Design and Parametric Study of Monopole Blade Antenna for UHF-Band Aerospace Applications

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Abstract. This paper provides an idea to design a wideband antenna suitable for UHF-band aircraft application. The blade antenna (BA) has been simulated for different elementary parameters using CST simulator. Antenna performance characteristic with the parametric variation of the antenna model have been studied and demonstrated. The simulation results of the designed antenna show 3.18 dBi gain, and 53-degree half power beamwidth (HPBW) over the entire frequency range 0.9 GHz to 2.0 GHz. Further, the designed antenna a very good return loss performance with VSWR <2.2 in the entire frequency band. This antenna can find its application in aircraft GPS navigation system and datalink operation as well.

Keywords: Blade antenna · Monopole antenna · Omnidirectional

1 Introduction

In the receiver chain for any wireless system, antenna plays a significant role in the complete performance. Its function is to ensure a proper transition between a transmission line and free space. It necessitates enough impedance matching and gain at the same time. The rapid development in wireless communication requires broadband antennas to assist high data rate performance of wireless systems such as aircraft system, radar systems, and satellite communication system. At the same time, omnidirectional radiation from an antenna is preferred for 360-degree radiation coverage. Dipole and monopole antennas (whether electric or magnetic) are well known for their omnidirectional radiation coverage [1–6]. In recent times, monopole antennas have got tremendous attention over its dipole counterpart due to compactness in size [4–6]. As we know bandwidth achieved by a conventional λ/4 monopole antenna is narrow, a wide impedance bandwidth is possible only when the structure of antenna is manipulated using different techniques. One such solution is; by diminishing the length to diameter ratio of the antenna [7], modifying antenna geometry with respect to angle; triangular sheet for planar and conical structure for non-planar are the widely used structure for this technique.

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Different types of broadband antennas suitable for airborne application are available out of those many; one of the most accepted antennas is the BA, and the reasons are; low air drag, lightweight and low-cost [8, 9]. A conventional BA is often a monopole antenna, that employs the first two listed techniques to achieve a broader bandwidth. A broadband monopole antenna with the inverted hat is reported in [10]. This antenna covers a frequency range 0.5 GHz to 2.0 GHz with a very low gain and complex structure. In [11], a broadband reconfigurable antenna that covers VHF/UHF/L-bands is reported for aircraft application. This antenna is modified in biconical shape and frequency reconfigurability is achieved by PIN diode. A broadband (0.5–2 GHz) BA, printed on RO5880 with a dielectric constant 2.2 and substrate thickness 1.6 mm, was reported in [12]. In this antenna, an inductor coil filled with air core, and shaping of the triangular shape help to attain extra bandwidth of 0.5 GHz from a BA reported in [12]. Another BA fabricated with a 2 mm thick Aluminum sheet, designed with an oblique edge to achieve a broadband (0.03–0.60 GHz), is reported in [13]. The oblique edge used in this paper helps to reduce the height of the antenna. However, these antennas require a large ground plane. As a matter of fact, the broadband in these two papers has been achieved by employing a large ground plane, while in many applications such as unmanned aerial vehicles, to have a low radar cross-section airplane surface is made up of dielectric materials. Recently wideband slotted BA dipole form is reported in [14], and it does not employ any ground plane. However, in contrast to the conventional monopole blade antenna, this antenna requires more implementation area and also does not support an aerodynamic profile.

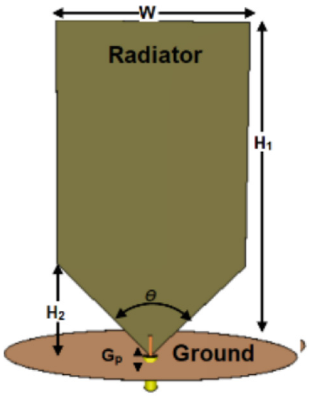
In this paper, a detailed analysis of a BA with an oblique edge and compact ground size, covering 0.90–2.0 GHz, has been introduced. This paper is arranged as: Sect. 1 mentions a brief introduction to the monopole BA for airborne applications, and Sect. 2 describes the design method of the BA. Sect. 3 consists of the various simulation results. Finally, the paper is concluded in Sect. 4. The antenna is simulated for a 2 mm thick aluminum sheet. The final optimized dimensions of this BA is 100×56 mm^2 with an elliptic ground plane with major and minor diameter dimensions of 85 mm and 30 mm, respectively.

