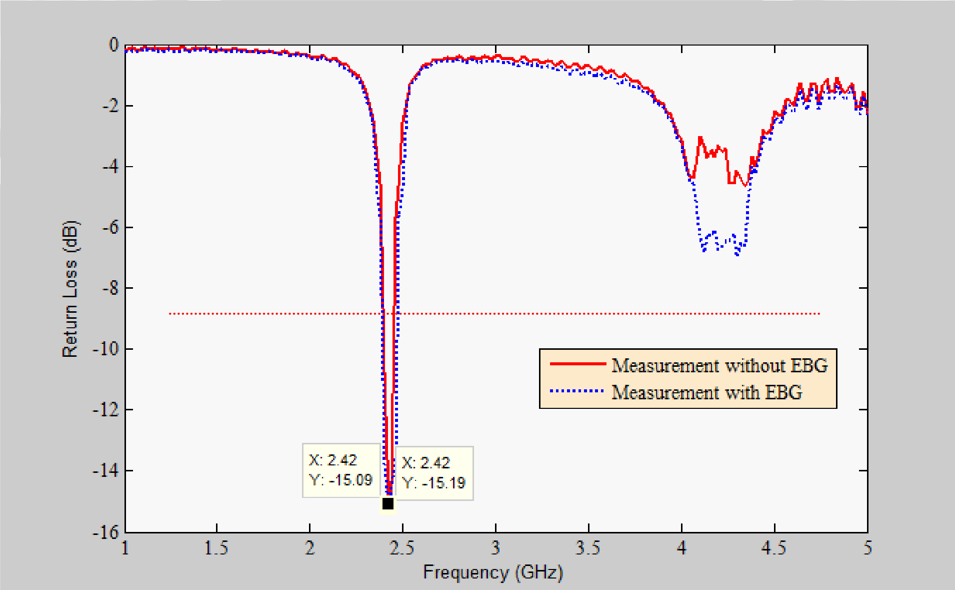


Figure 4.10 Return loss Comparison of measured microstrip antenna with and without EBG

Figure 4.11 shows the bandwidth comparison between measured antenna without EBG and with EBG. With the criteria of S_{11} less than -10 dB, the bandwidth of 40 MHz and 50 MHz for antenna without EBG and with EBG respectively are obtained

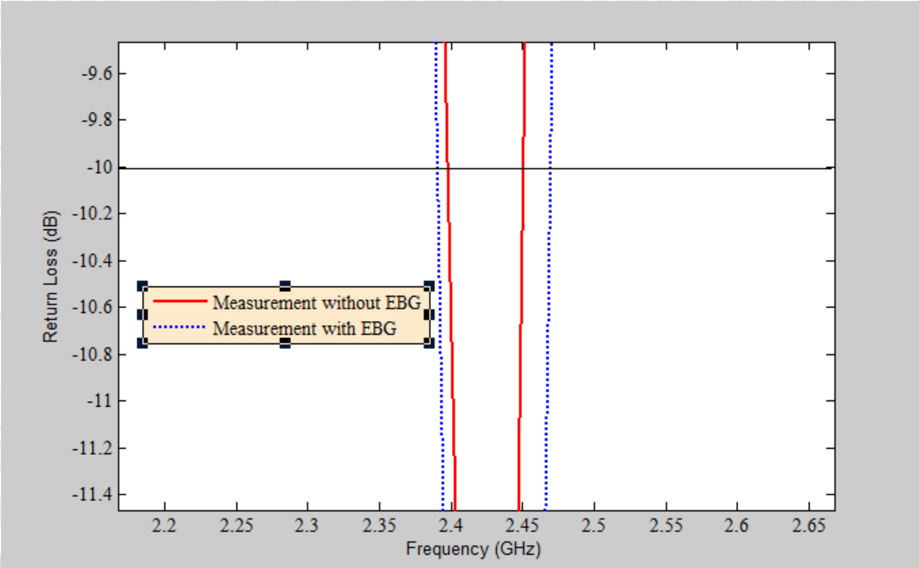


Figure 4.11 Bandwidth Comparison of measured microstrip antenna with and without EBG

4.6.3 Comparison of Simulated and Measured Antenna without EBG.

Comparison of return loss value versus frequency between simulated and measured antenna without EBG is shown in Figure 4.12. From Figure 4.12, it is clearly seen that there is frequency shifting between these graphs. Measured antenna has maximum resonant frequency at 2.42 GHz with return loss value -15.09 dB, meanwhile the simulated antenna has maximum resonant frequency at 2.4 GHz with return loss value -22.56 dB.

