Dual-Resonance Microstrip Patch Antenna

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Abstract: In this work, a dual resonance microstrip patch antenna which operates at two center frequencies of 5.32 GHz and 6.05 GHz, is designed and simulated. As a commercial simulation tool, Sonnet Suites [1], a planar 3D electromagnetic simulator was used. Details of the simulation results are presented and discussed. Main application of the work would be the radar systems in SHF band.

Keywords: Microstrip, Patch, Antenna, Compact, Dual-resonance

1. Introduction

In this design study, the main purpose was to design a microstrip patch antenna for the radar systems used in the frequency range of 5 to 7 GHz. Some articles and applications are examined about microstrip antennas [2-3]. There is another dual-frequency antenna which operates in similar bands as compared to this work, but they do have a wider band [4]. An optimizations is performed on the geometry and substrate by changing several parameters. Details of this is in the following section.

2. Design Procedure

Top view of the antenna can be seen on Figure 1. The antenna is in a 203.2 x 203.2 mm. box with 20.07 x 15.24 mm. patch dimensions. Design started with the main patch shown with the letter A in Fig. 1. Afterwards the layers B and C are added but the return loss was still less than -10 dB. When the layers D and E are added, two resonance frequencies are determined. Those values are on Table 1. As a dielectric, Arlon Foam Clad (ε_r =1.25) is used. A 3D view of the antenna is in Figure 2.

Table 1:Change in S11 and the center frequency with the geometry

Layer	Magnitude (S11:dB)	Resonance Freq. (GHz)
A	-3.35	6.52
B	-4.16	6.51
C	-10.5	6.27
D	-6.10	5.5
	-19.80	6.4
E	-8.43	5.63
	-34.69	6.44

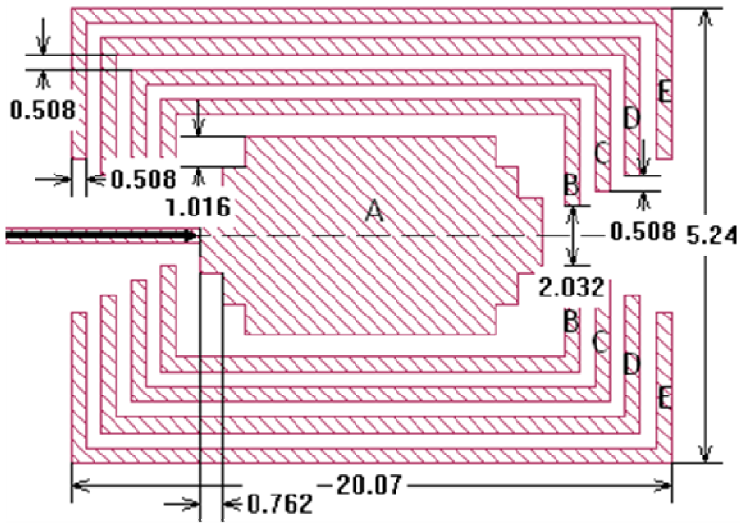

Fig. 1. Top view of the antenna.

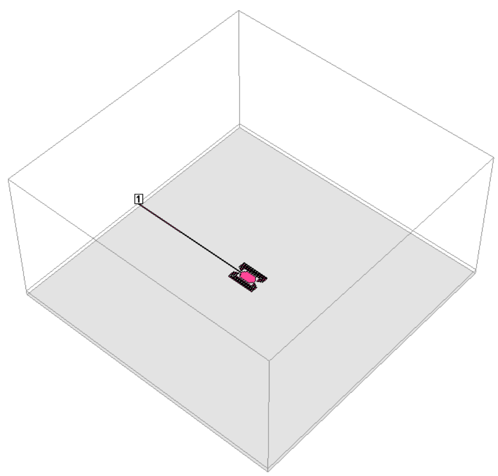

Fig. 2. 3D view of the antenna.

The next work was the optimization of the air layer thickness. The results are seen in Table 2. It is clearly seen that when air height is increased, the parameters are getting better.

Table 2:Optimization of the air layer height

Air thickness (mm)	Magnitude (S11:dB)	Resonance Freq. (GHz)	Z_{in} (real)	Z_{in} (imaginary)	Gain (dB)
40	-8.34	5.63	25.4	16.3	6.21
	-32.23	6.44	48.1	1.51	6.33
70	-10.31	5.63	29.2	12.81	6.91
	-23.37	6.44	47.6	6.17	7.13
100	-10.65	5.62	34.6	20.3	6.3
	-23.47	6.44	49.1	6.6	7.9

3. Simulation Results

Simulation results of the S11 is in Fig. 3. The real part of the input impedances are in Figure 4. The imaginary parts are, -1.389 Ω for 5.32 GHz and 2.822 Ω for 6.05 GHz.

