

CPW-fed slot bow-tie antenna at 90 GHz for a mm-wave detector matrix

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Abstract—In this work we investigate a slot bow-tie antenna fabricated using wet-etching technique on a 5mil laminate having a low dielectric constant ($\epsilon_r = 2.2$). The planer antenna is aiming to operate, linearly polarized, in the range of 85-95 GHz. The return-loss measurements show acceptable agreement with FEM simulations. The simulated radiation patterns and Co/Cross polar patterns are also presented.

I. INTRODUCTION

The demand for easy fabrication of antennas at millimeter wave frequencies is growing due to various applications that are emerging in this frequency range. In this paper we present a Slot bow-tie antenna fabricated on Duroid using a single metal layer. A similar topology has been reported in [1] and [2], however due to the large increase of operating frequency (an order of magnitude), one has to compensate for fabrication effects (i.e. under-etching in lithography methods) throughout the design process.

II. ANTENNA DESIGN CRITERIA

The considered antenna array would be used for a wideband mm-wave imaging detector and was intended to cover the frequency range of 85-95 GHz. This range is not fully used by the system but the wideband design has been chosen to compensate for fabrication inaccuracies. The term “array” here refers to a matrix of antennas that operate independently and require a low cross-coupling between neighboring antenna cells. The system only utilizes a single (vertical) polarization. Since the system would be used to image humans, the horizontal angle of view has more flexibility compared to the vertical angle of view. Therefore the antenna front radiation pattern should cover as much as possible in the vertical plane. Simplicity and the possibility to easily integrate with active and passive detector elements is another requirement.

III. ANTENNA SELECTION AND DESIGN

A planar structure was chosen to facilitate the integration of the antenna with passive or active detector elements (e.g., the flip-chip process). Due to size requirements and alignment issues between different metal layers, a single layer approach was found to be practical for easy fabrication. The drawback would be little flexibility for the designer. Satisfying the 10% bandwidth would require a wide band structure and having only a single metal layer available for fabrication, the feed

topology would be forced to a (coplanar waveguide) CPW configuration. For this antenna design the Duroid 5880 substrate with dielectric constant equal to 2.2 has been used. It proved to be fairly acceptable for this frequency range however a detailed characterization is required to estimate the loss tangent and the true dielectric constant within the W-band. To reduce the losses a 5 mil (127 μm) substrate with the minimum available copper thickness (9 μm) is used.

The antenna center frequency proved to be very sensitive to “bow-spacing” and “bow-opening” (for definitions see Fig.1). For this reason, the CPW feed was resized to satisfy the spacing parameters which modified the port impedance to 77 Ohm. A simple transition was added at the beginning of the antenna feed to match it to 50 ohm port impedance. The fabrication (due to under etching) would create angled walls (i.e., 45° instead of 90°, see Fig. 1). The antenna design needed precise implementation of the walls constructing the CPW feed in the 3D model. This would affect the port impedance and would shift the frequency due to the effect it imposes on other sensitive parameters (i.e., “bow-spacing”). The HFSS solver has been used to model all the 3D features.

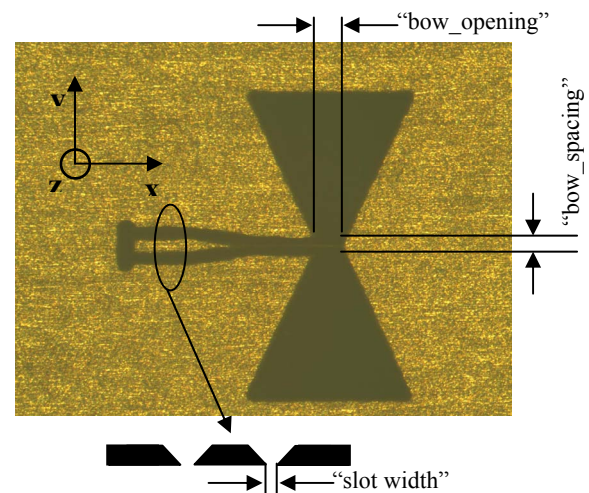


Fig.1 Antenna picture with “bow-opening” & “bow-spacing” parameters.

IV. RETURN-LOSS MEASUREMENTS

The return-loss of this antenna has been measured using a VNA utilizing a GSG probe (100 μm probe pitch). To investigate the fabrication accuracy and sensitivity two similar antennas were designed. The first sample has a CPW with slot width of 20 μm and the second with a 10 μm slot width. The simulated and measured data for the two are given in Fig.2 and Fig.3. The exposure to the solvent liquid creating wider/thinner slots is not fully controlled and could affect the antenna parameters. As can be seen on the graphs, the fabrication has clearly caused a shift of the center frequency but the wideband nature of the antenna keeps it well operable at 90 GHz.

Two measurements have been carried out on these antennas: 1- while the substrate is suspended in air, ten wave lengths away from a metal plane. 2- while the substrate was fixed on a slab of Polystyrene foam. According to [3] this material exhibits electrical characteristics very similar to air even at Terahertz frequencies. There was however a slight frequency shift noticed (see Fig. 3). A measurement on the suspended substrate is practically difficult due to the relatively flexible substrate and carries the risk of damaging measurement probes.

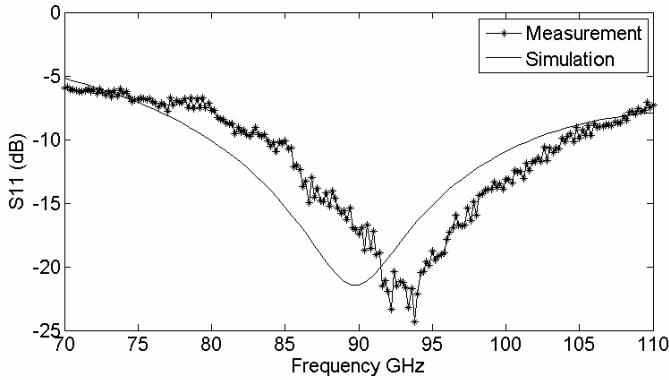


Fig.2 Simulation and measurement of Bowtie antenna with 20 μm slot width.

