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# Design and Analysis of Meshed Microstrip Patch Antenna

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***Abstract:****This paper presents the design, simulation and fabrication of meshed ground plane to operate in the 2.4-2.5 GHz WLAN band (802.11b). The antenna design consists of seven samples of metallic mesh ground plane with different sizes of linewidth for the microstrip patchantenna. The patch antenna can be integrated in glass for mobile communication applications. These meshed patched antennas were compared with a solid patch of the same dimensions. Using the mesh ground plane for rectangular patch antenna gives improved bandwidth than the conventional patch antennas.*

***Key Words****: Meshed ground plane; Impedance bandwidth; Antennas.*

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## I. Introduction

Microstrip patch antennas have a wide range of applications including printing on or within glass areas of vehicles for intelligent and telematics systems providing a cost-effective solution [1-3]. Rectangular printed patch antennas made from conducting mesh have improved bandwidth but have low gain. To examine the effect of meshing on the antenna performance and to normalize the meshed antenna to a reference, a solid patch antenna was designed, fabricated from FR4 substrate and tuned to the same frequency as the meshed antennas.Meshed patch antennas have been studied by Classen and Langley [1] considering mesh lines with fixed line width.Using meshed geometry as unit cells of a reflect-array was studied [4] by integrating it on top of solar panels. The reflect-array consists of three-part top array element, substrate and ground as the same with a patch antenna,

This work explains the design of meshed ground plane for microstrip antenna in section II. Section III describes the measurement and analysis of the various antenna samples. The conclusion provides the findings in Section IV.

## II. Materials and Method

In their study they examined meshed patch antenna with solid ground plane and meshed ground plane but the effects of the line width $(L_w)$ and the mesh spacing on the resonant frequency and the gain were compared with using a reference patch antenna. The microstrip patch were evaluated and designed using approximate equations in Balanis [5] to get the dimension of the ground plane.The meshed ground plane was designed using the guidelines from [1] considering the fundamental mode as shown in Fig.1. The meshed ground plane consist of two lines, one carrying the desired current and the other line is orthogonal to current path. The patch antenna has two radiating slots of length $W_p$.The microstrip antenna is either fed with a microstrip line or cable. Many modal waves are excited. In this study the antenna was fed with a microstrip line. The dorminant $TM_{10}$ mode which the patch antenna radiates upward from the ground plane is excited by adjusting the length of the patch antenna. The antenna design frequency$f_c = \frac{c}{2L\sqrt{\varepsilon_r}} = 2.45\ GHz$. The resonant length from the theoretical calculation $L = \lambda_{eff}/2$ gives 29.5 mm but the actual physical length is set to 28 mm. The rectangular patch antenna had a length$L_p = 28\ mm$, width of the patch $W_p = 38\ mm$, relative permittivity $\varepsilon_r = 4.3$, thickness of the dielectric substrate is 1.6 mmand the loss tangent $tan\delta = 0.018$. The theoretical length is slight longer than the physical length as expected due to fringing effect. The ground plane covers the entire side of the substrate and is made of copper sheet of 0.035 mm thickness. The radiating element is designed with the same thickness copper. The substrate is FR4($\varepsilon_r = 4.3$ and loss tangent $\delta = 0.018$) has a size of $W_g \times L_g = 70\text{ mm} \times 65\text{ mm}$ of substrate height $h_s = 1.6$ mmis used for all the antennas. The size of the patch $W_p \times L_p = 38\text{ mm} \times 28\text{mm}$. The feedline has a characteristic impedance of $50\ \Omega$ for maximum power transfer.The designed antenna has been simulated using the 3D electromagnetic CST Microwave Studio 2019.