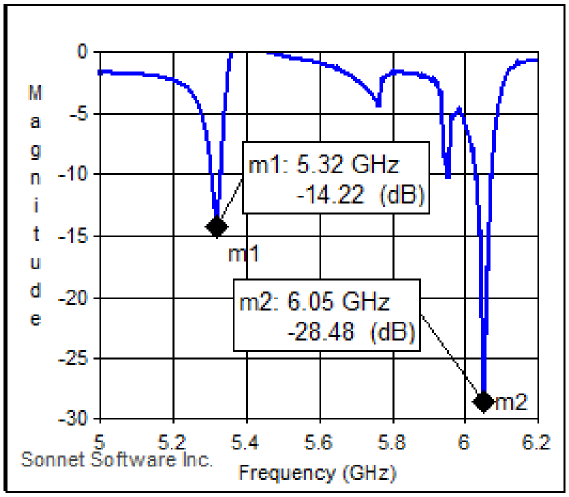

Fig. 3. Input ref. coefficents with dual-resonance.

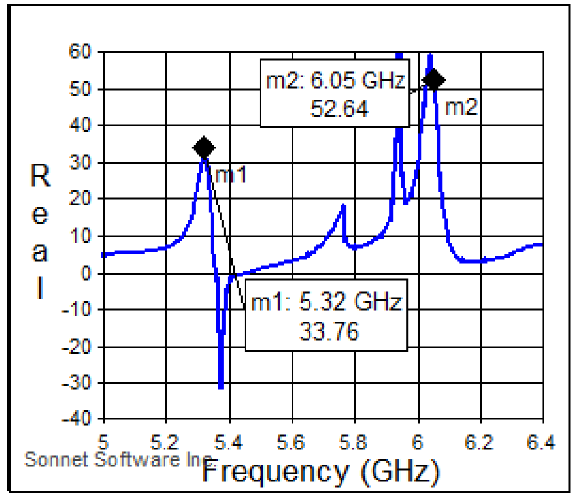

Fig. 4. Real part of the input impedances.

Theta polarized electric field radiation patterns are in Figures 5 and 6 respectively, for two resonance frequencies.

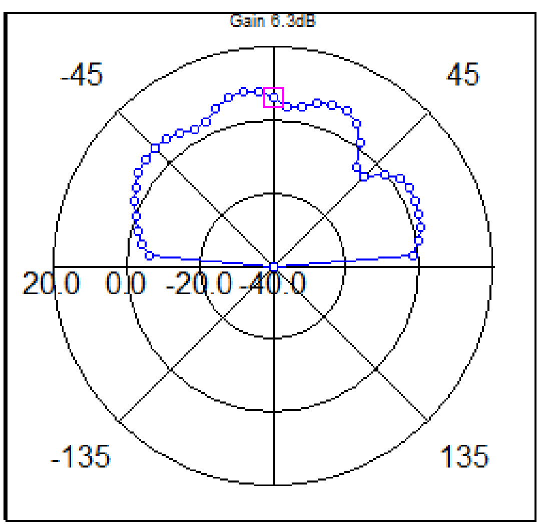

Fig. 5. Radiation pattern at 5.32 GHz.

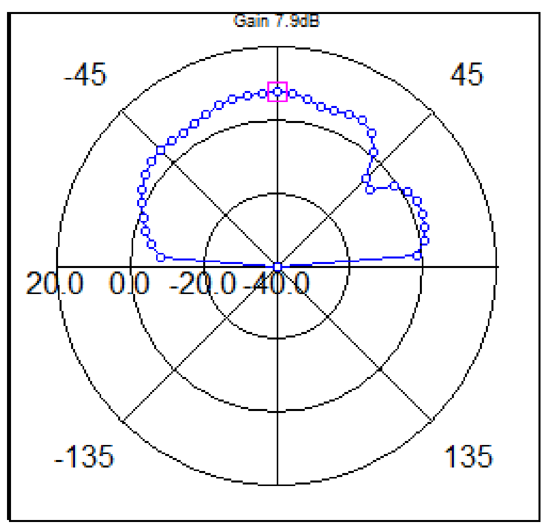

Fig.6. Radiation pattern at 6.05 GHz.

An observation on the results was a loss at $+45^0$ even though the antenna geometry is completely symmetric. Next work was aimed to eliminate or decrease this loss. First, there are some geometry changes on Table 3 and the optimization on the dielectric thicknesses is seen at Table 4.

