Design and simulation of UWB microstrip patch antenna for Ku/K bands applications

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Article Info

Article history:

Received Feb 23, 2019
Revised May 15, 2019
Accepted Jun 27, 2019

Keywords:

5G
Ku/K bands operation
Satellite communication slotted
RMPA
UWB

ABSTRACT

In this paper, a compact Rectangular Microstrip Patch Antenna (RMPA) fed by microstrip line has been designed to operate for Ku/K bands applications. The proposed antenna is slotted and optimized to reach a large bandwidth and cover various applications such as 5G communication (in frequency range 24.25-27.5 GHz), fixed and mobile satellite, radionavigation, space research, radiolocation etc. In this design, the substrate used is FR4 with a relative permittivity of 4.4 and a thickness of 1.6 mm. The slotted RMPA has been simulated using Advanced Design System (ADS) software and the obtained results are presented and discussed. The proposed antenna achieves a return loss less than -10 dB and VSWR (voltage standing wave ratio) < 2 in frequency range from 16.58 to 25.29 GHz. The percentage bandwidth provided by the proposed microstrip antenna is 41.61%.

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1. INTRODUCTION

Ultra-wideband (UWB) antennas are essential elements of today's communication systems. They are the indispensable elements of the wireless communication devices. Microstrip planar antennas have attractive advantageous features such as low profile, inexpensive, light weight, ease of fabrication, conformability and also they can be manufactured either as a stand-alone element or as a part of an array. Because of their simplicity and compatibility with printed circuit technology microstrip antennas are widely used in the microwave frequency spectrum.

In higher frequency bands many researchers have great interest in designing UWB antennas used in systems operated in Ku (12 GHz-18 GHz) and K (18 GHz-28 GHz) bands [1-6]. Antennas operating in Ku-K bands are integrated in many applications, including mobile 5G services, mobile satellite services (MSS), broadcast satellite services (BSS), fixed satellite services (FSS), and Radar [7-10]; as for example vehicle monitoring and tracking, weather forecasting, portable satellite telecasting and aeronautical/maritime navigation.

In this paper, the proposed compact antenna which has a wide bandwidth and covers Ku/K bands applications has been presented. A parametric study has been carried out to understand the effects of various dimensional parameters and to optimize the performance of the proposed antenna. The antenna is successfully designed with a compact size on the epoxy FR4 substrate. An impedance bandwidth ranging from 16.58 to 25.29 GHz is achieved by using a new slot on the patch. Compared to recent related work, the proposed antenna has a large bandwidth, a compact size and a simple configuration. In the next sections antenna design has been explained in detail and results of antenna parameters are discussed.

This paper is divided into 4 sections. The first section comprises of introduction. The proposed antenna design is described in Section 2. Discussion of simulation result has been done in Section 3 and conclusion is drawn in Section 4.

2. ANTENNA DESIGN

The proposed antenna is etched on the dielectric material FR4 substrate of a relative permittivity $\varepsilon_r = 4.4$, loss tangent $\tan\delta = 0.02$, and a thickness $h = 1.6\,mm$. The geometry of the proposed UWB Ku/K bands antenna is shown in Figure 1.

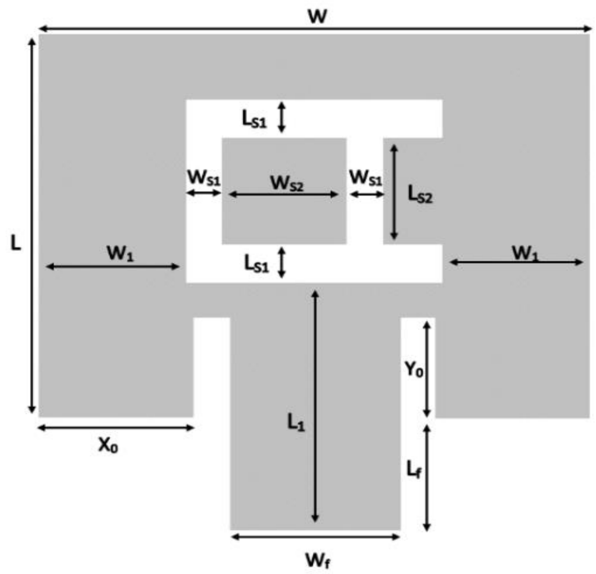


Figure 1. Geometry of the proposed antenna

The designed antenna has a patch length of $L = 7.72\,mm$ and width of $W = 9.12\,mm$. The antenna is slotted in order to obtain a compact size and a good bandwidth. The slot-shape introduced on the radiating surface of the proposed microstrip antenna looks like the alphabetic character 'A' which can be displayed by seven-segment display. The character is rotated by 90° counterclockwise on the radiating surface.

