# Design of a Low-Profile Dual-Band SIW-based H-Plane Horn Antenna

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***Abstract*—This paper presents the design of a low-profile dual-band substrate integrated waveguide (SIW) based H-plane horn antenna with microstrip feeding. The dual band is generated by implementing four different types (levels) of vias in the flare part of the horn. The feeding section of the antenna employs three quarter-wave transformers to improve the impedance matching and bandwidth. The measured fractional bandwidths (FBWs) of 3.08 and 1.23%, the peak gains of 6.22 and 6.02 dBi, the radiation efficiencies of 89.55 and 85.24%, and cross-polarization levels more than 47.29 and 33.43 dB have been achieved at resonating frequencies of 13.63 and 14.61 GHz, respectively. The proposed antenna is designed for Ku-band applications.**

***Index Terms*—Dual-band antenna, Impedance bandwidth improvement, Low-profile antenna, Substrate integrated waveguide (SIW), Quarter-wave transformer.**

## I. Introduction

Substrate integrated waveguide (SIW)-based horn antennas are gaining attraction over traditional rectangular waveguide-based horn antennas due to their two-dimensional (2D) nature, making them easier to connect with other 2D-radio frequency (RF) components [1]. RF and antenna engineers have made continuous efforts to improve the performance of SIW-based planar horn antennas [2]. As with the rectangular horn antenna, SIW provides an inadequate impedance mismatch, low gain, and front-to-back ratio (FTBR) when substrate height is much smaller than $\lambda_0$ ($\lambda_0$ is free-space wavelength at the resonant frequency). In practice, the substrate thickness is smaller than $\lambda_0/6$ [3] or $\lambda_0/10$ [4]. Yet, a few SIW-based H-plane horn antennas have been designed and tested, and the methods to improve the impedance matching with air, like, air-via perforated dielectric slab[5] and parallel plates [6] have been reported in the literature.

This paper presents the design of a low-profile dual-band SIW-based planar H-plane horn antenna with improved performance. The antenna is designed with three quarter-wave transformers in the feeding part to improve the impedance matching of the proposed structure. Then, for the dual-band generation, four different types (levels) of vias in the flare-part of the horn were used. The thickness of substrate used is 1.524 mm ($< 0.08\lambda_0$), which is equal to $0.069\lambda_0$ or $0.074\lambda_0$ at the first or second resonant frequencies, respectively. The antenna propagates EM waves and excites the $TE_{10}$-mode for both resonant frequencies (13.60 and 14.60 GHz). Finally, the antenna was fabricated and tested, and the results are compared with the previously published ones. The proposed antenna is most suitable for Ku-band applications.

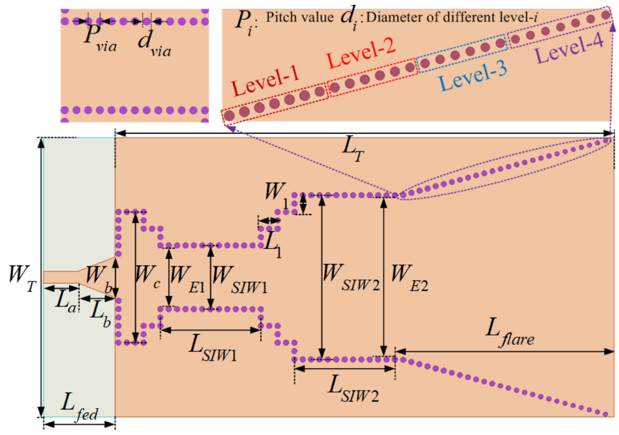
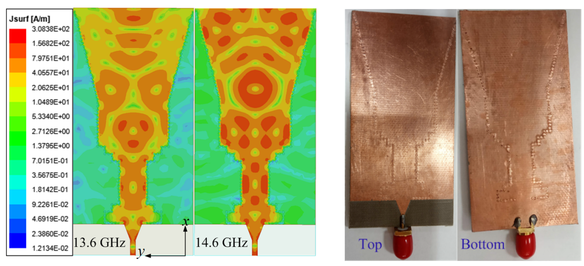



Fig. 1. Structure and dimensions of the proposed antenna.

