

Miniaturized Ultra-Wide Band Antennas for UAV Applications

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5 Abstract.

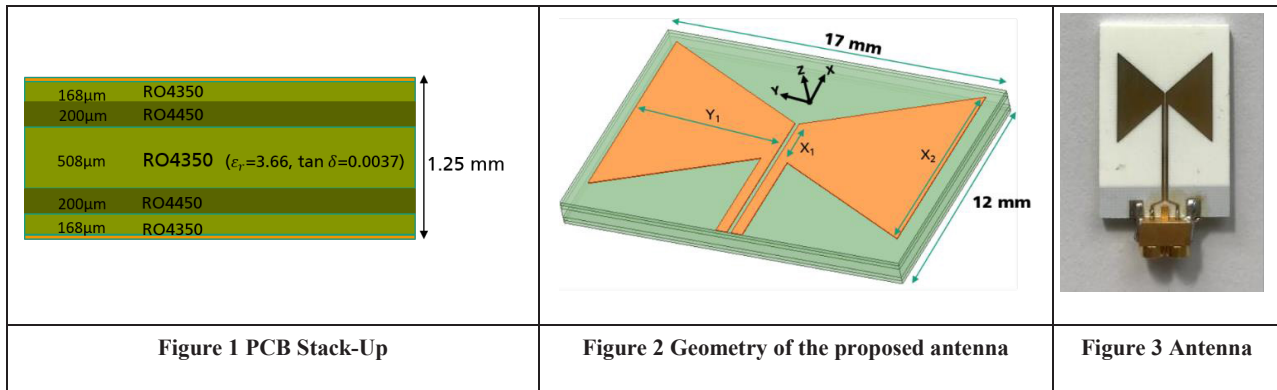
This paper proposed a differential bowtie antenna which can be directly integrated to a system-on-chip (SoC) ultra-wideband pulse radar module which will be used in sense and avoid applications for drones. Proposed antenna is very compact with a total size of 17 x 12 x 1.25 mm. Reflection coefficient of the antenna, $|S_{11}|$, is less than -10dB between 6.1 GHz and 10 GHz, corresponds to percentage bandwidth of 48%. Also, it is exhibiting very high radiation efficiency over the operating bandwidth. Moreover, it has very stable and uniform radiation pattern in all frequencies, which is leading good time domain behavior. This miniaturized antenna with differential feeding exhibits constant gain over the frequency bandwidth, while having broadband operation. Therefore, in this paper, a UAV antenna satisfying all of the requirements of a sense and avoid radar according to integrate to current MMICs is presented.

1. Introduction

15 Unmanned aerial vehicles (UAV) for different applications are becoming popular recently. They have many applications in areas like the toy market, filming, supply chain, surveillance systems and agriculture. Up to now, due to their advantage and features of the UWB systems, many types of UWB antennas are also exhibited [2]. Most of these presented antennas, in published papers on the subject of UWB antenna, are single-ended designs. If these single ended antennas are chosen to be used as a part of a differential RF circuit, baluns are needed in front of the antenna feed, to convert the signal to differential signal. With the addition of the balun, general size and cost of the circuit increases, also overall efficiency of the system drops. A bowtie type antenna is proposed, to address all the requirements of UAV sensors. Various examples of microstrip bowtie antennas can be seen in literature for this type of antennas [3]. Another essential aspect of the antenna is related to its radiation pattern, because a UWB module should be able to detect the approaching obstacles or objects in all directions. For this reason, isotropic radiation pattern is demanded from antennas for this drone sense and avoid system. Best practical candidate for this type of necessity is the omnidirectional antennas. This antenna is directly suitable to be integrated in a RF front-end of a MMIC while exhibiting very compact size, constant stable gain, and broadband features. Firstly, the geometry of the proposed antenna is given very clearly. Also, parametric analysis of the dimensions is analyzed. Later, a feeding structure to measure the antenna is shown. Finally, radiation characteristics and reflection coefficient of the antenna are plotted.