2 Antenna Design with Parametric Study

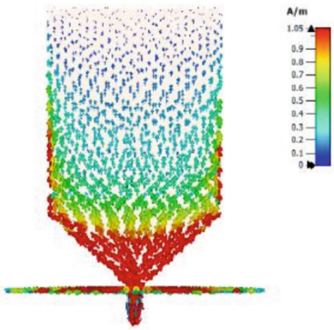
The physical outline of the antenna with current distribution are shown in Fig. 1. It is well identified fact that in the BA the current distribution is intense at the border of the monopolar patch (Fig. 1 (b)).

Therefore, the resonant frequency of the antenna can be tuned by tuning the height of the BA. So, H1 decides the lower resonating frequency (f_{01}). The effect on the S-parameter for different values of H1 is plotted in Fig. 2. This figure clearly indicates a lowering of f_{01} with the increment in the value of this parameter. Figure 3 shows the *S*-parameter magnitude (dB) versus frequency for the swept θ. The result indicates that for $\theta = 80^0$, a good impedance match is found for f_{02}. Parametric analysis has been done to attain broader bandwidth with a good impedance match over the entire band.

However, $\theta = 90^0$ has been chosen for covering the entire band with a minimum reflection of -10 dB at least. Figure 4 shows the *S*-parameter magnitude (dB) versus frequency for the swept *W*. The result indicates that as we increase the value of the W



(a)



(b)

Fig. 1. Monopole BA: (a) physical geometry outline (b) surface current distribution.

there will be hardly any change in the resonating frequency rather than getting a good match @ f_{02}. However, due to fabrication constraints, this parameter is selected to be 2 mm.

The effect of different design parameters along with the final optimized value (for H1 = 42 mm and elliptic ground plane with major and minor diameters 85 mm and 30 mm, respectively) of the antenna parameter is listed in Table 1.

Final optimized *S*-parameter is shown by blue line curve in Fig. 5 of the BA with different value of *Gp*. Further, the VSWR and the smith chart plot of the input impedance of the final design are shown in the Fig. 6.

Figure 6 (b) illustrates that in the frequency range where the current path length becomes less than 0.25 λ, input impedance becomes capacitive. The radiation pattern at $\Phi = 0^0$ and 90^0 plane are plotted Fig. 7. The gain pattern characteristics for different frequency are listed in Table 2.

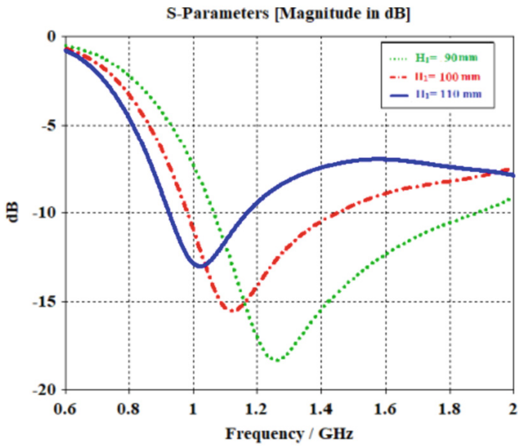


Fig. 2. Scattering parameter of the BA with the variation of H_1.

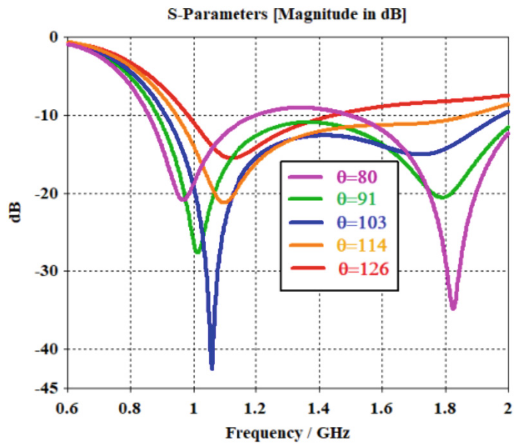


Fig. 3. *S*- parameter of the BA with the variation in oblique angle.