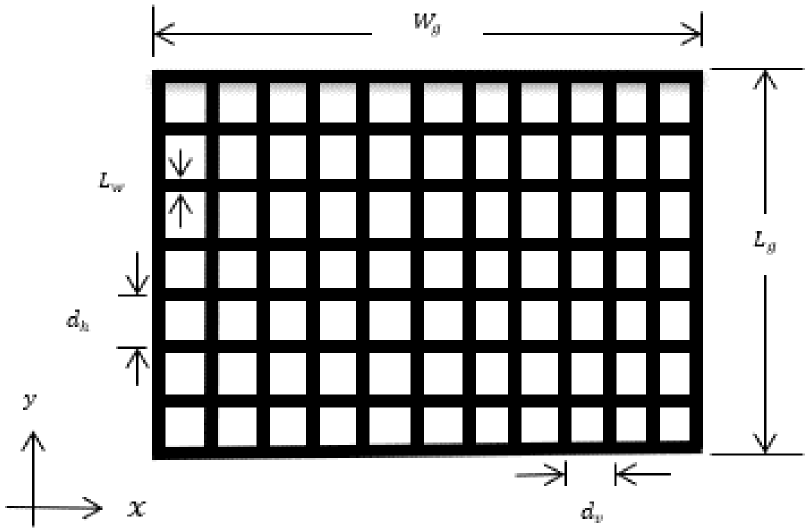


Figure 1 Meshed ground plane elements

## III. Experimental Study and Results

### A. Simulated and measured resultof meshed patch antenna

The resonant frequency and reflection coefficient of all the designed samples of antennas were measured using a 37397D Vector Network Analyser at the Loughborough University UK, to verify the theoretical analysis, The simulated and the measured $S_{11}$ of the antenna sample is shown in Fig.2. The measured result $S_{11}-11.87$dB at 2.45 GHz with bandwidth of 70 MHz compared with the simulation $S_{11}$ of $-13.87$dB at 2.45 GHz and $-10$ dB bandwidth of 64 MHz.

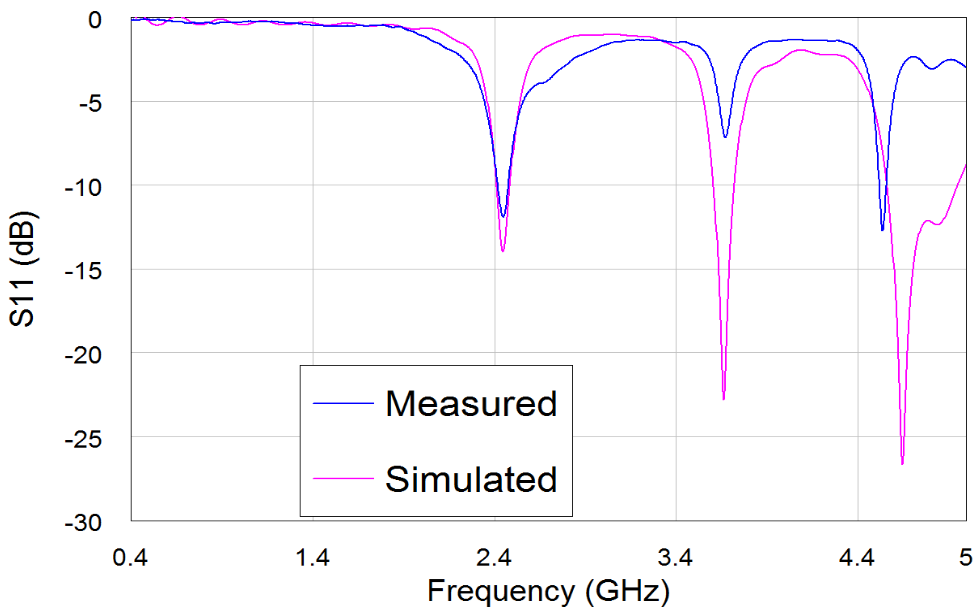


**Figure 2** The reflection coefficient of Antenna design A with solid ground plane.

### B. Meshed ground plane

Table 1 shows the parameters of four simulated solid patch antennas with meshed ground planes. $N_H$ and $N_V$ are the number of horizontal and vertical lines of the meshed ground plane. The horizontal lines are perpendicular to the resonant length of the patch. The number of horizontal lines is 14 and number of vertical lines is 15 for all the antenna referred to as antenna design $A - E$. Line width, $L_w$, is 0.2 mm and thickness of copper layer is 0.035 mm. These antennas were excited by a 50 Ω microstrip line in CST Microwave Studio.