Table 3:Change on the patch location.

Trial	Patch location	Magnitude (S11:dB)	Resonance Freq. (GHz)	Gain (dB)	$+45^0$ loss
1	Patch shifted back 0.5 mm	-11.43	5.62	5.79	-6.9
		-20.9	6.44	7.49	-22.84
2	Patchs right end shifted back 0.25 mm	-11.79	5.62	6.09	-5.7
		-26.8	6.44	7.55	-18.3
3	Patchs right end shifted back 2.25 mm & patch addition	-14.2	5.32	8.6	-4.5
		-28.4	6.05	7.9	-5.7

Table 4:Comparison of the dielectric thickness.

Dielectric thickness (mm)	Magnitude (S11:dB)	Resonance Freq. (GHz)	Gain (dB)	$+45^0$ loss
2.8	-7.69	5.32	5.83	-4.79
	-17.24	6.05	7.64	-4.71
3.05	-9.6	5.33	6.74	-10.49
	-21.15	6.05	7.77	-5.04
3.5	-14.2	5.32	6.3	-4.5
	-28.4	6.05	7.9	-5.7
4	-19.21	5.31	5.83	-4.9
	-22.31	6.05	8.11	-6.7

Figure 7 has the current on the antenna which shows that main radiated elements are the layers C,D and E as mentioned on the section 2.

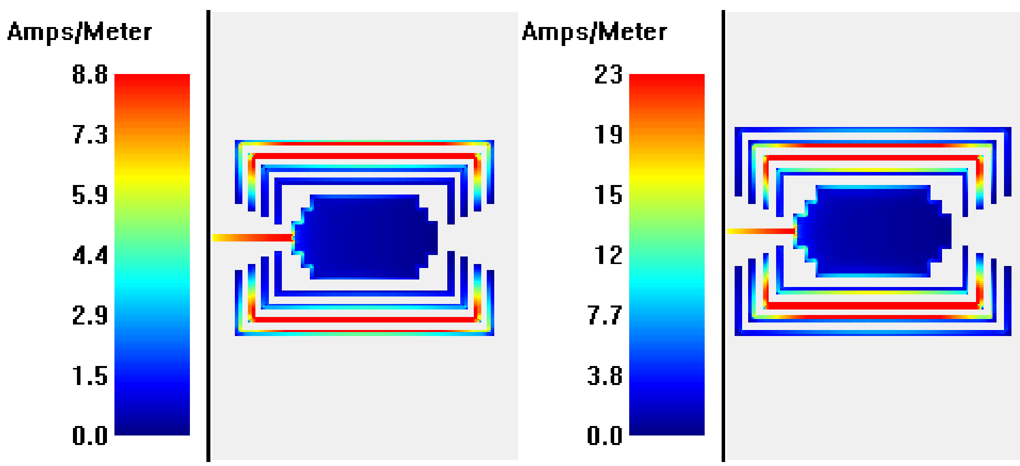

Fig. 7. Current distribution (5.32 GHz and 6.05 GHz) on the antenna.

Finally, circular via is used instead of long edge-feeding. Simulation results of the S11 is in Figure 8. The real part of the input impedance is in Figure 9.

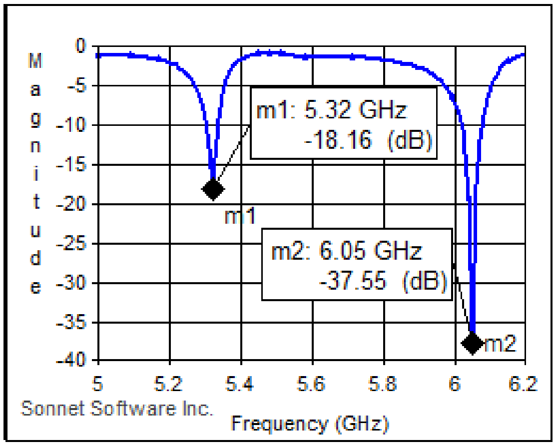

Fig. 8. Input reflection coefficents with circular via.

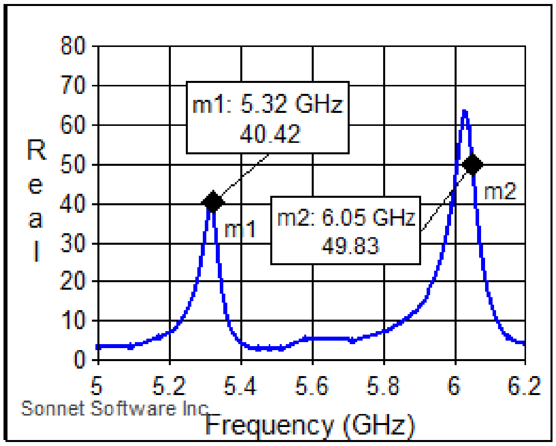

Fig. 9. Real part of the input impedances.