2. Differentially Fed Bowtie Antennas

30 The PCB stack-up is chosen according to the RF front-end design of the UWB module. The stack-up consists of Rogers RO4350 PCB core substrate and RO4450 prepreg substrate (cf. Figure 1). Rogers RO4350 laminate has a dielectric constant of 3.66, and a loss tangent of 0.0037, and Rogers RO4450 laminate has a dielectric constant of 3.52, and a loss tangent of 0.004. Also, width of the differential lines is $s = 0.55$ mm, and the gap between them is $g = 0.2$ mm.



Antenna design consists of a differential feeding line and a bowtie structure (cf. Figure 2). The geometry is given in Table 1.

35 **Table 1 Antenna Dimensions**

Parameter	W	L	s	g	x1	x2	y1
Value(mm)	17	12	0.55	0.2	1.8	9.8	15.5

3. Antenna Characterization

By increasing the length of x_1 matching can be increased at the center of the operating frequency band, however with the increase of the x_1 lower cut-off frequency increase and higher cut-off frequency is decreasing and reducing the bandwidth of the antenna (cf. Figure 4). Effect of the x_2 is very limited on impedance matching but by increasing x_2 the lower cut-off frequency can be decreased. Main effect of the x_2 parameter would be on the efficiency of the antenna by increasing or decreasing the total aperture of the antenna (cf. Figure 5). Finally, width of the bowtie y_1 parameter has been investigated (cf. Figure 6). Lower and higher cut-off frequencies of the operating bandwidth of the antenna directly related to the y_1 parameter. As the width of the antenna decreases operating band also slides to the higher frequencies. The radiation patterns have been simulated at three frequencies 6, 7, 8 GHz. Simulated patterns certainly show that the antenna has a flat gain in the all operating bandwidth in Figure 7. It is very clear that the antenna has an isotropic radiation pattern on the XZ plane according to the coordinate system in the Figure 2. Also, in the YZ plane a bit more bidirectional features can be observed on the radiation pattern of the antenna. Stability of the radiation patterns in all operating bandwidth is one finest characteristic of the antenna especially for UWB applications. Radiation efficiency of the antenna is simulated as 98% over the operating bandwidth.