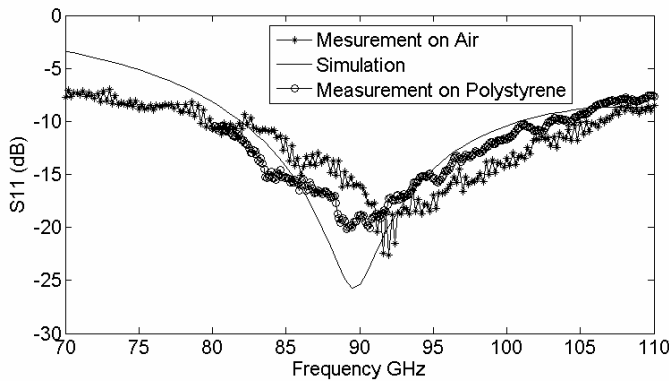


Fig.3 Simulation and measurement of Bowtie antenna with 10 μm slot width, suspended in air and on a Polystyrene slab.

V. RADIATION PATTERNS AND EFFICIENCY

The simulated radiation patterns are given in Fig. 4. In this case with a system using single polarization, the co-polar element of the electrical field is of interest; this would be E_θ in E-plane($\phi=0$) and E_ϕ in H-plane ($\phi=90$) (referring to axis definition as in Fig.1). As illustrated in both patterns of Fig. 4, the Co-Polar component is well above the Cross-Polar, this clearly indicates a linearly polarized antenna.

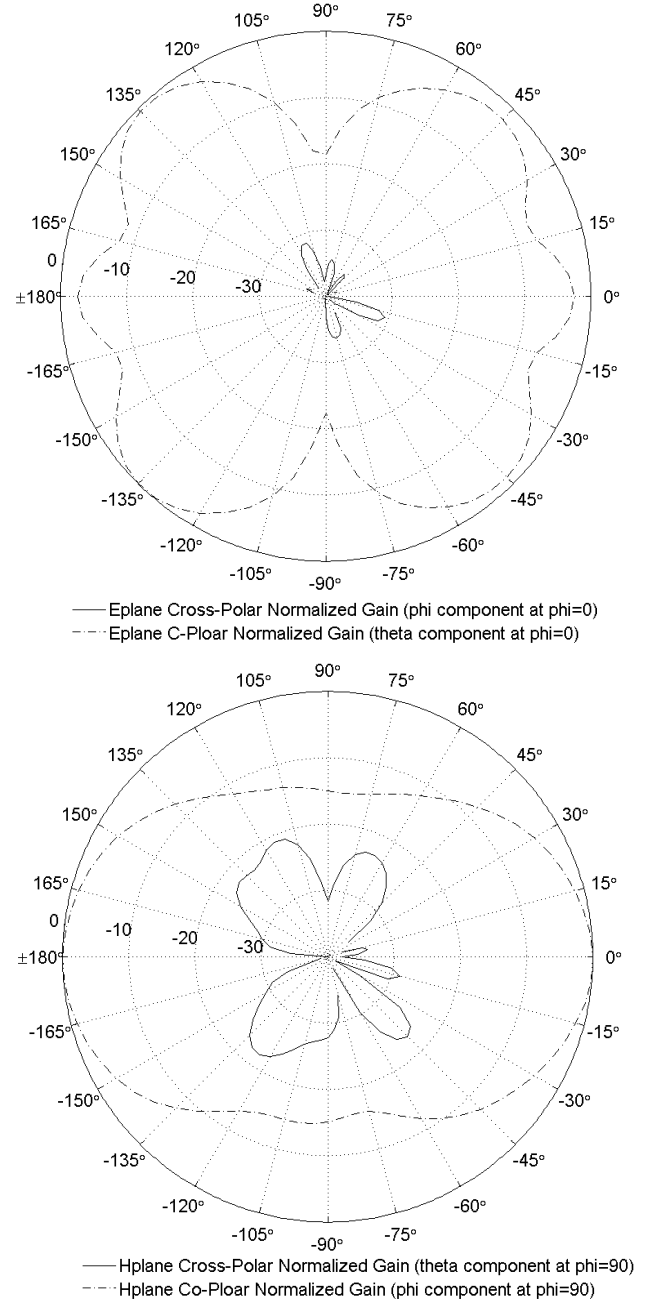


Fig.4 Simulated Co/Cross-Polar E-plane and H-plane radiation pattern at 90 GHz; refer to axis definition in Fig.1

Since only the front face of the antenna collects power and the relatively thin substrate with low dielectric constant causes

almost symmetric radiation on both sides, it is expected that the practical radiation efficiency would be less than 50%. The radiation efficiency of the antenna using only the front radiation patterns was calculated around 44%. This value excludes the mismatch losses at the input port and has been calculated using substrate dielectric constant=2.2 and loss tangent =0.001 that are not present in the data sheet of the substrate material within the W-band and have been extrapolated.

VI. CONCLUSIONS

The Slot fed bowtie antenna has been investigated and proved to be practical for imaging and wide-band communications at 90 GHz. Unlike pervious reports on this topology, employing it at the W-band with a relatively thick metal layer, requires precise 3D modeling of the metal walls.

The design can be modified to cover other ranges within the W-band.

ACKNOWLEDGMENT

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