The imaginary parts are, 5.80 Ω for 5.32 GHz and -1.31 Ω for 6.05 GHz. Theta polarized electric field radiation patterns are in Figures 10 and 11 respectively, for two resonance frequencies.

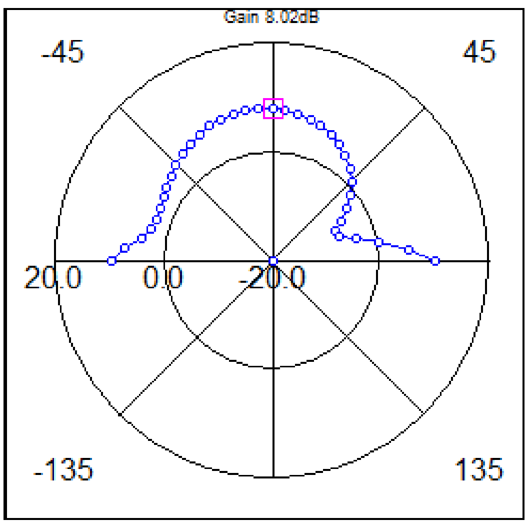

Fig. 10. Radiation pattern at 5.32 GHz.

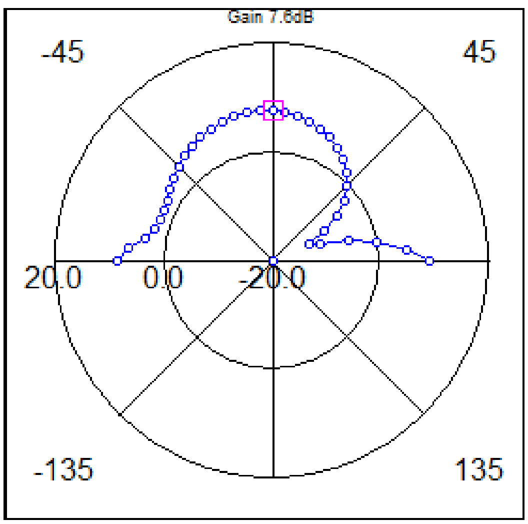

Fig.11. Radiation pattern at 6.05 GHz.

There is still a loss at $+70^0$ but the gain is more smooth and increased as compared to edge-feeding. Finally, there is an optimization analysis about the size of the via on Table 5.

Table 5:Comparison of the size of the circular via

Size (mm)	Resonance Freq. (GHz)	Magnitude (S11:dB)	Gain (dB)	$+70^0$ loss (dB)
0.8x0.8412	5.32	-10.29	8.09	-7.14
	6.06	-13.75	7.66	-12.89
1.4x1.472	5.33	-19.21	8.10	-11.10
	6.06	-25.18	7.66	-12.43
1.7x1.787	5.33	-18.85	8.09	-11.27
	6.05	-25.24	7.64	-11.55
Vias right end shifted back 0.762 mm	5.32	-18.15	8.02	-6.84
	6.05	-37.54	7.60	-10.66

4. Conclusions

The main work was here to have a dual-resonance patch antenna in the frequency range of 5 to 7 GHz. After having an optimization on the geometry, dielectric, air thicknesses, best results are achieved as follows: for a return loss of -14.22dB at 5.32GHz, the gain is 6.3dB, for a return loss of -28.48 dB at 6.05 GHz, the gain is 7.9 dB. At 5.32 GHz there are two more gain points which have a better gain of 8.68 dB at $\theta = -10^0$, and 7.37 dB at $\theta = 20^0$. Cross-pol. level is less than -40 dB.

The second work was to change the feeding to via in order to get rid of the long edge-feeding line. The best results are: for a return loss of -18.16 dB at 5.32 GHz, the gain is 8.02 dB; for a return loss of -37.55 dB at 6.05 GHz, the gain is 7.6 dB. At 5.32 GHz a maximum gain of 8.11 dB is observed at $\theta = -5^0$, and the other resonance frequency of 6.05 GHz has a maximum gain of 7.70 dB at $\theta= -5^0$. The next work is to use another simulation program and see if there is still a loss at $+70^0$ and afterwards fabricate the antenna.

References

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