Multi-Forked Microstrip Patch Antenna for Broadband Application

Wa'il A Godaymi , Raed M Shaaban, Al-Tumah, Akeel STahir and Zeki A Ahmed

Physics Department, Science College, Basrah University, Basrah , Iraq
Email: raed.shaaban@uobasrah.edu.iq

Abstract. In this paper, a new design simulation of multi-forked microstrip patch antenna is presented. The proposed antenna design consists of rectangular patch structure loaded multi-slotted forked with Arlon AD320A (tm) dielectric, direct coaxial probe feed technique, and microstrip edge feed, the novel forked shaped patch. The composite effect of integrating these multi-shapes forked patches techniques and by introducing the new multi-slotted patch. The best result of proposed antennas was a wide impedance bandwidth of 114 % at 10.31 GHz resonance frequency for microstrip line feed approach, and maximum achievable gain is 6.3 dB for coaxial probe feed approach. The return loss, directivity gain, and voltage standing wave ratio are simulated results using HFSS 13.0 software.

Keywords: Multi-Forked, Multi-Slotted, Impedance Bandwidth, Directivity Gain, High Frequency Structure Simulator (HFSS).

1. Introduction

Simply microstrip patch antennas consist of a dielectric substrate on one side of a ground plane with metal patch on the side other [1-2]. In recent years the broadband microstrip antennas are attractive and wide spread proliferation for both military and commercial application because of low profile, light weight and low cost [3-5]. Narrow bandwidth of less than 3% confines their use in recent wireless communication systems, so academics have obtainable numerous approaches like hole coupling, use of shorting pins, stacking, modifications in the feed and use of coupled parasites to enhance the bandwidth and gain directivity of MSA [6-9]. In this project, broadband impedance matching is proposed for bandwidth enhancement. This technique means the attachment of a using two types techniques feed such as coaxial probe feed, and microstrip line feed, add to modification shape rectangular patch structure loaded by multi-forked patch [10-11].

This article a microstrip rectangular patch structure loaded multi-slotted forked slotted antenna is presents different frequencies (10.31GHz,11.83GHz, 18.09GHz and 19.89 GHz), within limits X and K band frequencies[12]. The standard element is a dual rectangular patch loaded by multi-slotted forked. Integrating multiple functions on an antenna can reduce the antenna’s size and weight and increase the electrical properties of the antenna [13-15]. This result simulated can be divided into two sections. In Section I, broadband slotted rectangular patch structure loaded by multi-forked (SRLM-F) is designed with coaxial probe feed for dual bandwidth in X, K band respectively. In Section II, broadband (SRLM-F) is designed with microstrip edge feed for (X-KU) band. The simulation results is shown that the multiband antenna has achieved good results used for radar, wireless communication,
and satellite communication system [16-19]. The design and performance of antennas are carried out using HFSS 13.0 software.

2. Antenna Design

The geometry of the proposed antenna fabricated on an Arlon AD320A (tm) substrate of dielectric constant 3.2 with thickness 1.9 mm, the tangent loss of 0.0032 and total size is about \(29 \times 24 \times 1.9\) mm\(^3\) is shown in Fig.1. The measurement of multi-forked MSPA is shown in Table 1. The top and side view of two types feed proposed design is shown in Figs.2 (a), and 2(b), respectively. The first type feed antenna is coaxially probe fed at (1,-2.5), and it resonates for 11.83 GHz, and 18.09 GHz. In second feed design, the antenna is fed by microstrip edge feed the size of microstrip line is \(W_4, L_3\), and it resonates for 10.31 GHz. The length and the width of the patch are calculated initially by the relationships [20-21].

\[
W_F = \frac{v_0}{2f} \times \sqrt{\frac{2}{\varepsilon_r + 1}} \quad \ldots \ldots (1)
\]

\[
L_F = \frac{v_0}{2f \sqrt{\varepsilon_e}} = 2\Delta L \quad \ldots \ldots (2)
\]

Where

\[
\Delta L = 0.41h \times \frac{\varepsilon_e + 0.3}{\varepsilon_e - 0.258} \times \left(\frac{W_F}{h} + 0.264\right) \quad \ldots \ldots (3)
\]

where \(\Delta L\) is extension in length due to fringing effects and effective dielectric constant is given by

\[
\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2 \sqrt{1+\frac{h}{W_F}}} \quad \ldots \ldots (4)
\]

Where \(f\) and \(v_0\) is the resonant frequency (in GHz) and the velocity of light.