**Table 1** Simulated results of patch antenna with meshed ground plane [8]

| Antennas design | Simulated $f_0$ (GHz) | Simulated $S_{11}$ (dB) | -10 dB Bandwidth (MHz) | Simulated Directivity (dBi) | Simulated Gain (dB) | Simulated Radiated Efficiency (%) |
|---|---|---|---|---|---|---|
| A. | 2.44 | -13.97 | 60 | 7.1 | 6.31 | 88 |
| B. $L_w = 0.2$mm | 2.24 | -16.05 | 70 | 5.66 | 5.25 | 93 |
| C. $L_w = 0.4$mm | 2.28 | -13.07 | 70 | 5.81 | 5.5 | 93 |
| D. $L_w = 0.6$mm | 2.31 | -32.9 | 80 | 6.08 | 5.74 | 92 |
| E. $L_w = 0.8$mm | 2.37 | -14.78 | 90 | 6.48 | 6.05 | 90 |

In [4] the resonant frequency, gain and efficiency of the meshed patch antennas decrease when the transparency of the patch antenna is increased. The number of horizontal line and vertical lines were kept constant, changing the line width to examined the transparency The transparency of the meshed ground was computed using equation (1). From the study its was observed that $L_w = 0.2\ mm$ the transparency is 91.5%, $L_w = 0.4\ mm$ gives a transparency of 83.4%, $L_w = 0.6\ mm$ the transparency is 75.8 % and $L_w = 0.8$ mm the transparency is 68.4%. Meshed patch antenna design with thin lines produces more transparent antennas but with gain loss of the antenna.

$$T_{transparency} = \frac{L.W - L_w.N_h.L - L_w.N_v.W + L_w^{\ 2}.N_v.N_h}{L.W} \quad (1)$$

Increasing the linewidth from 0.2 mm to 0.8 mm increases the impedance bandwidth and shifts the resonant frequencies from 2.44 $GHz$ to of 2.22 $GHz$as shown in Fig.3. The bandwidth of microstrip antennas is proportional to the thickness of the substrate. The FR4 substrates are very thin in terms of the wavelength (thickness $\ll {}^{\lambda_0}/_4$ making the bandwidth narrow as shown in Table 1. The gain and the resonant frequency decrease with a decrease in the line width while the mesh spacing increases. Meshing of the ground causes gain loss of the antenna.

