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A Low-Profile Dielectric Waveguide Altimeter Antenna

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Abstract

In this paper, design and implementation of a compact, low-profile and low-cost altimeter antenna is presented. A top-open dielectric waveguide is utilized to obtain a radiation pattern that illuminates from 20 to 70 degrees on the elevation plane. The proposed antenna pair can be used efficiently as a radar altimeter antenna in the course of landing. The antenna can cope with high skin temperatures, especially in supersonic flights because a high-temperature resistant dielectric material is used. Satisfactory results are obtained from EM simulations and antenna measurements.

1 Introduction

There is a growing demand for compact and low profile antennas in military, aircraft and spacecraft applications. Especially in radar altimeters, a pair of transmit and receive antenna is utilized to measure the altitude over the terrain. Usually the allocated space is highly limited due to the surrounding electronic components and RF systems. Another challenge for the implementation of aircraft antennas is the skin temperature of the aircraft during the flight. Although high temperature resistant radome grades are available in the market, the sudden rise of the skin temperature in supersonic flights can degrade the RF performance dramatically. Thermal insulators are usually utilized in such applications at the cost of antenna loss in a certain degree. Ceramic PCB antennas can also be developed to cope with the high temperatures; however, further challenges arise due to high values of relative permittivity. Recently, a dielectric filled top-open waveguide antenna is introduced [1]. In that work, the waveguide is filled with material of high dielectric constant. By inserting the inner conductor of the coaxial cable into the dielectric material, a slow wave propagation is achieved inside the waveguide. The height of the waveguide is decreased gradually in the direction of the propagation and an end-fire radiation is observed.

In this work, an altimeter antenna is designed and implemented to utilize in the course of landing of high-speed systems such as jet aircrafts and missiles. Similar to [1], a dielectric waveguide antenna is developed at 10 GHz by gradually decreasing its height and removing the top metal surface. Since the landing angle can vary according to operator's choice, the antenna is designed to radiate from 20 to 70 degrees in the elevation plane. Ketron-1000-Peek [2] is chosen for the dielectric filling. Besides having a very low dielectric constant of $\varepsilon_r = 3.2$, it is resistant up to 250°C. Change in the electrical properties with respect to the temperature is also negligible at our operating frequency.

The organization of this paper is as follows: Section II briefly gives design and implementation aspects of the proposed altimeter antenna. Section III demonstrates the electrical characteristics and the radiation performance of the antenna. Section IV draws the conclusion.

2 Design and Implementation Aspects

The cross section of the dielectric waveguide antenna is given in Fig. 1. EM simulations are carried out using CST Studio Suite and following parameters are determined: h_1=0.5 mm, h_2=1.55 mm, h_3=6.5 mm h_4=1.3 mm, h_5=5.2 mm, d_1=4.8 mm, d_2=12 mm, d_3=3.25 mm and d_4=3.9 mm. It is also possible to work at lower or higher frequencies by scaling these dimensions. It is observed that using dielectrics with higher dielectric constant would cause narrower bandwidth. Beside this, while keeping antenna dimensions same, increasing the dielectric constant of the material would shift the frequency band to lower frequencies.

Since the starting point of this work is to design an altimeter radar antenna, a pair of transmitting and receiving antennas is needed. The proposed pair of the antennas before being assembled is depicted in Fig 2. To achieve low mutual coupling, antennas are located 12.5 cm apart. The ground case is made of aluminum. Both dielectric and conducting parts are processed in CNC machine tools. The picture of the end product is given in Fig 3.

3 Results

The antenna pair is fed through 50 Ω SMA-type connectors. In the two-port system, the first port can be regarded as the input port of the transmit antenna. Similarly, the second port is the input port of the receiver antenna. The S-parameters are measured via VNA and the results are given in Fig. 4. A wide-band behavior can be observed as the return loss is below -10 dB throughout most of the observed

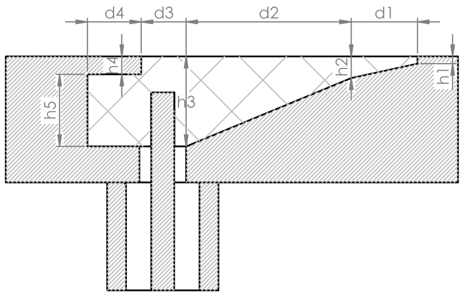


Figure 1. The cross section of proposed antenna.

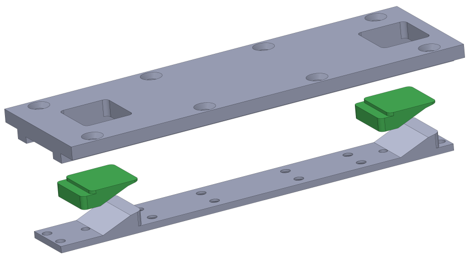


Figure 2. The drawing of the produced antenna pair before being assembled.

frequency band. Mutual coupling between two antennas is about -40 dB, which is highly desired especially in radar applications.