## II. Antenna Structure and Dimensions

Fig. 1 shows the top, enlarged flare part (top right corner) and enlarged feeding SIW part (top left corner) views of the antenna. Two waveguide sections with dimensions $L_{SIW1} \times W_{SIW1}$ ($14.4 \times 9.1$ $mm^2$) and $L_{SIW1} \times W_{SIW1}$ ($15.6 \times 23.5$ $mm^2$), connected via $\lambda_g/4$ ($\lambda_g$ is guided wavelength) transformer $(L_1, W_1)$=(3.2, 3.2 mm) are used for generating the dominant mode ($TE_{10}$). Where the $L_1$ and $W_1$ is the length and width of the $\lambda_g/4$ transformers. Two other $\lambda_g/4$ transformers in cascade ($W_b$, $L_b$, and $W_c$) are implemented in the feeding part. These transformers are improving matching between the microstrip feed and antenna. The antenna is designed for Ku-band (12-18 GHz). To generate the dual band, four different types (levels) of




(a) (b)

Fig. 2. Surface current distribution at two resonant frequencies (13.6 and 14.6 GHz) (a) and fabricated antenna prototype (b).

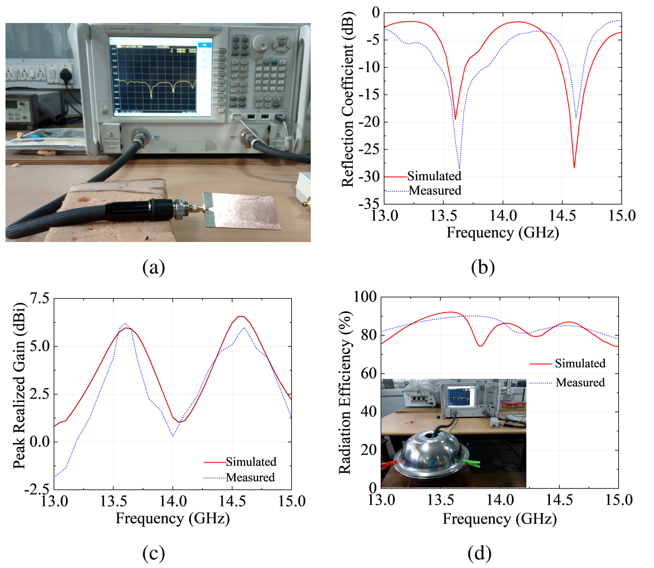



Fig. 3. VNA test setup, simulated and experimental results of proposed antenna: (a) Experimental setup, (b) Reflection coefficient, (c) Peak realized gain, and (d) Radiation efficiency measurement.

metallic vias of a single row are used, as shown in Fig. 1 (top right corner). The diameters of vias are $d_i$ ($i = 1, 2, 3, 4$) for the different levels, the pitches $P_i$ are also different. These ($P_i, d_i$) are (1.14, 0.75 mm), (1.06, 0.7 mm), (1.0, 0.6 mm), (0.92, 0.6 mm) for the levels1, 2, 3 and 4, respectively. The flare angle of the metallic rows is about $35^0$. The mode of propagation in the SIW cavity is $TE_{10}$ at both the resonant frequencies: 13.60 and 14.60 GHz. If the length of each $\lambda_g/4$ transformer is $L_1$ (3.2 mm), this is equal to $0.25\lambda_g$ and $0.27\lambda_g$ at 13.60 and 14.60 GHz resonant frequencies, respectively. Other antenna dimensions are: $d_{via} = 0.8$, $P_{via} = 1.2$, $L_T = 71.5$ $W_T = 40$, $W_b = 5.8$, $L_a = 5.0$, $L_b = 5.26$, $W_C = 18.7$, $L_{feed} = 10.26$, $L_{flare} = 30.2$, $W_{SIW1} = 9.1$, $W_{SIW2} = 23.5$, $W_{E1} = 8.53$, $W_{E2} = 22.92$, $L_{SIW1} = 14.4$, $L_{SIW2} = 15.6$, $W_1 = 3.2$, $L_1 = 3.2$, $h = 1.524$; unit: millimeters. The substrate thickness is 1.524 mm ($< 0.1\lambda_0$), which are $0.069\lambda_0$ and $0.074\lambda_0$ at 13.6 and 14.6 GHz, respectively. The antenna is designed using RO4232 substrate ($\varepsilon_r = 3.2$ and dissipation factor=0.0018), and simulated with EM software HFSS ver. 2020R2.