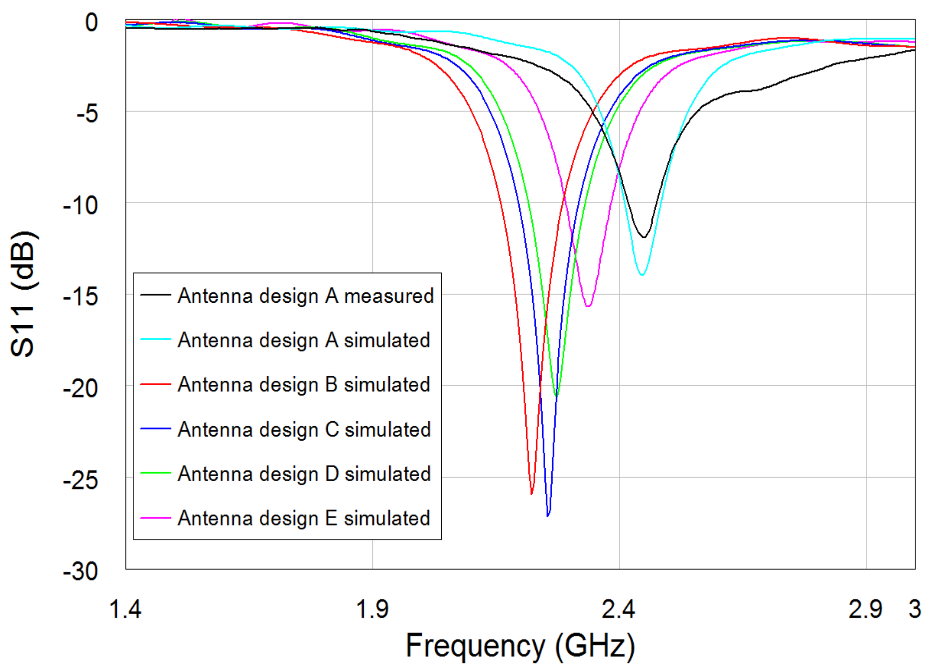


**Figure 3** Effect of the linewidth on the resonant frequency of rectangular meshed ground for patch antenna.

**C. Microstrip Patch (Inset feed) at 2.45 GHz with differing ground plane**

A set of four rectangular patch antennas (see Fig.4 for the dimension of the patch) with meshed ground plane with line width 0.2 mm were printed on FR4 substrates backed with meshed copper grounds is shown in Table 2. The design of meshed patch antenna using three horizontal line were studied by [7]. Similar concepts were used to design the meshed ground plane of the microstrip antennas in this study where three horizontal lines one at the top, one at the bottom and the other at the feed point at the middle were used. This horizontal line at the feed allows current to flow to the vertical lines Antenna samples (antenna 5 and antenna 6) had a ground plane of 65 mm by 70 mm. The meshed ground of antenna 5 consist of number of vertical lines $N_v = 25$ and number of horizontal lines $N_h = 3$. This antenna has a transparency of 91.5% and metal coverage of 8.5%. Antenna 6 has $N_v = 36$ and $N_h = 3$, the transparency of 88% and metal coverage of 12%. Antenna 5 has a finer meshed ground plane giving a higher resonant frequency and better impedance bandwidth than antenna 6 because the meshed is coarse and closedly compact together[8]. The resonant frequency of antennas 5 and 6 are higher than conventional antenna 4 because the electrical lengths of antenna 5 and 6 are shorter as in Fig.5and Fig.6.

Antenna 7 and 8 are etched on a FR4 substrate of ground plane (70 mm by 70 mm) but of the same dimension of the patch as antenna 4 Antenna 7 has $N_v = 15$ and $N_h = 8$ transparency of 93.5% and metal coverage of 6.5% and Antenna 8 is built with a solid patch (see Table 2) [7-8] over a meshed ground plane and a dielectric constant of substrate between the patch and ground plane is 4.3 and thickness of 1.6 mm.The meshed ground plane consist of $N_V = N_h = 15$ transparency of the antenna is 91.5% and metal coverage of 8.5%. The transparency of these antenna increased the antenna directivity and the resonant frequency reduces as reported [1]. Antenna 7 has higher centre frequency and better impedance bandwidth than antenna 8 because of the reduced number of parallel lines to the length of antenna ground plane.

