RESEARCH PAPER

Novel Design of Microstrip Patch Antenna based on Two-Shape Structure

Halgurd N. Awl 1, Rashad H. Mahmud 2

1Department of Communication, Engineering College, Sulaimani Polytechnic University, Kurdistan Region–Iraq.
2Department of Physics, College of Education, Salahaddin University–Erbil, Kurdistan Region–Iraq.

ABSTRACT:
Recently, most of researches concentrate on design broadband and high gain microstrip antenna with a low profile to fulfill modern communication system requirements. This paper presents a novel design of microstrip patch antenna. The design is based on the number two (Two-Shape) shape using the Computer Simulation Technology (CST) microwave studio. The novel design is operated at the X-band frequency, and it provides a very wide bandwidth which is around 25% at the center frequency 10.25 GHz. The antenna realized gain fluctuates between 5.3-7.7 dBi over the entire X-band frequency. The antenna provides a Fan-beam radiation patterns with very low side lobe levels, which are below -10 dB in both of the E- and H-planes. Due to the simplicity and compatibility, it is believed the antenna could be of interest to the radar applications.

KEY WORDS: Microstrip, antenna, X-band, Radar
DOI: http://dx.doi.org/10.21271/ZJPAS.31.s4.3
ZJPAS (2019), 31(s4); 26-29.

1. INTRODUCTION:

The recent developments of wireless communication systems increase the attention of researchers to enhance the performance of the components of wireless systems. Antennas, which are key components placed at the very front end of any communication system, is required to have a low profile, wide bandwidth and high gain performances in many applications. Such performances are not easy to achieve in a conventional design of antennas. Microstrip patch antennas are considered as low profile due to their simplicity in fabrications. Basically, the configuration of microstrip patch antennas consists of conducting material placed on the one side of the dielectric substrate and ground plate on the other side.

Various kinds of substrates can be used for microstrip antenna design and the common range of their dielectric constant is $2.2 \leq \varepsilon_r \leq 12$. Copper and gold are a good candidate to be utilized as a conducting material while copper is more common due to inexpensiveness. The geometrical shape of the patch can be designed based on any possible shapes including rectangular, triangular, square, circular elliptical and dipole. (Constantine, 2005). These shapes can be modified in order to achieve better antenna performance. A rectangular patch was the most conventional used structure for the design of microstrip antennas. However, its performance,
more specifically the narrow bandwidth, is the main drawback of this kind of antenna structure. Recently, different approaches have been introduced to enhance the bandwidth such as microstrip antenna Lamminen (2011), Vivaldi antenna Rusch (2011) and Quazi-Yagi antennas utilizing the Ga substrate Beer (2010). Recently, different approaches are employed to enhance the microstrip patch antenna bandwidth such as coupled circular patches (Blondeaux, 2001; Blondeaux, 2000; Hunter, 2003; Abunjaileh, 2008). In this paper a novel design structure of the microstrip patch antenna is presented. Instead of rectangular patch, the number two shape (Two-shape) has been introduced as shown in Figure 1. The structure provides an extreme wide bandwidth. Also, it is very simple to fabricate using the conventional microwave printing circuit. This paper is organized as follows. In section 2, the design of the antenna is discussed. Then, the simulated results obtained from the antenna using the CST microwave studio are shown in section 3. Later, the conclusions obtained from this work are highlighted in section 4.

2. ANTENNA DESIGN

The design of the antennas is designed as shown in Figure 1. It is based on the microstrip structure. Instead of a rectangular patch, a two-shape structure is placed on the top layer of the design colored in yellow (Figure 1). In the second layer is the substrate layer, with a thickness of 3.127 mm and designed from the material called RT Druid 5880LZ. This material has a dielectric constant ($\varepsilon_r$) 1.96. The geometrical dimensions of the antenna are summarized in Table 1.

![Figure 1. Geometry layout of the proposed Two-shape antenna.](image)

The dimensions of the proposed antenna have been obtained as follows (Balanis, 2005)

$$E_{r} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{1 + 12 \frac{h}{W}}$$  \hspace{1cm} (1)

The width of the microstrip antenna is calculated:

$$W = \frac{1}{2 f_r \sqrt{\varepsilon_\infty \mu_0}} \sqrt{\frac{2}{\varepsilon_r + 1}}$$  \hspace{1cm} (2)

The length of the antenna increases electrically because of fringing, so the increase in length is:

$$\Delta L = 0.412h \left( \frac{E_{r} + 0.3(W + 0.264)}{E_{r} - 0.258(W + 0.8)} \right)$$ \hspace{1cm} (3)

The length is increased on both sides of the Microstrip antenna. Thus, the effective length is:

$$L_{eff} = L + 2\Delta L$$  \hspace{1cm} (4)

$$L = \frac{\lambda_{eff}}{2} - 2\Delta L = \frac{1}{2 f_r \sqrt{E_{r} \mu_0 \varepsilon_\infty}} - 2\Delta L$$  \hspace{1cm} (5)
The ground plane dimensions, Width ($W_g$) and Length ($L_g$) is given by:

$$W_g = W + 6h$$ \hspace{1cm} (6)

$$L_g = L + 6h$$ \hspace{1cm} (7)

It is worth mentioning that all the dimensions of the antennas are optimized using the optimal server in the CST simulator. Also, the dimensions $l_1$, $l_2$, and $l_3$ are normalized to the antenna operating frequency. The feeding port is designed at one of the ends of the antenna. This is to facilitate the measurement process. It should be mentioned that the port is designed to be matched with a standard connector feature (50 $\Omega$).

