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Design of Microstrip Array Antenna for WiMAX and Ultra-Wideband Applications

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Abstract --**This paper presents two designs of array antenna for two different applications achieving almost same return loss from type of inset-fed microstrip patch antenna with linear polarization. A widely used probe/coaxial feeding technique have been applied in the antenna design. One microstrip array (2x2) antenna is designed to operate at 2.4 GHz, which operates in S band with the WiMAX lower 2.4 GHz band. Other microstrip array (1x4) antenna is designed to operate at 7.285 GHz, which operates in C band for ultra-wideband (UWB) applications such as sattelite communications and sometimes WiFi & cordless telephone system. Both designs are simulated using CST Microwave Studio and the substrate used is FR4 Board (Fire Retarded 4) with a dielectric constant of 4.7, thickness of 1.6 mm and a tangential loss of 0.019. Both designs yield return loss <-30dB. Simulations also show that the array antennas give better results in terms of return loss and antenna gain compared to the single patch. The higher number of patches in an array will improve the performance of the antenna.**

Index Terms— Array antenna, inset-fed, linear polarization, micro strip patch antenna, WiMAX , WiFi.

I. INTRODUCTION

Microstrip antenna has been chosen in this research due to it low profile, conformable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed circuit technology. They are mechanically robust when mounted with rigid surfaces, compatible with MMIC designs.

When the particular shape and mode are selected, they are very versatile in terms of resonant frequency, polarization, pattern and impedance. Despite the advantages, microstrip antenna has a few disadvantages where they have narrow bandwidth and low gain [1]-[5]. Furthermore, the topic reveals the design equation and procedure of the single patch microstrip antenna and linear polarized 2x2 array patch microstrip antenna.

II. DESIGN PROCEDURE

The single patch microstrip antenna as shown in Figure 1 has been designed using CST software. The antenna is fabricated on FR4 board with the relative dielectric constant, $\varepsilon_{r=}$4.7, substrate thickness of 1.6 mm with tangential loss of 0.019.

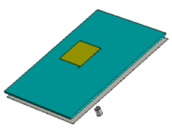


Fig. 1 Layout of single patch microstrip antenna

A widely used probe/coaxial feeding technique have been applied in the antenna design. The microstrip antenna was designed to operate at 2.4 GHz with the dimension of the patch after optimization is 27.5 mm x 37 mm where the dimension of the substrate is 11 mm x 125.5 mm. With bigger ground plane, the magnitude of the back lobe can be reduced while it increased the gain of the antenna [6].

In brief, the port is placed in the centre of X-axis and 1/3 from the bottom of the patch in Y-axis as shown in Figure 2. Intended for a good return loss (S_{11}) which is below -10 dB, the position of the port is then been optimized by varying the value of its position in Y-axis dB, the position of the port is then been optimized by varying the value of its position in Y-axis.

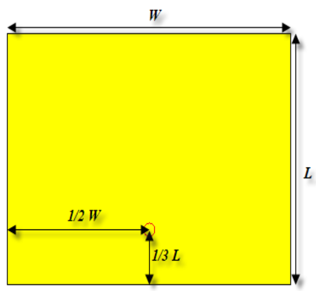


Fig. 2 Coaxial port coordinates

This array is used to increase the gain and directivity and perform various functions beyond the capability of a single element [7]. The transmission line feeding technique has been used to feed the arrays .A simple power divider and quarter-wave transformer method is used in the construction of the transmission line. The power divider is used to divide the power equally to all junctions meanwhile the quarter-wave transformer is used for the impedance matching between two transmission lines.

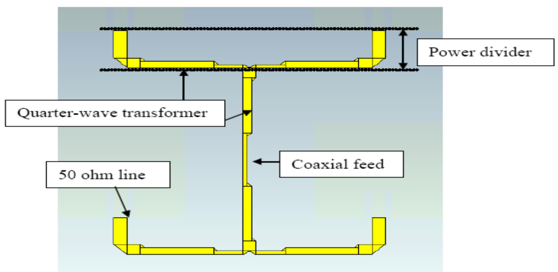


Fig. 3 Layout of the transmission line feeding technique

Figure 3 shows the detail of the transmission line that has been designed. Inset feed matching technique is used to match the patch to the 50 ohm transmission line. The 2x2 array microstrip patch antenna as shown in Figure 4 and 1x4 array microstrip patch antenna as shown in figure 5 have been designed [8]. The size of the 2x2 array antenna is 115 mm x 102 mm and the patches size is 29 mm x 29 mm. The size of the 1x4 array antenna is 78mm x 36.5mm and the size of the patch is 69.5 mm x 45.5 mm. The patches are fed by a transmission line feeding technique. The substrate used is FR4 board with a dielectric constant of 4.7, thickness of 1.6 mm and a tangential loss of 0.019 [9].