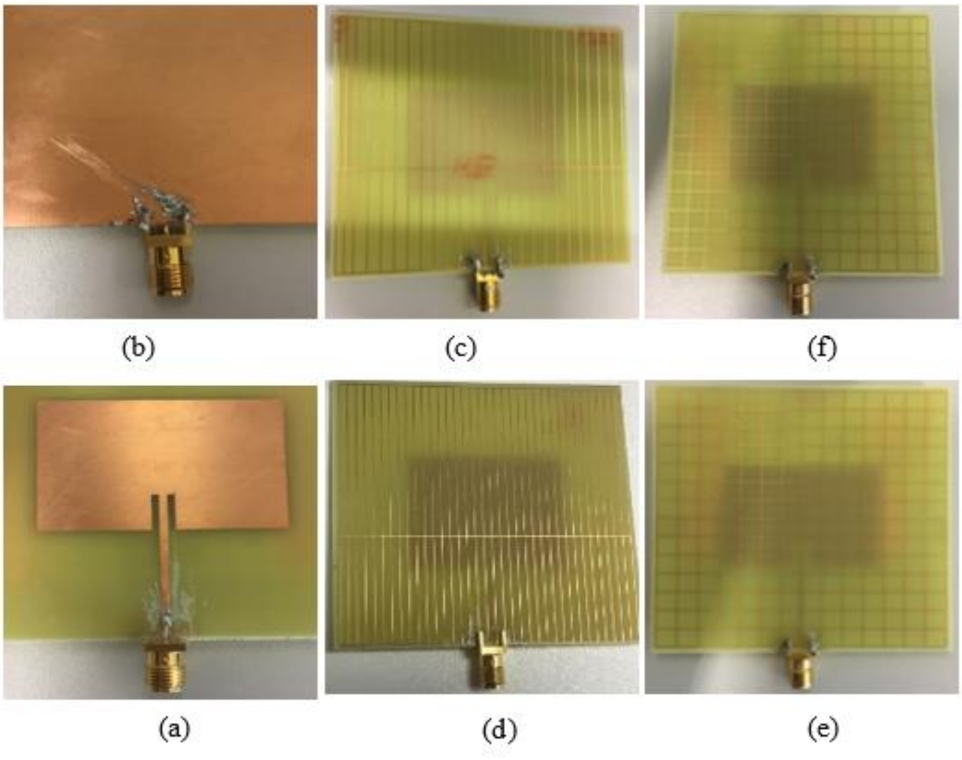


**Figure4** Antenna design structure (a) Top patch (b) solid ground plane:Antenna 4 (c) Antenna 5, (d) Antenna 6, (e) Antenna 7 and (f) Antenna 8

**Table 2** Simulated and measured result of representative examples for meshed ground plane

| Antenna design | Simulated $f_0$ (GHz) | Measured $f_0$(GHz) | Simulated $S_{11}$(dB) | Measured $S_{11}$(dB) | Simulated gain (dB) | Simulated Radiation Efficiency (%) |
|---|---|---|---|---|---|---|
| Antenna 4 | 2.46 | 2.45 | -25.8.0 | -21.4dB | 7.1 | 91 |
| Antenna 5 | 2.54 | 2.53 | -22.2 | -37.8 | 6.48 | 79 |
| Antenna 6 | 2.52 | 2.50 | -14.3 | -30.1 | 6.52 | 84 |
| Antenna 7 | 2.45 | 2.51 | -29.6 | -22.8 | 5.87 | 92 |
| Antenna 8 | 2.3 | 2.25 | -36.3 | -14.9 | 5.67 | 92 |

Figure 5 shows the $S_{11}$ values for three antennas described in the previous paragraph. Antenna 4 has a good impedance match $-25.7\ dB$ at 2.46 $GHz$ $-10\ dB$ bandwidth of $87MHz$ and measured values $-21.5dB$ at 2.43$GHz$ $-10dB$ bandwidth of $61MHz$. The measured $S_{11}$ value of Antenna 5 is $-37.9dB$ at 2.53 $GHz$ and impedance bandwidth $153MHz$ while the simulated result is $-17.5\ dB$ at 2.51 $GHz$ $-10dB$ bandwidth of $80MHz$. The measured result shows that antenna 6 resonates $-21.8\ dB$ at 2.53 $GHz$with an impedance bandwidth of $110\ MHz$ while the simulated results are $-24.2dB$ at 2.50$GHz$ $-10dB$ bandwidth of $80MHz$. Meshing the ground plane gives an enhanced bandwidth compared to a solid ground (2.5 %) to meshed ground (7.5%). The difference between simulation results and the measured results may be attributed to inductance offered by the coaxial probe. Another reason, may be as a result of no nexact values of the dielectric constant of FR4 substrate being available for the process of fabrications [8].