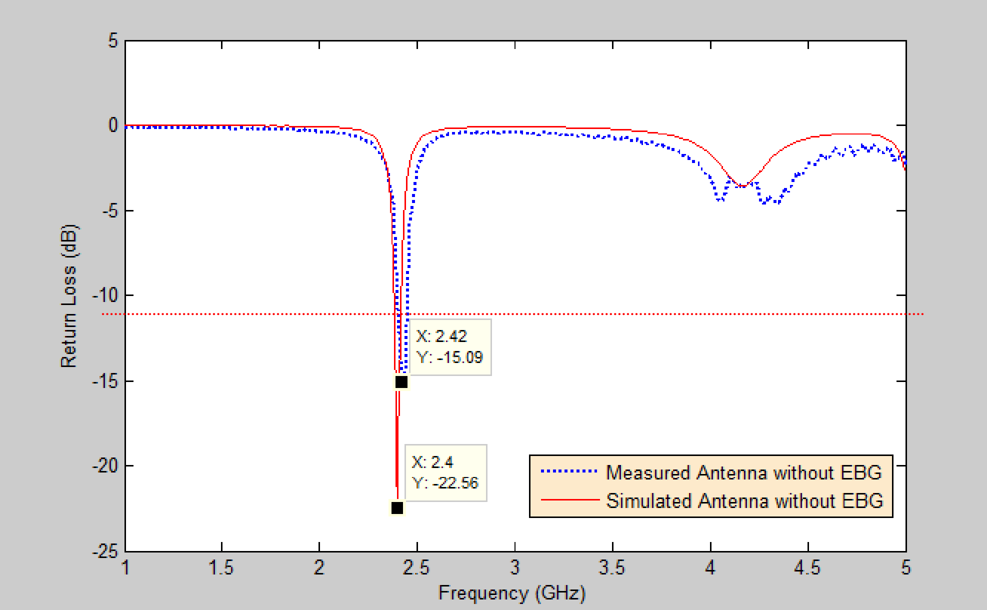


Figure 4.12 Return loss comparison between simulated and measured antenna without EBG

4.6.4 Comparison of Simulated and Measured Antenna with EBG

Figure 4.13 demonstrates the simulated and measured return loss for these prototype antennas. Figure 4.13 shows that the simulated return loss value is -15.19 dB at 2.42 GHz, meanwhile for the measured return loss value is -18.46 dB at 2.392 GHz.