Table 1: parameters of proposed antenna

| Parameters | Value (mm) | Parameters | Value (mm) |
|------------|------------|------------|------------|
| $W$        | 35         | $l_1$      | 5.4        |
| $L$        | 35         | $w_1$      | 4.7        |
| $w_g$      | 32         | $l_2$      | 7.5        |
| $L_g$      | 23         | $w_2$      | 26         |
| $W_f$      | 2.5        | $l_3$      | 5          |
| $l_f$      | 2.9        |            |            |

3. SIMULATION RESULT

The Two-shape antennas presented in this paper is simulated at the X-band frequency using the CST studio. The initial design dimension values, which are entered to the simulator, are obtained based on the conventional microstrip equations. Then, the optimiser feature in the CST is involved in order to enhance the antenna electrical performances such as the return loss ($S_{11}$), and antenna gain.

The return loss of the proposed antenna after performing the optimization is shown in Figure 2. Using the -10 dB criteria, it can be seen that the return loss of the antenna is below -10 dB for frequencies 9.12-11.42 GHz, and has a very wide reflection coefficient bandwidth (23 %) at the center frequency 10.25 GHz. As addressed by Constantine (2005), obtained bandwidth of a microstrip patch antenna with microstrip fed line is typically between 2–5%. In comparison to this, the designed antenna with the broadband performance and simple structure is a good candidate to be utilized in the operated band. On the other hand, the voltage standing wave ratio is below 1.5 from 9.5-11 GHz as shown in Figure 3.

![Figure 2. Return loss versus Frequency.](image1)

![Figure 3. The voltage standing wave ratio (VSWR) of the proposed antenna](image2)

The antenna has a very stable realized gain over the entire operating frequencies, as can be depicted in Figure 4. Looking the frequency range of interest, the realized gain fluctuates from 6.1 to 7.9 dBi within the frequencies 9.12 GHz to 11.42 GHz. The gain still increases with the increase of frequencies. However, due to the losses, the efficiency of the antenna reduces when operating at such high frequencies. The E- and H-plane radiation patterns are shown in Figure 5. The main beam is shifted to left in the E-plane and to the right in the H-plane. This is due to the phase difference occurrence. The patterns have very low side lobe levels, which are below -10 dB. The antenna considered to be well operated in X-band frequency. However, the other bands ignored due to the distorted radiation patterns.
4. CONCLUSIONS

This paper has presented a novel patch shape of the microstrip antenna named the two-
shape microstrip patch antenna. The Two-
shape has low profile, high antenna and extremely wide bandwidth. The antenna is
operated at the X-band frequency, and it provides a wide bandwidth which is around
23% at the center frequency 10.25 GHz. The antenna realized gain fluctuates between 6.1-
7.9 dBi over the entire X-band frequency. The antenna provides a Fan-beam radiation
patterns with very low side lobe levels, which are below -10 dB in both of the E- and H-
planes.

REFERENCES

Abunjaileh, A. I., Hunter, I. C., & Kemp, A. H. 2008. A circuit-theoretic approach to the design of quadruple-mode broadband microstrip patch antennas. IEEE transactions on microwave theory and techniques, 56(4), 896-900.

Beer, S., Adamiuk, G., & Zwick, T. 2010. Planar Yagi-Uda antenna array for W-band automotive radar applications. In Antennas and Propagation Society International Symposium (APSURSI), 2010 IEEE (pp. 1-4). IEEE.

Blondeaux, H., Baillargeat, D., Leveque, P., Verdeyme, S., Vaudon, P., Guillon, P., ... & Cailloce, Y. 2001. Microwave device combining filtering and radiating functions for telecommunication satellites. In Microwave Symposium Digest, 2001 IEEE MTT-S International (Vol. 1, pp. 137-140). IEEE.

Blondeaux, H., Baillargeat, D., Verdeyme, S., Guillon, P., Carlier, A., Cailloce, Y., & Rogeaux, E. 2000. Radiant microwave filter for telecommunications using high Qu dielectric resonator. In Microwave Conference, 2000. 30th European (pp. 1-4). IEEE.

Constantine, A. B. 2005. Antenna theory: analysis and design. MICROSTRIP ANTENNAS, third edition, John wiley & sons.

Hunter, I. 2003. Broad-band matching of antennas using dual-mode radiators. In Microwave Conference, 2003. 33rd European (Vol. 1, pp. 431-434). IEEE.

Lamminen, A., & Säily, J. 2011. Wideband stacked patch antenna array on LTCC for W-band. In Antennas and Propagation (EUCAP), Proceedings of the 5th European Conference on (pp. 2962-2966). IEEE.

Rusch, C., Schäfer, J., Kleiny, T., Beer, S., & Zwick, T. 2011. W-band Vivaldi antenna in LTCC for CW-radar nearfield distance measurements. In Antennas and Propagation (EUCAP), Proceedings of the 5th European Conference on(pp. 2124-2128). IEEE.