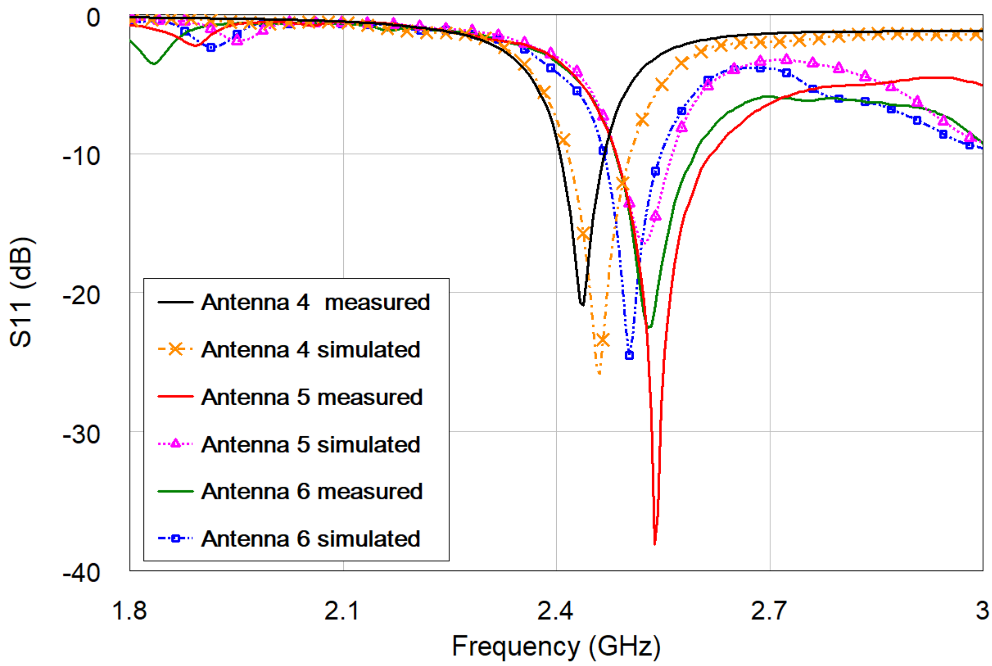


**Figure 5** $S_{11}$ result for meshed ground plane and conventional patch antenna (antenna 4)

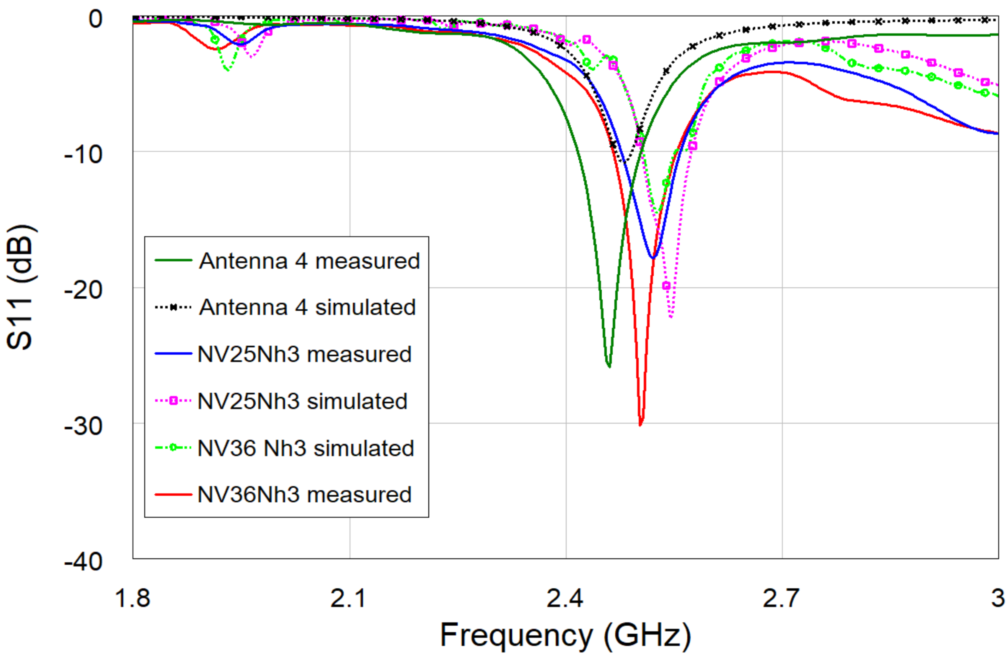


**Figure 6** $S_{11}$ Simulation results of horizontal lines($N_H = 3$) and varying vertical lines ($N_V$) of meshed ground plane

Two patterns in two plane *yz* and *xz* were defined in Balanis [5]. Simulated pattern of reference antenna A has a maximum gain of 7.1 dB. The E-plane and H-plane at boresight is the same. The front to back ratio of the solid patch $FBR_{dB} = 15\ dB$. There are no side lobes but back lobes as a result of the finite ground plane. A larger ground plane or use of EBG materials will reduce the backlobe.Figure 7 show the radiation patterns in the E- and H-plane simulated at 2.45 GHz.Antenna 4 has maximum directivity at a peak value of 6.93 dBi whereas antenna 6 has directivity of 6.52 dBi. Both antennas have very similar patterns.Antenna 4 is an inset fed solid patch with a solid ground plane. The other antenna samples 5,6,7 and 8 are solid patch with meshed ground ground on FR4 substrate.