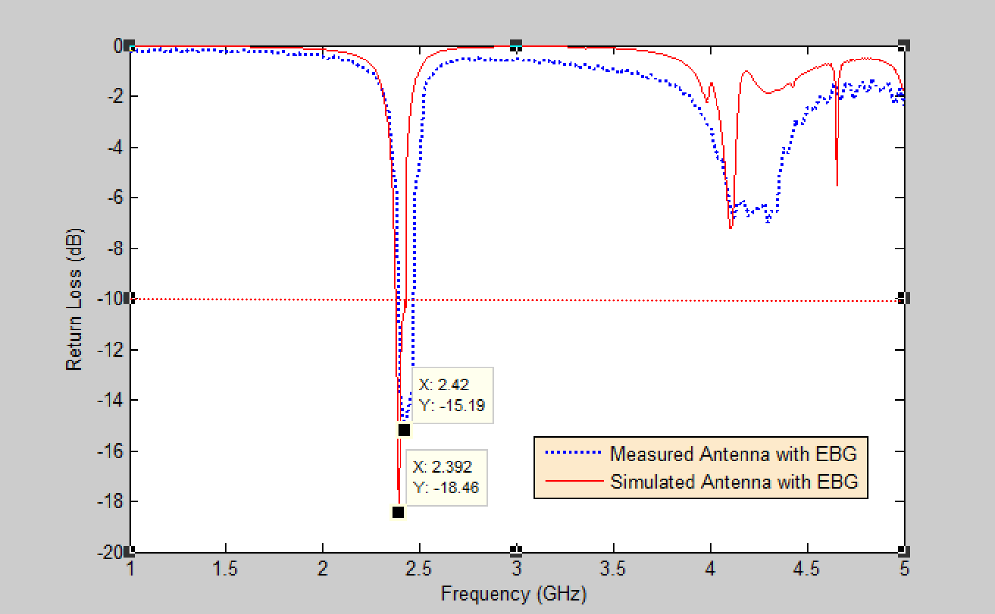


Figure 4.13 Return loss comparison between simulated and measured antenna with EBG.

4.6.5 Comparison of Simulated and Measured EBG.

To get the characteristic of the EBG structures, the EBG is analyzed. EBG is analyzed using suspended transmission line method. S_{21} parameter is investigated to get band gap characteristic of EBG. The comparison between simulated and measured of S_{21} value of both EBG are shown in Figure 4.14. From this figure, simulated result shows minimum value of S_{21} is -24.93 dB at 2.4 GHz, meanwhile from measured result of S_{21} is -16.17 dB.at 2.4 GHz.

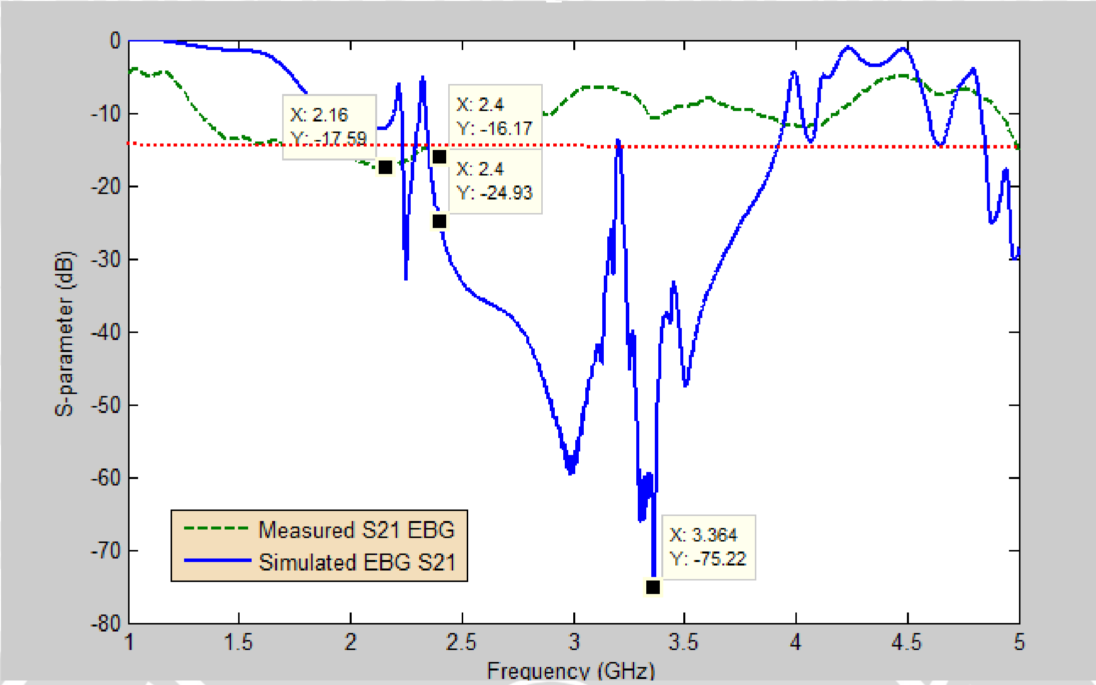


Figure 4.14 S_{21} comparison between simulated and measured EBG structure

4.7 Directivity

Directivity is an important parameter of antenna. Directivity of antenna shows in Figure below studied in 2.4 GHz. Figure 4.15 is 3-D image that shows directivity of antenna microstrip patch without EBG structure. As shown in Figure 4.15, microstrip patch antenna without EBG has 5.682 dBi.