And the ground plane dimensions would be given as[23]:

\[
W = 6(h) + W_F \quad \ldots \ldots (5)
\]

\[
L = 6(h) + L_F \quad \ldots \ldots (6)
\]
Figure 1. Top and Side view of the two types feed method

Table 1. Proposed antenna are dimensions.

| Parameters                  | Values (mm) |
|-----------------------------|-------------|
| \((L_s, W_g, h)\)           | (29, 24, 1.9) |
| \((L_E, W_E)\)             | (21.5, 16.5) |
| \((L_1, L_2, L_3, L_4)\)   | (11, 21.5, 4.75, 2.5) |
| \((W_1, W_2, W_3, W_4)\)   | (2, 4.5, 1.25, 2.5) |
| \((x_f, y_f)\)              | (1, −2.4)    |

3. Simulation and discussions

The results of proposed antenna is done using using of a commercial software Ansoft HFSS (13.0). The reflected power (S11) and (VSWR) of both antennas at their resonant frequencies lies in the variety between 8 and 30 as shown in figures 2 and 3 respectively. In figures 2a, and 2b can be seen the
low return loss at the frequency of 11.83 GHz, and 10.31 GHz for coaxial probe feed and microstrip edge feed method at -30.2, and -24.6 respectively. For both feed methods can be calculated the bandwidth from the return loss characteristics are 5.5%, 30%, and 114% at 11.83 GHz, 18.09 GHz and 10.31 GHz respectively. The presentation of VSWR for the proposed microstrip patch antenna is shown in Fig. 3, which lies amid 1 and 2 for all resonant frequencies with least reflected power of less than –24.6 dB. In table 2, explicate the antennas parameters under various resonant frequencies and fed methods.

Fig. 4 shows the radiation pattern for the MPA for two feeding methods, coaxial probe feed and microstrip edge feed at 18.09 GHz and 10.31 GHz resonant frequencies. 3-D radiation pattern for 18.09 GHz resonant frequency is shown in Fig. 5. Fig. 6 shows the electric field distribution on the MSA. The electric field distribution is followed an entire patch at all feeding methods.

![Figure 2](image1.png)  ![Figure 3](image2.png)

**Figure 2.** Return loss (a) coaxial probe feed (b) microstrip edge feed.

**Figure 3.** VSWR (a) coaxial probe feed (b) microstrip edge feed.
Table 2. Proposed antenna efficiency with various feeding methods.

| Parameters                  | Coaxial Probe Feed | Microstrip Edge Feed |
|-----------------------------|--------------------|----------------------|
| Resonance frequency (GHz)   | 11.83              | 18.09                |
| Bandwidth (%)               | 5.5                | 30                   |
| Gain (dB)                   | 3.16               | 6.3                  |
| VSWR                        | 1.06               | 1.12                 |
| Return loss (dB)            | -30.2              | -24.6                |

Figure 4. Radiation pattern for the MSA, (a) coaxial probe feed (b) microstrip edge feed.

Figure 5. 3D radiation pattern for 18.09 GHz resonant frequency.
4. Conclusion

A Multi-Forked RMSA and two types technique for enhancing the band width and gain has been developed and implemented successfully. The antenna offers a bandwidth of 114% from 8.46 GHz to 20.25 GHz showing good radiation characteristics and gain. The return loss for all resonant frequency is less than $-24.6$ dB and VSWR lies in the range between 1 and 1.12. The proposed antennas is suitable for for X and K band frequency applications.