As shown in Figure 1, the slotted antenna is fed by a $50\,\Omega$ microstrip line with length $L_f = 1.37\,mm$ and calculated width $W_f = 3.6\,mm$. The width of the feed line is designed to match the impedance of a $50\,\Omega$ connector. Several parametric studies are performed in this work, but not presented here, to enhance the performance of the antenna in the Ku/K bands. The parametric dimensions of the proposed microstrip patch antenna are optimized and illustrated in Table 1 and Table 2. In comparison with the other works presented in literatures, the proposed antenna has a wide bandwidth, a compact size and a simple configuration.

Table 1. General dimensions of the proposed antenna

Parameter	Value (mm)
W	9.12
L	7.72
W_f	3.6
L_f	1.37
X_0	1.46
Y_0	2.53

Table 2. Optimized slot dimensions and its position on the patch

Parameter	Value (mm)
W_{S1}	0.6
L_{S1}	0.7
W_{S2}	2.065
L_{S2}	1.95
W_1	2.435
L_1	4.32

3. RESULTS AND DISCUSSION

The proposed antenna is designed and simulated using Advanced Design System (ADS) simulator software. Figure 2 illustrates the simulated results of the return loss (RL) S_{11} parameter as a function of frequency. The simulation results show that the antenna has an impedance bandwidth from 16.58 GHz to 25.29 GHz (8.71 GHz Bandwidth) which is suitable for the higher part of the Ku band and 7.29 GHz bandwidth of the lower part of the K band spectrum. The simulation results shown that the percentage bandwidth of the proposed microstrip patch antenna achieves 41.61%. Therefore, the proposed antenna satisfies the Ultra-Wide Band characteristics because at -10 dB the bandwidth is greater than 500 MHz.

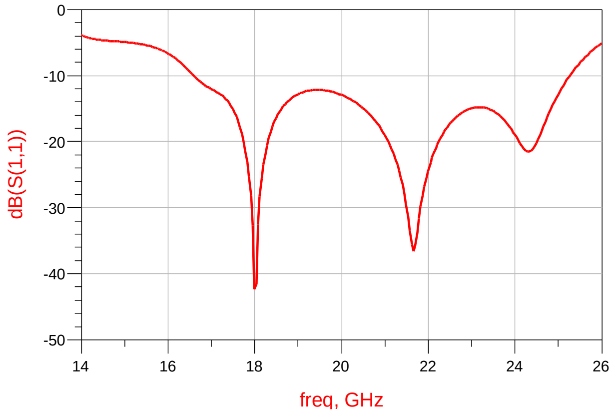


Figure 2. Simulated return loss of proposed antenna

As shown in Figure 2, the proposed antenna has three resonant frequencies. The resonant frequency of the antenna is the frequency at which minimum dip in magnitude of S_{11} is obtained. The designed antenna has the return loss of -42.43 dB, -36.1 dB and -21.6 dB at their resonant frequencies 18 GHz, 21.7 GHz, 24.33 GHz respectively.

The voltage standing wave ratio (VSWR) is a measure of the impedance mismatch between the transmitter and the antenna. The higher the VSWR, the greater is the mismatch. The minimum VSWR which corresponds to a perfect match is unity. Figure 3 shows the simulated VSWR results for the proposed antenna. From the above simulations result we can emphasize that the VSWR is less than 2 over the frequency range from 16.58 to 25.29 GHz (the entire bandwidth).