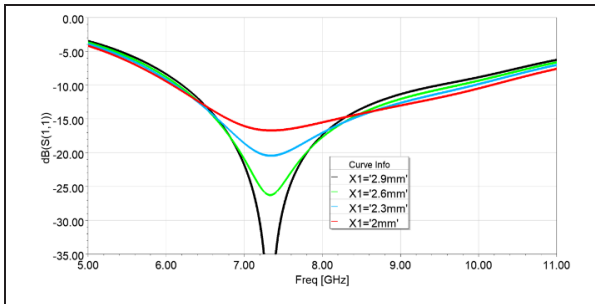


Figure 4 Reflection coefficient with respect to x_1

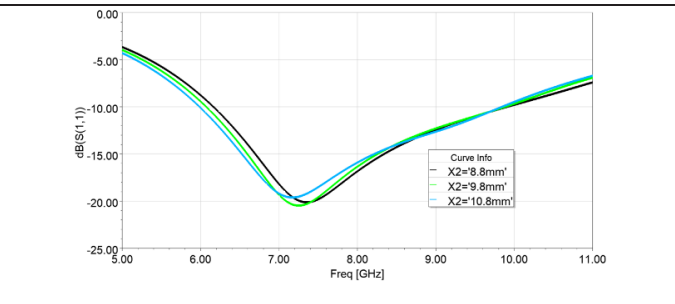


Figure 5 Reflection coefficient with respect to x_2

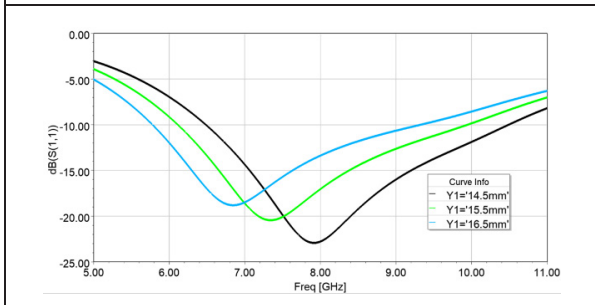


Figure 6 Reflection coefficient with respect to y_1

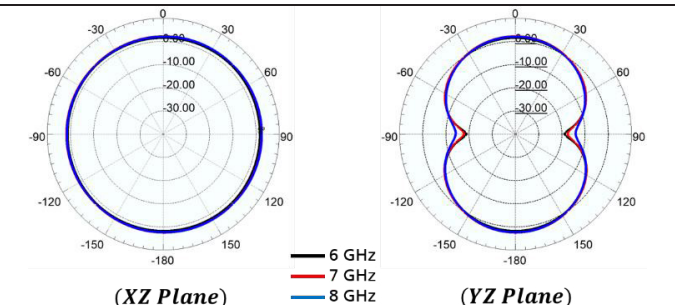


Figure 7 Radiation patterns at 6, 7 and 8 GHz

Measurements

50 The reflection coefficient measurement is plotted by three different ways. Firstly, antenna is measured by using the 2-port of the Vector Network Analyzer (VNA) and the data is converted to 100Ω differential. Secondly, by using the balun direct differential measurement is obtained with VNA. Reflection coefficient results obtained by these methods and with simulation are plotted in Figure 8.

The antenna is measured by using the 2-port of the Vector Network Analyzer (VNA) and the data is converted to 100Ω differential. Secondly, by using the balun direct differential measurement is obtained with VNA. And lastly, reflection coefficient results are improved by addition of second calibration including the feeding structure. In this method, short, open, load and thru (SOLT) structures are used. This calibration components are shown **Fehler! Verweisquelle konnte nicht gefunden werden..** Reflection coefficient results obtained by these methods and with simulation are plotted in Figure 8.

Also, radiation pattern of the antenna is measured in the anechoic chamber with the help of balun. Radiation patterns are plotted in Figure 9. It is seen that with the addition of the connector and the feeding structure, radiation of the antenna leans towards to the top of the antenna or in the direction opposite of the connector.

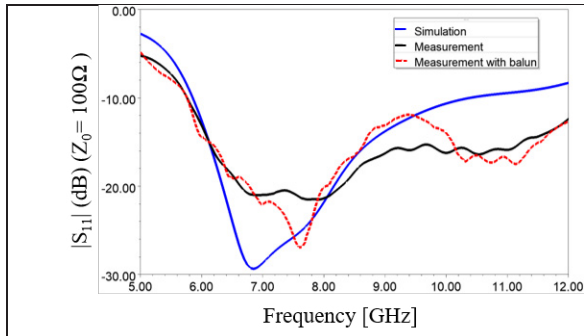


Figure 8 Simulation and measurement results

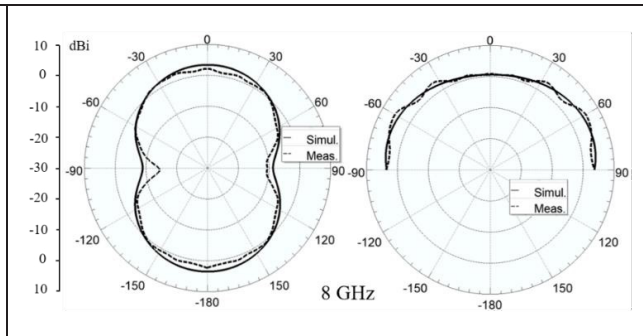


Figure 9 Radiation patterns at 7 GHz

4. Conclusion

Depicted UWB antenna is very compact with total dimensions of 17 x 12 x 1.25 mm. Its natural differential structure eliminates the need of the balun to integrate a differential circuit. It has a very uniform radiation pattern with high radiation efficiency characteristics in all operating bandwidth which is leading good time domain behavior. Reflection coefficient of the antenna, $|S_{11}|$, is less than -10dB between 6.1 GHz and 10 GHz, corresponding to a percentage bandwidth of 48%. Due to the general properties of the antenna, it is a very pleasant candidate for UWB pulse radar systems which are using differential MMICs. Also, compared with the antennas on the market **Fehler! Verweisquelle konnte nicht gefunden werden.** It is seen that this antenna shows all the necessary characteristics needed for sense and avoid radar of an UAV.

70 5. Acknowledgement

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6. References

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