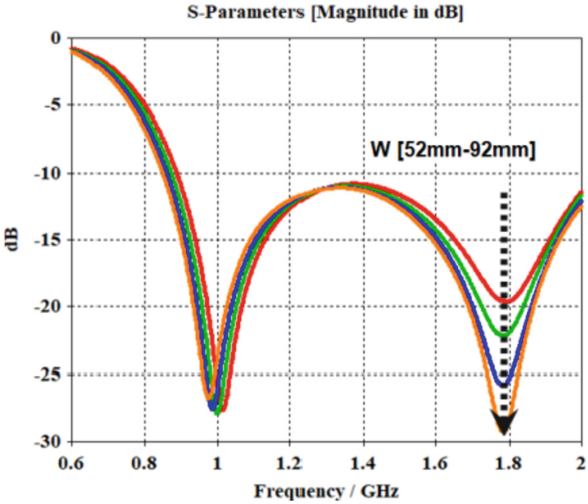


Fig. 4. *S*-parameter of the BA with the variation of *W*.

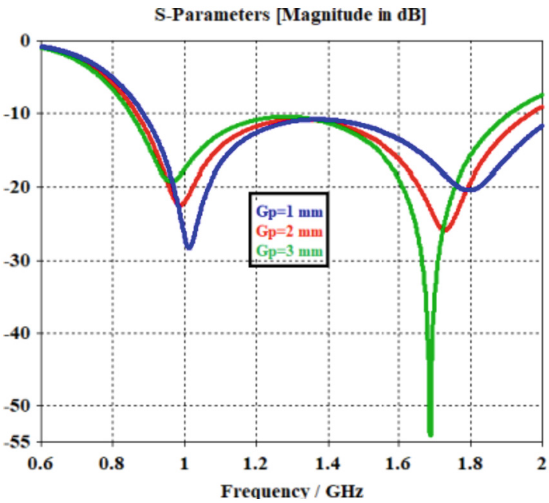
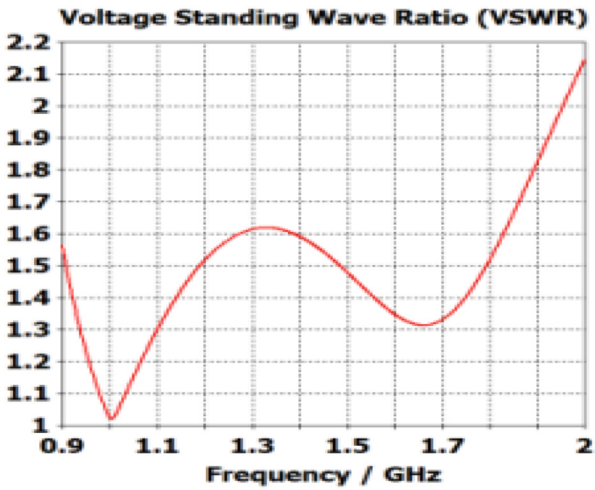
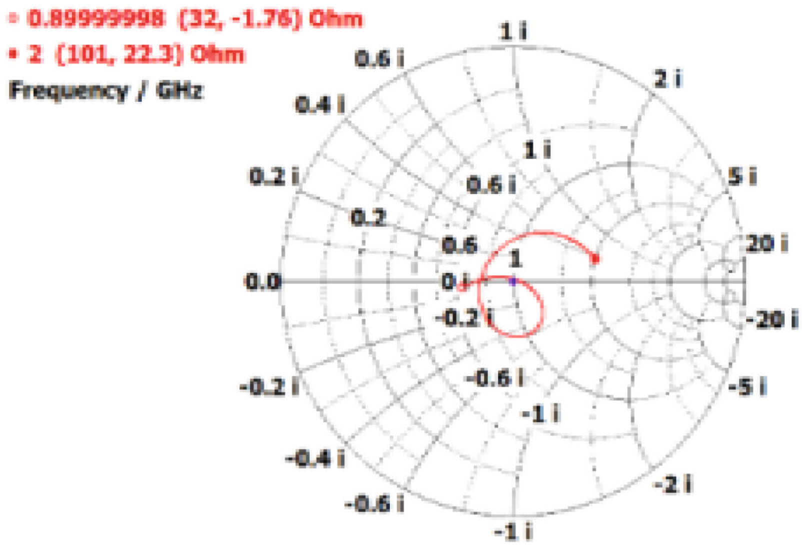


Fig. 5. *S*-parameter of the BA with the variation of G_p.



(a)



(b)

Fig. 6. Plot of (a) VSWR and (b) smith chart plot of the antenna input impedance of optimized antenna.

Table 1. Parametric Study Summary.