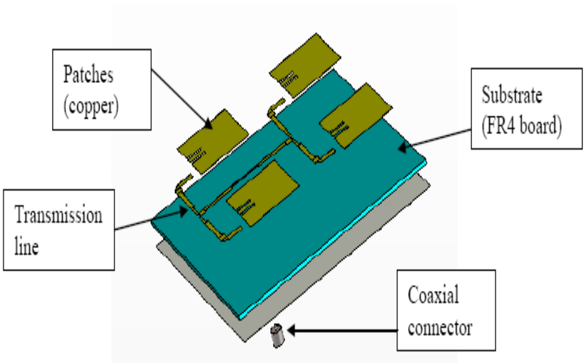


Fig. 4 Layout of linear polarized 2x2 array microstrip patch antenna

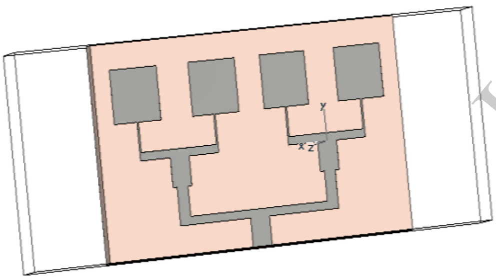


Fig. 5 Layout of 1 x 4 array microstrip patch antenna

III. Result Discussion

After calculation of all dimensions, the design has been simulated in CST Microwave studio to observe return loss, radiation pattern and antenna gain.

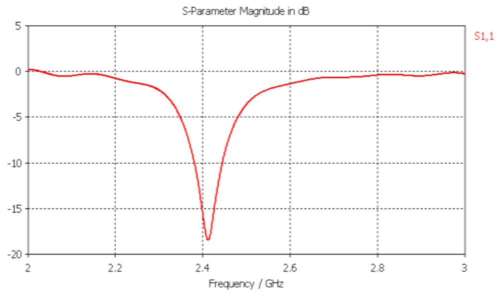


Fig. 6 Return loss, S_{11} of the single patch microstrip antenna

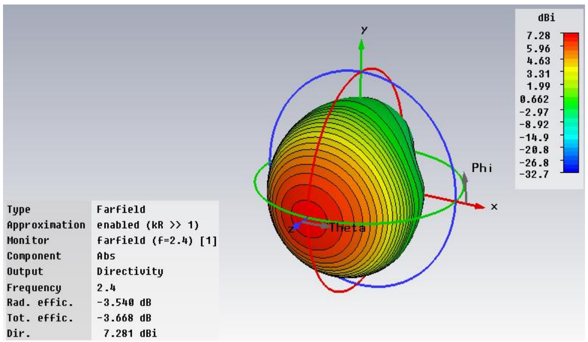


Fig. 7 3D radiation pattern at 2.4 GHz

The result in Figure 6 shows that the value of the return loss (S_{11}) at 2.4 GHz is -17 dB. The antenna's bandwidth is 2.5 % from 2.38 GHz to 2.44 GHz. Figure 7 shows the radiation pattern of the antenna at 2.4 GHz where the value of directivity is 7.281 dBi and the total efficiency is around 43 %. The low value of the total efficiency is due to the losses of the substrate used. Figure 8(a) shows the polar plot of the radiation pattern in H-plane where the 3 dB beam-width is 78.7^0 and Figure 8(b) shows the E-plane of the radiation pattern where the 3 dB beam-width approximately similar value to the H-plane.

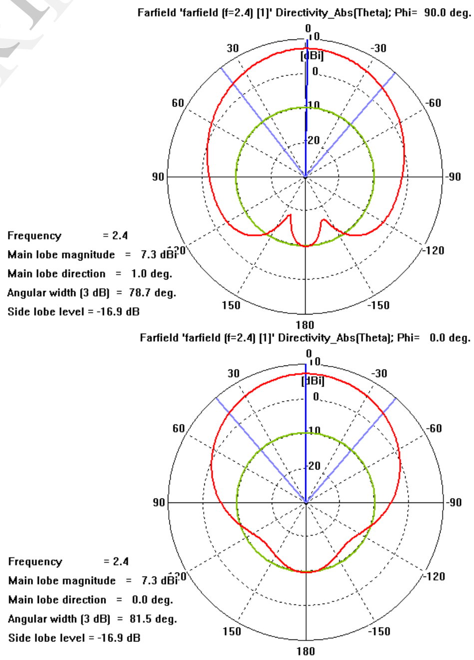


Fig. 8. (a) Polar plot of radiation pattern at 2.4 GHz in H-plane and (b) Polar plot of radiation pattern at 2.4 GHz in E-plane

