Design of a Wideband Cylindrically Conformed H-Shaped Slot Antenna for Space Communication

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Abstract: A simple and compact wideband cylindrically conformed H-shaped slot antenna is presented in this paper. Proposed antenna is composed of an H-shaped slot on the ground plane which is conformed on a cylindrical surface. Different substrate materials has been analyzed and Rogers RT/duroid 5880 (Ɛ_r = 2.2) shows better results. Simulation results has been observed for different curvature of conformal antenna. The operating bandwidth of proposed conformal slot antenna exists over Ku and K bands. An impedance BW (S_11≤-10dB) of 2.75 GHz (16-18.75 GHz) and percentage BW of 15.77% is achieved. Maximum gain of 23.86 dB at θ= 51.34º at resonant frequency is observed. Radiation results has been simulated by using FEM based simulation software Ansoft HFSS Ver 13.

Index terms: H-shaped slot antenna, wideband, conformal antenna, HFSS Ver 13.

I. INTRODUCTION

Wideband conformal antenna with minimum physical protrusions are important in many radar and communication applications for meeting stringent aerodynamic and scattering requirements [1-2]. More and more conformal antennas are used in communication, radar and navigation technology. The possibilities of conforming them in a determined shape makes them attractive for aircraft, automobiles or ships, where aerodynamic may well be improved by adjusting the antennas to the contour of the vehicles. Microstrip antennas are superior to conventional antenna due to their low profile, compact size, conformability to planar and non-planar surfaces, simple and inexpensive structure, robustness, compatibility with MMIC designs [3][10][11][13]. The slot antenna fed by microstrip line is one type of microstrip antenna which has special advantages such its simple structure, less conductor loss, and better isolation between the radiating element and feeding network [14-16]. The slot antennas can also provide the merits of small size, low cost and easier integration with other circuits and conformability to a shaped surface [17]. These antennas also have some demerits like low power, low efficiency and small bandwidth [10][11]. Lots of work has been done to make these antenna suitable for wideband applications. Another significance of using a wideband antenna is the no. of antennas mounted on the surface of aircrafts or high-speed vehicles can be reduced[1].

In this paper we proposed a conform microstrip patch antenna which has a wide impedance bandwidth, compact size and thin enough to avoid extra drag. Ideally an antenna having paper thin structure would best suit for aerodynamic and mechanical structures. These antennas neither disturb the aerodynamic flow, nor it would protrude inwardly to disturb the mechanical structure of missile, aircraft or other vehicle. A planar dual band H-shaped slot antenna for WLAN is reported in [17]. Fig 1 shows the planar antenna structure. The cylindrically conformed model of above discussed planar antenna is presented in this paper with some minor modifications in the design to enhance the radiation characteristics and simplicity of the antenna. The antenna structure is simulated using FEM based software HFSS Ver 13. Simulation is done with different substrate material and different central angles, which is made by the curvature of antenna at the center of cylindrical surface, to achieve better radiation properties & wider bandwidth. Sections II will discuss about the design specifications of the proposed antenna. In section III the simulation results of planar and conformal antenna are discussed.
II. ANTENNA DESIGN

The geometry and configuration of the planar H-shaped slot antenna is shown in Fig 1. The requirement of conformal antenna, which have to be wrapped or mounted over the curved surface of aircrafts or vehicles, is the substrate height should keep as low as possible. Such antennas does not cause any extra drag and aerodynamic flow can also be maintained. In this paper we also proposed an structure with low profile and reduced antenna height. The planar structure of antenna is reported previously in [17]. With some minor modification in the antenna geometry we proposed a wideband slot antenna. Antenna height is kept constant at h=1.6mm. The proposed antenna structure is composed of an H-shaped slot on the ground plane with size of 23mm×32mm. The antenna is fed by microstrip line at its top. The total external size of H-shaped slot is W×L with the depression part’s size d×m. The antenna parameters are given in Table 1. The proposed conformal antenna is designed in two steps. In first step we analyzed the radiation characteristics of the modified planar H-shape slot antenna with different substrate material. Then we conform the antenna on the cylindrical surface of different radius. Hence simulations are done with different curvatures. Proposed conformal antenna designed in HFSS is shown below in Fig 2.

III. SIMULATION RESULTS

The performance of the proposed antenna such as impedance bandwidth, radiation pattern and gain are simulated by HFSS Ver 13.

The simulated impedance bandwidth for different substrate material and different central angle are shown in Fig 3& 4. Table 2 shows the impedance BW corresponding to different substrate material. Rogers RT/duroid 5880 (tm) shows wider bandwidth hence this material is selected for the design.
The conformal antenna is simulated for different central angle i.e. for different radius of the cylindrical surface on which the slot antenna is wrapped. Antenna with cylinder radius of 80 mm to 100 mm (i.e. central angle of 13.17º to 16.46º) has been simulated and results shown in fig 4. It can be seen from fig 4 that impedance bandwidth is approximately fixed but the return loss varies. Minimum return loss of -49 dB is achieved for 15.49º at 17.676 Ghz. Fig 5 shows comparison of RL b/w planar and conformal antenna. Here it is clear that impedance BW of both the antennas are approximately similar but a huge difference can be seen in RL. Minimum RL for planar and conformal antennas are -22dB and -49dB respectively.

<table>
<thead>
<tr>
<th>Substrate material</th>
<th>Dielectric constant ($\varepsilon_r$)</th>
<th>Impedance bandwidth (GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rogers RT/duroid 5880 (tm)</td>
<td>2.2</td>
<td>3.16</td>
</tr>
<tr>
<td>Rogers RT/duroid 6002 (tm)</td>
<td>2.94</td>
<td>3.09</td>
</tr>
<tr>
<td>Rogers RO4003(tm)</td>
<td>3.55</td>
<td>2.85</td>
</tr>
<tr>
<td>Quartz_glass</td>
<td>3.78</td>
<td>2.68</td>
</tr>
</tbody>
</table>

The simulated radiation pattern of planar and conformal antennas are shown in fig.6. Radiation patterns are simulated in azimuth plane and elevation plane at resonant frequency 17.676 Ghz. Generally slot antennas are bidirectional radiators i.e. they radiates both side of the slot. But here it can be seen from fig 6 that maximum energy radiates in front direction of slot. So the radiation pattern of proposed antenna unidirectional.
IV. CONCLUSION

A wideband cylindrically conformed H-shaped slot antenna is presented in this paper. Antenna design is simple, compact and applicable. Impedance bandwidth of 2.75 Ghz (16-18.75 Ghz) is achieved with minimum RL of -49 dB. This antenna shows wideband characteristics and unidirectional radiation patterns with low RCS. This antenna can be easily mounted on curved surface of aircrafts, missiles and other vehicle. Overall, it can be concluded that this type of antenna is excellent candidate for various wideband radar and space applications.

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