	H1 ↑	W ↑	θ ↓	G_p ↑
	f_{01}	Improve the matching @ f_{02}, not any change in f_{01} and f_{02}	Improve the matching @ f_{02} with a slight shift in f_{01}	Improve the matching @ f_{02} with a slight shift in f_{01} and , f_{02}
Optimized Value	100 mm	56 mm	90^0	2 mm

Table 2. Gain Characteristics for $\mathbf{\Phi = 0^0/90^0}$.

Frequency (GHz)	Main Lobe Direction (degree)	Main Lobe Magnitude (dBi)	3 dB Angular width	Frequency (GHz)
1	83/83	1.71/2.37	86.5/81	83/83
1.3	70/74	1.64/2.82	76.6/72	1.3
1.6	58/64	2.61/4.01	62.5/61.3	1.6
1.9	50/58	3.18/4.55	53.4/53	1.9

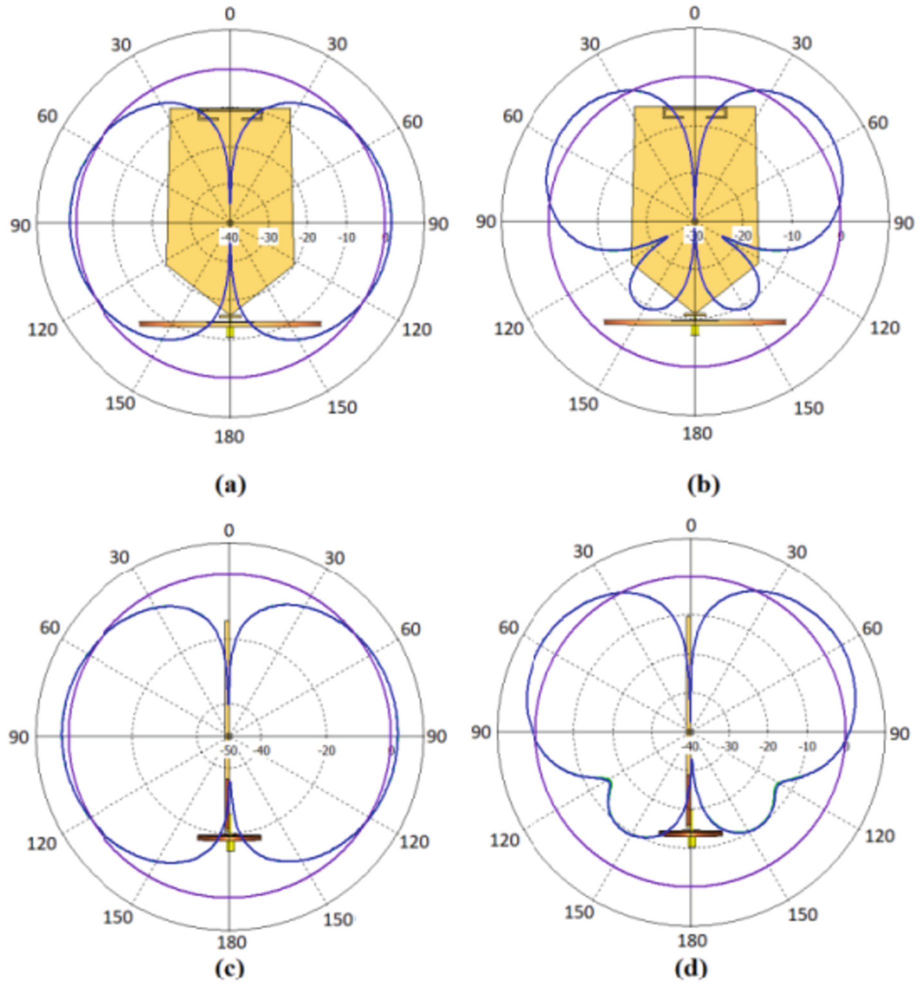


Fig. 7. Polar plot of radiation characteristic, (a) 0.9 GHz, $\Phi = 0^0$, (b) 1.9 GHz, $\Phi = 0^\circ$, (c) 900 MHz, $\Phi = 90^\circ$, (d) 1.9 GHz, $\Phi = 90^\circ$.

3 Conclusion

A wideband monopole BA for UHF band application (0.9–2.0 GHz) has been designed. The effect of various design parameters have been studied and illustrated to design an optimized BA. The simulation results show VSWR <2.2 over the entire bandwidth. An omnidirectional radiation pattern with a maximum gain of 3.18 dBi at 1.9 GHz is achieved. This antenna can be used for aerospace application.

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