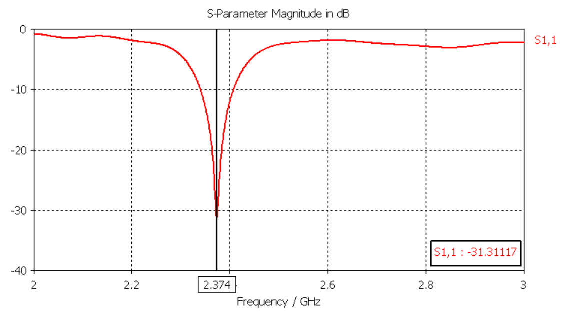


Fig. 9. Return loss, S_{11} of the 2x2 array patch microstrip antenna

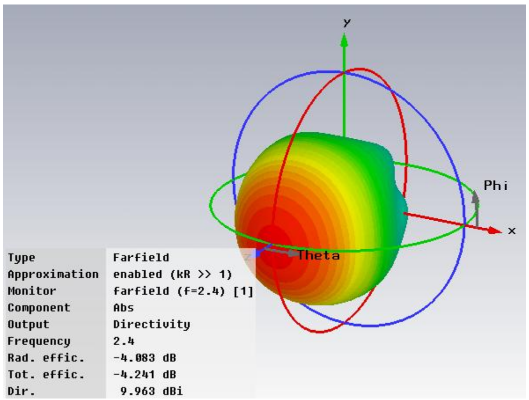


Fig. 10. 3D radiation pattern at 2.4 GHz

Figure 9 shows the return loss, S_{11} of the linear polarized 2x2 array microstrip patch antenna. The antenna is resonating at 2.374 GHz with a bandwidth from 2.34 GHz to 2.41 GHz. The bandwidth percentage is 2.9 %. The radiation pattern of the antenna is shown in Figure 10. The gain of the antenna is 9.963 dBi at 2.4 GHz and the total efficiency is 37.6 %. The low total efficiency of the antenna is due to the substrate loss where the value of the tangential loss is large. Meanwhile, Figure 11(a) and 11(b) show the E-plane and H-plane of the radiation pattern of the antenna. The 3dB beam-width of the antenna in E-plane is 55^0 and at the H-plane, the 3 dB beam-width is 61.8^0.

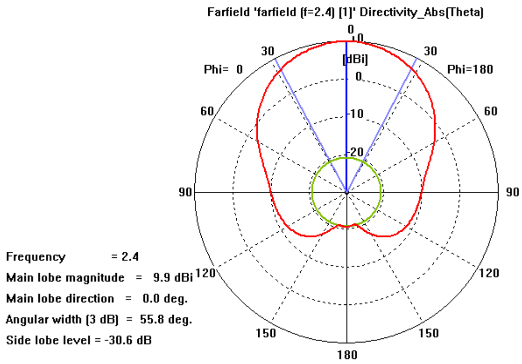


Fig. 11. (a) Polar plot of radiation pattern at 2.4 GHz in E-plane

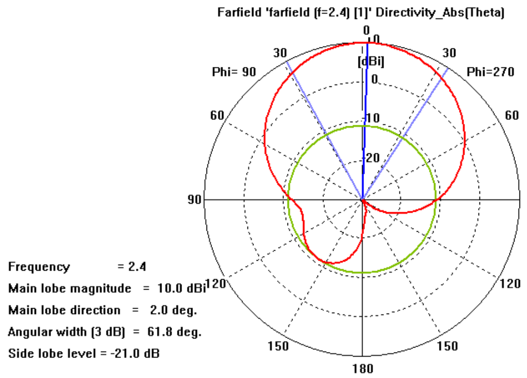


Fig. 11. (b) Polar plot of radiation pattern at 2.4 GHz in H-plane

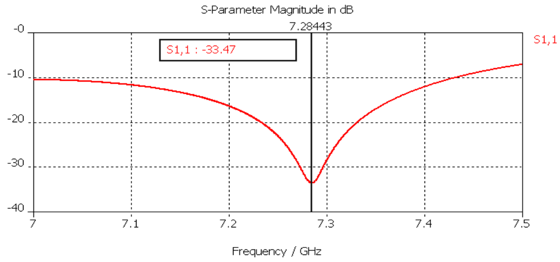


Fig. 12. Return loss, S_{11} of the 1 x 4 array patch microstrip antenna

Figure 12 shows the return loss, S_{11} of the linear polarized 1 x 4 array microstrip patch antenna .The antenna is resonating at 7.285 GHz.