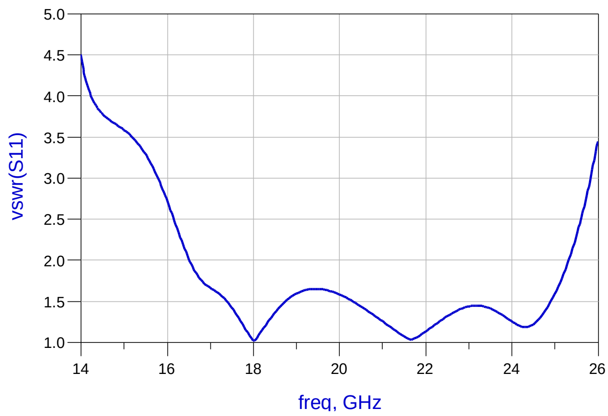


Figure 3. Simulated VSWR result of proposed antenna

Figure 4 shows the 3D radiation pattern of the proposed antenna at 18 GHz. As seen in Figure 4, the designed antenna exhibits good omnidirectional radiation properties and the radiation is perpendicular to the surface of the antenna. The Figure 5, Figure 6 and Figure 7 illustrated below present a comparison of Gain, Directivity and Power radiated by the proposed antenna at different resonance frequencies.

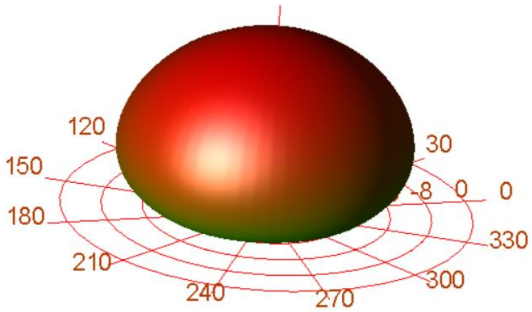
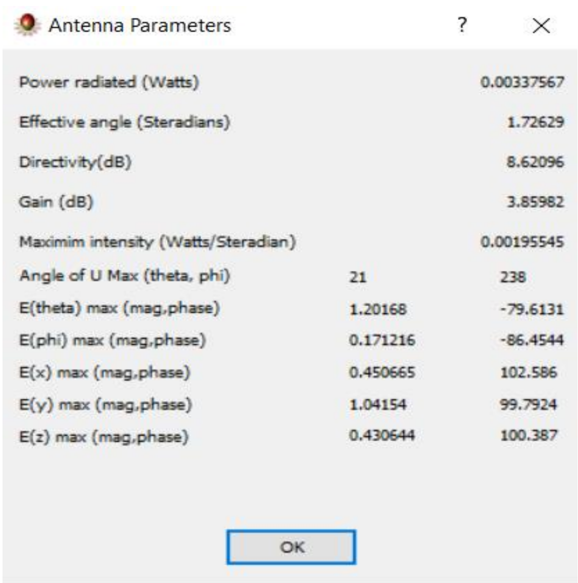


Figure 4. Radiation of the proposed antenna at 18 GHz



Antenna Parameters

Power radiated (Watts)		0.00337567
Effective angle (Steradians)		1.72629
Directivity(dB)		8.62096
Gain (dB)		3.85982
Maximim intensity (Watts/Steradian)		0.00195545
Angle of U Max (theta, phi)	21	238
E(theta) max (mag,phase)	1.20168	-79.6131
E(phi) max (mag,phase)	0.171216	-86.4544
E(x) max (mag,phase)	0.450665	102.586
E(y) max (mag,phase)	1.04154	99.7924
E(z) max (mag,phase)	0.430644	100.387

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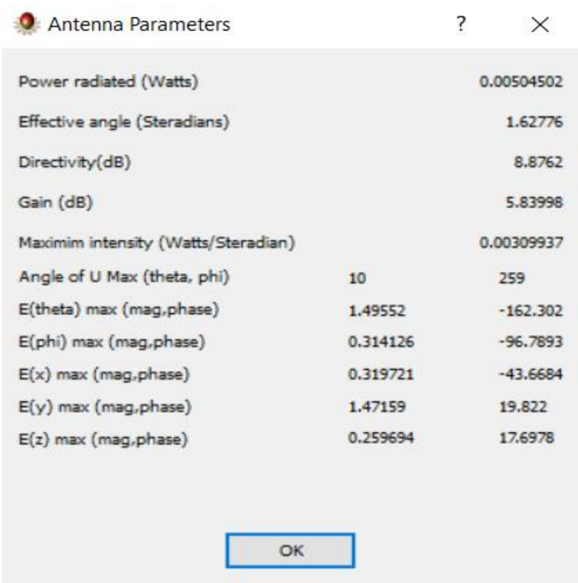
Figure 5. Antenna parameters at 18 GHz