5. References

[1] James j., and P.S. Hall (Eds), Handbook of microstrip antenna, Peter Peregrinus, London, UK, 1989.
[2] Antenna theory analysis & design by C.A. Balanis, 2nd Ed., John Wiley & sons, inc. 2005, New York.
[3] Pozar, David M. "Microstrip antennas." Proceedings of the IEEE 80.1 (1992): 79-91.
[4] Kaneda, Noriaki, et al. "A broadband planar quasi-Yagi antenna." IEEE Transactions on Antennas and Propagation 50.8 (2002): 1158-1160.
[5] Kumar, Alok, Nancy Gupta, and P. C. Gautam. "Gain and Bandwidth Enhancement Techniques in Microstrip Patch Antennas-A Review." International Journal of Computer Applications 148.7 (2016).
[6] Malekabadi, Seyed Ali, Amir Reza Attari, and Mir Mojtaba Mirsalehi. "Design of compact broadband microstrip antennas using coplanar coupled resonators." Journal of Electromagnetic waves and Applications 23.13 (2009): 1755-1762.
[7] Shaaban RM, Ahmed ZA and Godaymi WA 2016 Radiation patterns account of a circular microstrip antenna loaded two annular Journal of Natural Sciences Research 6 p 71-81.
[8] Dhakad, Shailendra Kumar, Ashkandh Prasad, and Umesh Dwivedi. "Design of a miniaturized microstrip patch antenna for triple-band operation in X, Ku and K band with band-notch characteristics." 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI). IEEE, 2017.
[9] Chaudhary, Leena, et al. "Gain and bandwidth improvement of microstrip antenna using RIS and FPC resonator." *Nascent Technologies in Engineering (ICNTE), 2017 International Conference on*. IEEE, 2017.

[10] Jain, Amit Kumar, and Monika Surana. "Modified Rectangular Patch Antenna Loaded With Multiple C Slots for Multiple Applications." *Journal of Applied and Computational Mechanics* 2.3 (2016): 192-199.

[11] Chen ZN 2009 Aperture-coupled asymmetrical C-shaped slot microstrip antenna for circular polarisation *IET microwaves, antennas & propagation* 3 p 372-378.

[12] Islam, Mohammad Tariqul, Mohammed Nazmus Shakib, and Norbahiah Misran. "Multislotted microstrip patch antenna for wireless communication." *Progress In Electromagnetics Research* 10 (2009): 11-18.

[13] Hwang, Yeongming. "Satellite antennas." *Proceedings of the IEEE* 80.1 (1992): 183-193.

[14] Yegnanarayanan, S., P. D. Trinh, and B. Jalali. "Recirculating photonic filter: a wavelength-selective time delay for phased-array antennas and wavelength code-division multiple access." *Optics Letters* 21.10 (1996): 740-742.

[15] Morishita, Hisashi, Yongho Kim, and Kyohei Fujimoto. "Design concept of antennas for small mobile terminals and the future perspective." *IEEE Antennas and Propagation Magazine* 44.5 (2002): 30-43.

[16] Goldsmith, Andrea. *Wireless communications*. Cambridge university press, 2005.

[17] Martinez-Vazquez, Marta, et al. "Integrated planar multiband antennas for personal communication handsets." *IEEE Transactions on Antennas and Propagation* 54.2 (2006): 384-391.

[18] Chen, Sheng-Bing, et al. "Modified T-shaped planar monopole antennas for multiband operation." *IEEE transactions on microwave theory and techniques* 54.8 (2006): 3267-3270.

[19] Zhang, Ting, et al. "A novel multiband planar antenna for GSM/UMTS/LTE/Zigbee/RFID mobile devices." *IEEE Transactions on Antennas and Propagation* 59.11 (2011): 4209-4214.

[20] Hillyard P, Qi C, Al-Husseiny A, Durgin GD and Patwari N 2017 In RFID (RFID) Int. Conf. *IEEE International Conference* Focusing through walls: An E-shaped patch antenna improves whole-home radio tomography *IEEE* p 174-181.

[21] Chair R, Mak CL, LeeKF, Luk KM and Kishk AA 2005 Miniature wide-band half U-slot and half E-shaped patch antennas *IEEE transactions on antennas and propagation* 53 p 2645-2652.