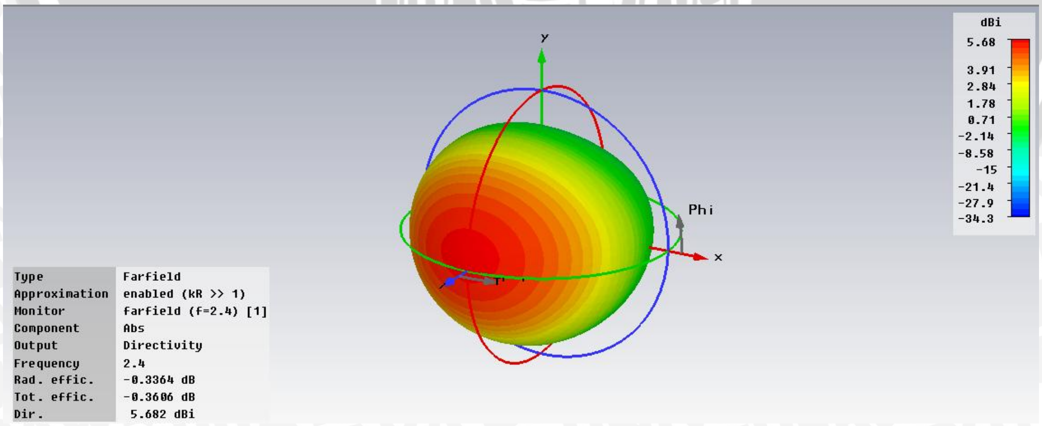


Figure 4.15 Directivity of microstrip patch antenna without EBG

Simulated directivity for microstrip patch antenna with EBG showed in Figure 4.16. Directivity value of antenna with the EBG structure is bigger than directivity value of antenna without EBG structure. Figure 4.16 shows directivity of microstrip antenna with EBG is 5.911 dBi

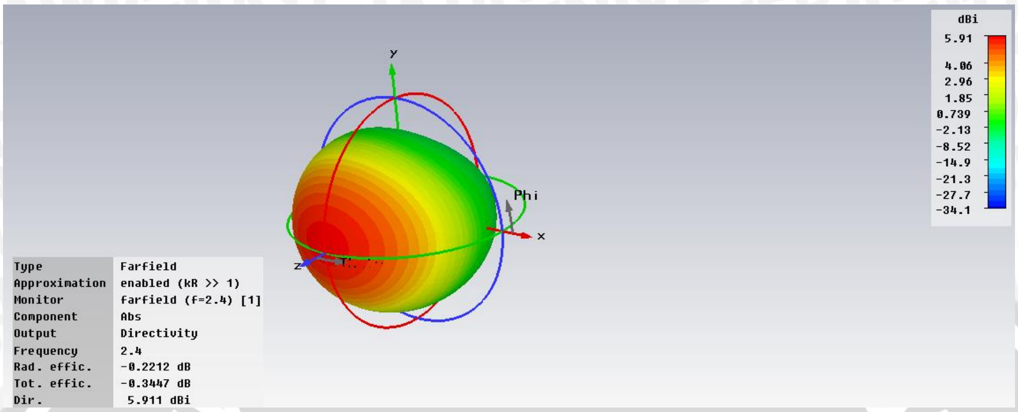


Figure 4.16 Directivity of microstrip patch antenna without EBG

It can be concluded that the application of EBG structures increase the value of antenna's directivity. The directivity increases about 0.229 dBi after EBG is employed.

4.8 Gain

Gain of the antenna is depends on antennas directivity [9]. Figure 4.17 shows the gain of microstrip antenna without and with EBG structure respectively.

Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=2.4) [1]
Component	Abs
Output	Gain
Frequency	2.4
Rad. effic.	-0.3364 dB
Tot. effic.	-0.3606 dB
Gain	5.345 dB

(a)

Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=2.4) [1]
Component	Abs
Output	Gain
Frequency	2.4
Rad. effic.	-0.2212 dB
Tot. effic.	-0.3447 dB
Gain	5.690 dB

(b)

Figure 4.17 Gain of microstrip patch antenna (a) without EBG (b) with EBG

Based on the simulation result, gain of antenna is increased when the EBG structure is employed with microstrip antenna. As shown as in Fig.4.17 (a), antenna without EBG structure has 5.345 dB gain antenna, meanwhile (as in Fig. 4.17 (b)) antenna with EBG structure has 5.690 dB gain. The gain is increased by 0.345 dB.

4.9 Table of Summary

Table 4.1 and Table 4.2 show the summary of the simulated and measured results respectively.

Table 4.1 Simulation Results

	Antenna Microstrip without EBG Structure	**Antenna Microstrip with EBG Structure**
Return loss, S_{11}(dB)	- 22.56	-18.46
Bandwidth (%)	13.5 (32.5 MHz)	15.29 (36.7 MHz)
Gain (dB)	5.345	5.690
Directivity (dBi)	5.602	5.911

Table 4.2 Measurement Results

	Antenna Microstrip without EBG Structure	**Antenna Microstrip with EBG Structure**
Return loss, S_{11}(dB)	-15.19	-15.09
Bandwidth (%)	16 (40 MHz)	20.8 (50 MHz)

4.10 Summary

The comparison of the simulation results of antenna with and without EBG is showed in Table 4.1. It is clear that there is difference between the data in Table 4.1.

For the antenna without EBG structure, return loss S_{11} value is -22.56 dB, meanwhile antenna with EBG structure return loss S_{11} value is -18.46 dB. Application of the EBG on antenna makes resonant frequency of the antenna is changed about 4.6 dB. Antenna without EBG has better resonant frequency than with EBG because employed of EBG structure with antenna affects the matching condition of the antenna. EBG is a reactive component that will affect the matching condition of the antenna. Application of EBG structure makes resonant frequency is shifted.

The application of EBG structure succeeds to improve the performances of antenna. As shown as in Table 4.1, antenna with EBG structure has better performances such as bandwidth, gain, directivity than antenna without EBG structure. The main goal of employment of EBG structure is bandwidth enhancement. As presented as in Table 4.1, bandwidth of antenna increases about 1.79 % (4.2 MHz).

Gain value of the antenna depends on directivity value of the antenna. There is an increment of gain and directivity value due to EBG application on microstrip patch antenna. Antenna without EBG structure has 5.345 dB gain and antenna without EBG structure has 5.698 dB gain. Then directivity of antenna microstrip patch without EBG structure is 5.602 dBi and directivity of antenna microstrip patch with EBG structure is 5.911 dBi. Gain increases 0.345 dB, meanwhile directivity increases 0.309 dBi.

Table 4.2 presents the measurement result of the antenna with and without EBG. Similar with the simulation result, S_{11} value of antenna without EBG structure have better value of the resonant frequency than with EBG. As presented as in Table 4.2, For antenna without EBG structure, return loss S_{11} value is -15.19 dB, meanwhile antenna with EBG structure return loss S_{11} value is -15.09 dB.

application of the EBG on antenna makes resonant frequency of the antenna is changed about 0.1 dB. Application of EBG also succeeds to increases bandwidth of antenna. As presented as in Table 4.2, bandwidth of antenna increases about 4.8 % (10 MHz).

It can be concluded that the measurement result succeeds to confirm simulation result. Application of EBG structure increases the performance of antenna in simulation and measurement result respectively

The presence of the difference between the simulation and the measurement values because simulations performed in ideal condition, meanwhile in the measurement process, the antenna tested in real condition where outside interference will actually interfere with the antenna. Other factors of human error, such as improper fabrication processes, soldering processes which are not precision and installation SMA connector will affect the outcome of the antenna. Imperfect installation of SMA connector will impact conductivity value of the materials.