Antenna Parameters

Power radiated (Watts)		0.00504502
Effective angle (Steradians)		1.62776
Directivity(dB)		8.8762
Gain (dB)		5.83998
Maximim intensity (Watts/Steradian)		0.00309937
Angle of U Max (theta, phi)	10	259
E(theta) max (mag,phase)	1.49552	-162.302
E(phi) max (mag,phase)	0.314126	-96.7893
E(x) max (mag,phase)	0.319721	-43.6684
E(y) max (mag,phase)	1.47159	19.822
E(z) max (mag,phase)	0.259694	17.6978

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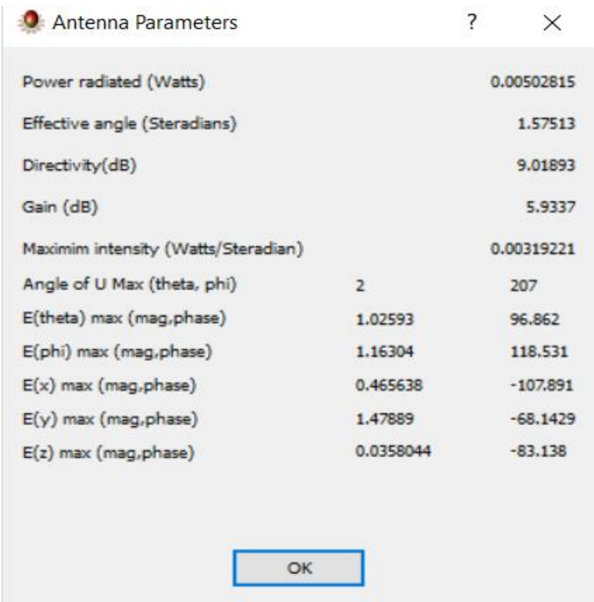
Figure 6. Antenna parameters at 21.7 GHz



Antenna Parameters

Power radiated (Watts)		0.00502815
Effective angle (Steradians)		1.57513
Directivity(dB)		9.01893
Gain (dB)		5.9337
Maximim intensity (Watts/Steradian)		0.00319221
Angle of U Max (theta, phi)	2	207
E(theta) max (mag,phase)	1.02593	96.862
E(phi) max (mag,phase)	1.16304	118.531
E(x) max (mag,phase)	0.465638	-107.891
E(y) max (mag,phase)	1.47889	-68.1429
E(z) max (mag,phase)	0.0358044	-83.138

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Figure 7. Antenna parameters at 24.33 GHz

The tabular form for Gain, Directivity and Power radiated corresponding to the resonance frequencies of the designed antenna is given in Table 3. By analysing the results shown in Table 3, we can note that at the 24.33 GHz resonance frequency, the directivity and gain parameters are better compared with those obtained for the other resonant frequencies. Based on these results, we believe that the antenna has a good Gain and Directivity and these parameters can be improved by using microstrip patch antenna array structure which depends on the number of the antenna in array [11]. The radiated power values at 21.7 and 24.33 GHz are almost similar and are greater than the radiated power value obtained at 18 GHz frequency. Moreover, the mismatch in the power radiated is due to the different reflection losses at different frequencies.

Table 3. Antenna parameters comparison at resonance frequencies

Frequency (GHz)	Gain (dB)	Directivity (dB)	Power radiated (mW)
18	3.86	8.62	3.37
21.7	5.84	8.87	5.04
24.33	5.93	9.02	5.02

4. CONCLUSION

In this work, a rectangular microstrip patch antenna with a new slot on the patch is designed and simulated. Through modeling and simulation, a wideband microstrip patch antenna which covers Ku/K bands applications was achieved. The simulated results of return loss and VSWR have been presented and discussed. We conclude that, with the proposed RMPA a large impedance bandwidth and a perfect impedance match can be obtained. It is clearly visible from the simulation results that VSWR is < 2 throughout the operating bandwidth. Further, the design resulted in compact size antenna with good radiation characteristics for all operating frequencies. Moreover, the performance of this presented antenna illustrates that it is a good candidate for Ku/K bands applications.

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