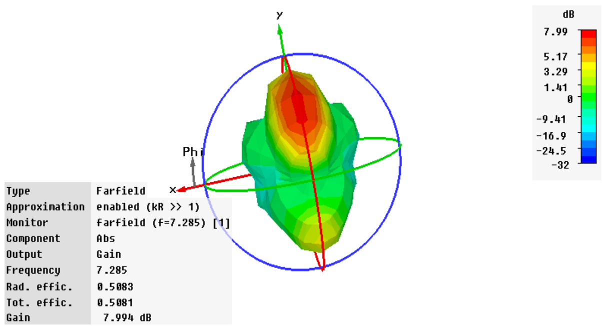
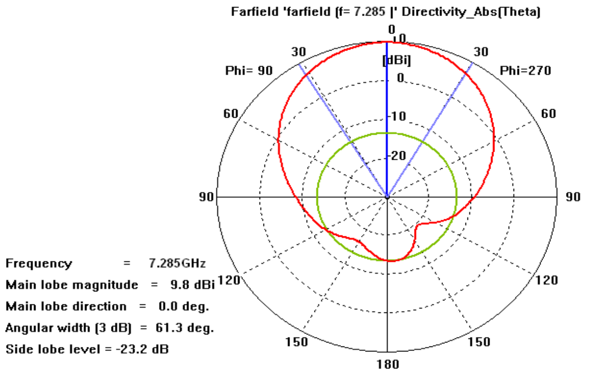
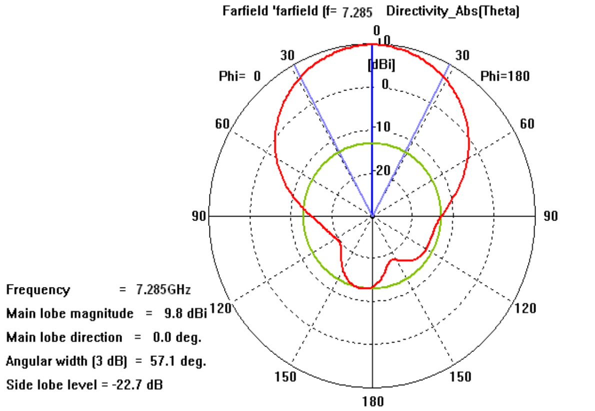


Fig. 13 3D Radiation pattern at 7.285 GHz

The radiation pattern of the antenna is shown in Figure 13. The gain of the antenna is 7.994 dBi at 7.285 GHz and the total efficiency is 50.8 %. The low total efficiency of the antenna is due to the substrate loss where the value of the tangential loss is large. Meanwhile, Figure 14(a) and 14(b) show the E-plane and H-plane of the radiation pattern of the antenna. The 3dB beam-width of the antenna in E-plane is 61.3^0 and at the H-plane, the 3 dB beam-width is 57.3^0.



(a)



(b)

Fig 14. (a) Polar plot of radiation pattern at 7.285 GHz in E-plane (b) Polar plot of radiation pattern at 7.285 GHz in H-plane

The important parameters can be summarized in Table 1 given below:

S. No	Antenna Type	Resonating Frequency	Return Loss (dB)	Directivity (dBi)	Total Efficiency (%)	% B.W
01	Single Patch	2.4 GHz	-17	7.281	43	2.5
02	2x2 Array Patch	2.4 GHz	-31.32	9.963	37.6	2.9
03	1x4 Array Patch	7.285 GHz	-33.47	7.994	50	5.7

IV. CONCLUSION

The single patch and two array designs can be compared on the basis of various parameters summarized in Table 1. Both the 2x2 and 1x4 array designs have nearly same return loss. The 1x4 array design has less directivity than 2x2 array, but still improved than single patch. Though size of 1x4 array is more than 2x2 array, enhancement in % bandwidth can be achieved. The various simulation results obtained are well appreciated for applications of 2x2 array and 1x4 array designs for WiMAX and UWB applications respectively.

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