## III. Experimental Verification

Fig. 2(b) shows the top and bottom views of the fabricated antenna prototype. The measurement setup with VNA is shown in Fig. 3(a). The simulated and measured results for reflection coefficient are illustrated in Fig. 3(b). They show the measured FBW is of 3.08 and 1.23% (simulated: 1.2 and 2.05%), respectively. Fig. 3(c) depicts the measured values of peak gains at 6.22 and 6.02 dBi (simulated: 5.96 and 6.56 dBi). The radiation efficiencies are shown in Fig. 3 (d) as 89.55 and 85.24% (simulated: 92.15 and 87.1%) at resonating frequencies of 13.63 and 14.61 GHz, respectively. The measured and simulated results of the E-plane and H-plane radiation patterns are shown in Fig. 4. The measured cross-polarization levels of H-plane (CPL) are less than 47.29 and 33.43 dB at first and second resonant frequencies, respectively. One can see that the experimental and simulated

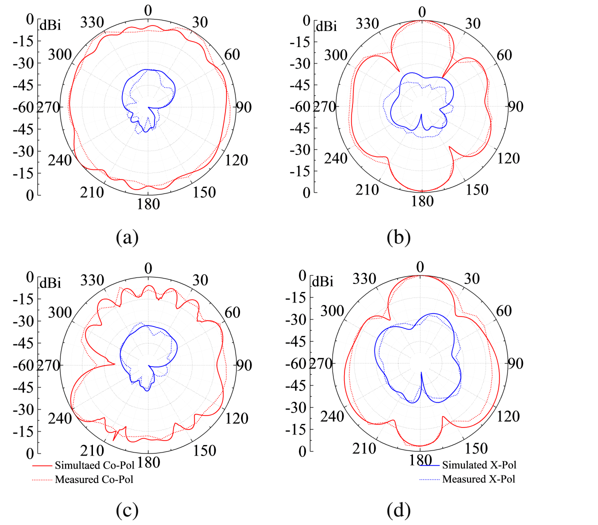



Fig. 4. Normalized radiation patterns: (a) E-plane, (b) H-plane at 13.6 GHz and (c) E-plane, (d) H-plane at 14.6 GHz.

Table I
Comparison of Competitive Proposed Antenna

| Ref. | Thickness, $h$ ($\lambda_0$) | Improving Technologies | BW(%) |
|---|---|---|---|
| [3] | 0.092 | Modified flare walls and arc-shaped-grated transition | 25.5 |
| [4] | 0.333 | Metallised via holes | 1.3 |
| **This work** | **0.069/0.074** | **stepped quarter-wave transformer** | **3.08/1.23** |

values of the antenna characteristics and parameters are in good agreement. Table I gives a comparison of the present and the previously reported results.

## IV. Conclusion

In this work, a low profile ($< 0.1\lambda_0$) and dual-band SIW-based H-plane horn antenna is presented. The measured FBW of 3.08 and 1.23%, peak gain of 6.22 and 6.02 dBi, radiation efficiency of 89.55 and 85.24%, and cross polarization level more than 47.29 and 33.43 dB at the resonating frequencies of 13.63 and 14.61 GHz, respectively, are obtained. The designed antenna is suitable for Ku-band applications.

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