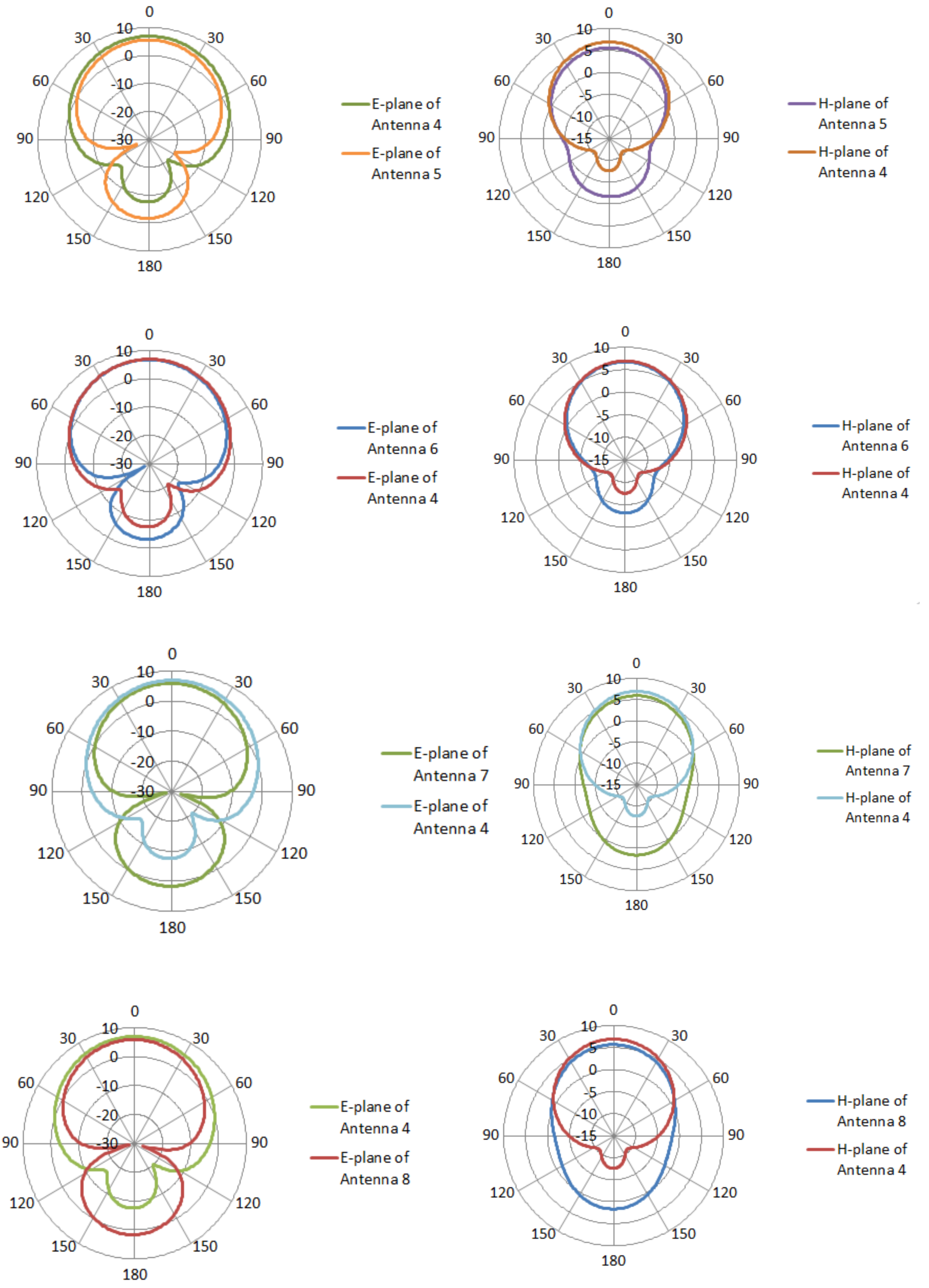


Figure 7Simulated radiation patterns for the Gain of antenna design 4, 5, 6, 7 and 8

## IV. Conclusion

Increasing the line width of the meshed ground plane of microstrip patch antenna improved the reflection coefficient, gain and radiation pattern. Using the meshed method increases the antenna bandwidth from the results.A transparency of 93.5% and metal coverage of 6.5% was achieved. From the radiation patterns, meshed ground shows some losses compared with solid patch antennas.

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