The gain distribution in 3-D space for the TX antenna is simulated and depicted in Fig. 5. As seen from the figure, the antenna radiates about 20 to 70 degrees on the elevation plane. As the antenna is mounted on the bottom surface of a jet aircraft or a missile, the altimeter radar system can transmit and receive data for any landing angle to determine the attained altitude. The radiation performance of the produced antenna is also measured in anechoic chamber. For a better illustration of the radiation pattern, both CST simulation results and measurement results are plotted on 2-D $(\theta - \phi)$ coordinate system. At the same time, the logarithmic range is set to 3 dB to visualize radiations only equal or larger than the half of the maximum radiated power. As seen from Fig. 6, the measured pattern is in accordance with the simulation result. The black rectangle on the figures indicate the area that covers from $\theta = 20°$ to $\theta = 70°$ and from $\phi = 45°$ to $\phi = 135°$. On both results, the illumination is focused on this area and the maximum gain is around 7.5 dBi. During the design process, it is also observed that when the antenna is mounted on a long metal surface, the gain slightly decreases and thus the illuminated area becomes larger. Further measurements will be carried out by mounting the antenna conformally on a large metal body. The antenna performance will also be tested under high temperatures, hence more results will be presented at the conference.

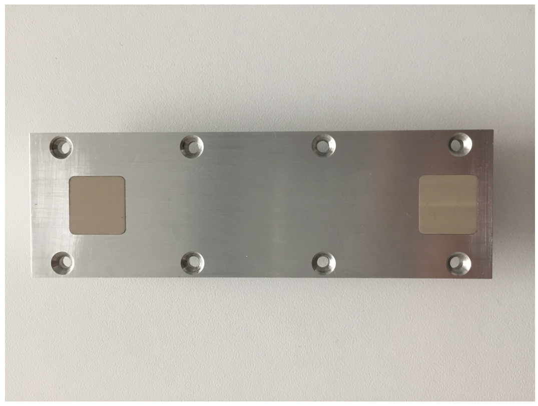


Figure 3. The picture of the produced antenna.

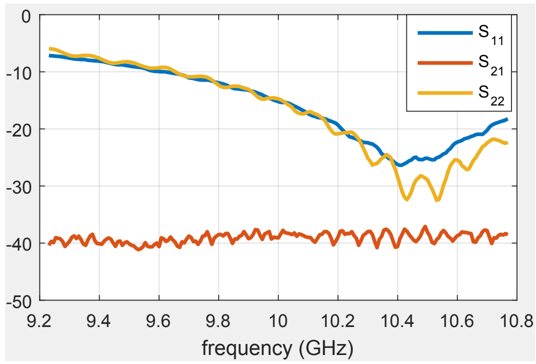


Figure 4. Measured S-parameters of the produced antenna pair.

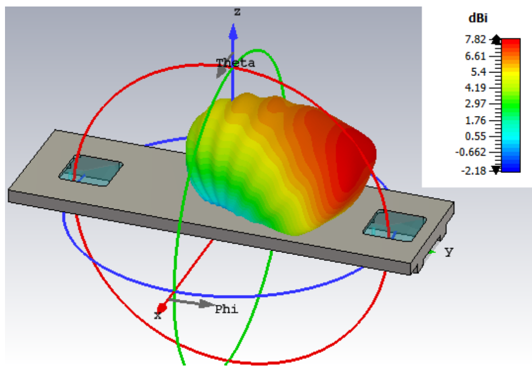
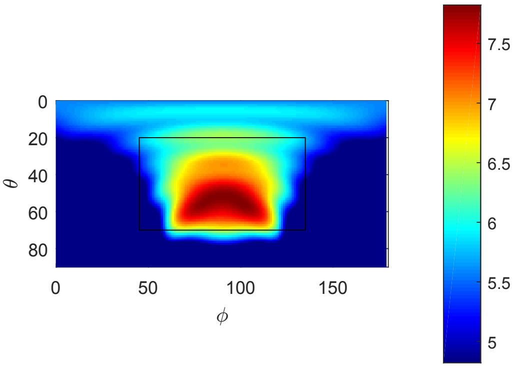


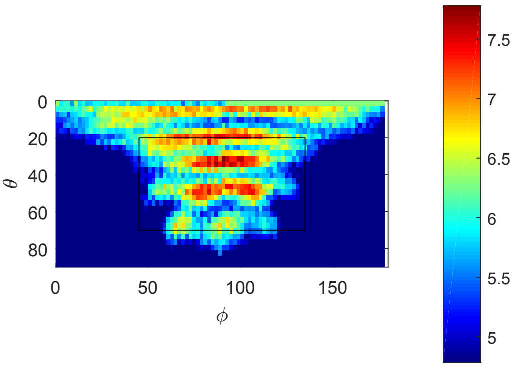
Figure 5. Simulated gain distribution of the TX antenna in 3-D space at 10 GHz.

4 Conclusion

In this paper, we design and implement a radar altimeter antenna pair. The performance of the antenna is verified by taking measurements in anechoic chamber. In order to construct a compact and low-profile antenna, a dielectric waveguide is converted into an antenna by gradually decreasing its height and removing the top ground. By producing the antenna with slight bending, it can be mounted conformally on cylindrical surfaces. This antenna can be very useful in the calculation of the altitude for the airborne structure in the course of landing. Since proposed structure



(a)



(b)

Figure 6. Gain distribution of the TX antenna at 10 GHz. (a) CST simulation result. (b) Anechoic chamber result.

is resistant to high temperatures, it can also be used on supersonic flights where skin temperature levels are very high. Because the outer surface of the antenna consists of a metal surface and a dielectric with good wear, abrasion and heat resistance, no need for a radome on the top of the antenna. As a result, feasible, efficient and low-cost antenna solution for an altimeter radar application is performed.

References

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[2] *Ketron 1000 PEEK*, Mitsubishi Chemical Advanced Materials, March 2019. [Online]. Available: https://www.mcam.com/fileadmin/quadrant/documents/QEPP/EU/Product_Data_Sheets_PDF/AEP/Ketron_1000_PEEK_PDS_E_30032019_01.pdf