Ultra-Wideband Millimeter-Wave Bowtie Antenna

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***Abstract*—We present an ultra-wideband antenna for mm-wave applications. The antenna consists of a bowtie patch integrated with the feeding network. The feeding network is implemented as a multilayer substrate structure. The differential excitation of the bowtie is performed in a similar way to Magneto-Electric Dipoles and Marchand baluns. The simulated antenna shows a relative bandwidth of $2.6:1$ with a reflection coefficient better than -8 dB. The radiation pattern remains fairly stable over $20-50$ GHz with a boresight directivity of $5.8-8.3$ dBi.**

***Index Terms*—Millimeter-wave, UWB antenna, Marchand balun, Magneto-Electric Dipole.**

I. Introduction

In the past few years, the ever increasing need for high data-rate communications has drawn lots of attention towards the millimeter-wave (mm-wave) frequencies due to the availability of large chunks of bandwidth [1]. The applications are many, e.g., high resolution imaging [2] and wireless communications over short distance at the V-band (60 GHz), but also over longer ranges at $20-40$ GHz, suitable for 5G wireless. [3]. In order to support multiple bands, especially for cellular applications, antennas with ultra-wide bandwidths (UWB) are preferred. Also, the antennas should be easily integrated with active and passive components as well as fabricated by simple manufacturing process.

Planar structures such as microstrip antennas are a flexible and cost-effective candidate for UWB applications. Planar dipoles and bowtie structures can be wideband [4], [5]; However, they require baluns to sustain their performance. In [6]–[8], Marchand baluns are employed to differentially feed dipole array elements and are built-in as a part of the impedance matching network. It was shown that the integration of the balun can improve the overall bandwidth, as compared to a simple differentially fed excitation. Magneto-Electric Dipoles (MEDs) are another planar designs with wide bandwidths and stable radiation patterns [9]–[11]. They use the idea of complementary antennas consisting of electric and magnetic dipoles. However, these structures have mostly been designed for lower frequency bands e.g., less than 20 GHz. In order to achieve the same performance for mm-waves, we need to comply with size restrictions dictated by the low cost manufacturing methods.

In this paper, we propose an UWB bowtie antenna for mm-wave applications. The design is comprised of a planar bowtie integrated with the feeding network. The design resembles the concept of planar dipoles integrated with a Marchand balun and MED structures. The integration of the feeding network to the bowtie has been accomplished by using multilayer PCB and via holes.

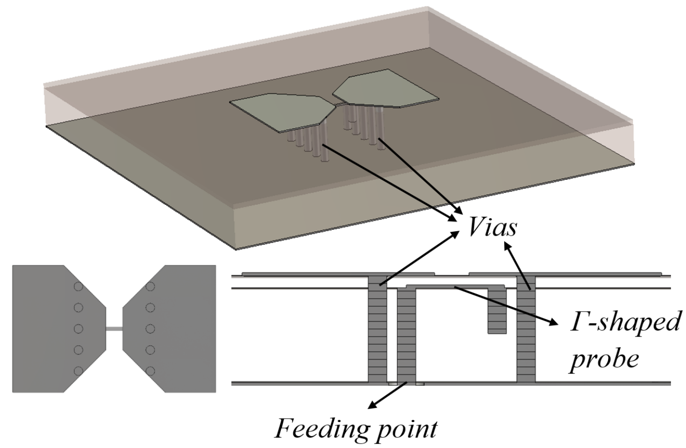

Fig. 1. The proposed antenna structure.

II. Antenna Design

Fig. 1 shows the geometry of the proposed antenna. It consists of a bowtie above a large ground plane. The ground plane helps the antenna to achieve a directional radiation pattern. A row of five vertical vias connects each petals of the bowtie to the ground plane. To excite the antenna, a Γ-shaped probe is employed, i.e., a similar method used to excite MEDs. The feeding probe has three different parts. The first vertical part is implemented by a via hole and is fed below the ground plane, through a 50Ω coaxial cable. This part, together with the row of via holes, transfers the fields to the second part of the Γ-shaped probe which is horizontally oriented. This is where the excitation of the grounded bowtie structure occurs. The length of this part and the third vertically oriented part of the probe, which acts as an open transmission line, can compensate each other to achieve a good impedance matching. One can also see the similarity of this design to the design of planar dipoles integrated with Marchand baluns.

The final structure has three layers. $RogersRT5880$ with dielectric constant of 2.2 is used as substrate. The diameter of via holes are $0.2\ mm$ to comply with manufacturing precision limitations. The total height of the antenna is $1.26\ mm$ and the size of the ground plane is $12 \times 12\ mm^2$.

III. Simulated Results

CST Microwave Studio has been used for electromagnetic simulations. The simulated reflection coefficient of three different types of excitations are compared in Fig. 2. First, we excite the bowtie by a discrete port with impedance of $150\ \Omega$. The second curve, represents the bowtie antenna excited by $150\ \Omega$ discrete port, including two rows of via holes. Finally,

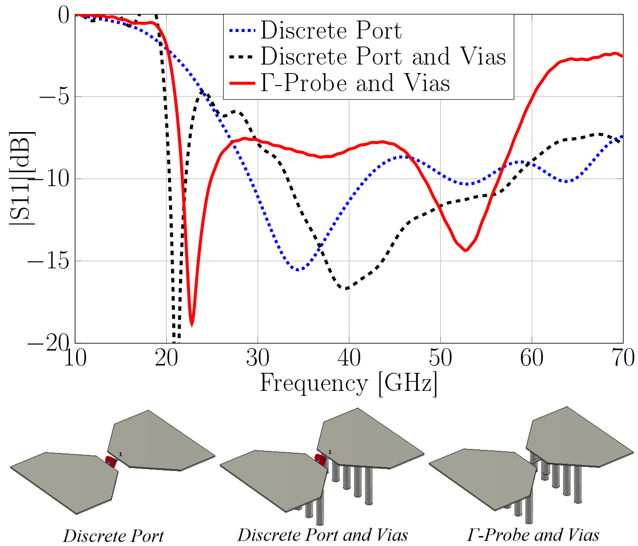

Fig. 2. The comparison of the reflection coefficient for three different excitations.

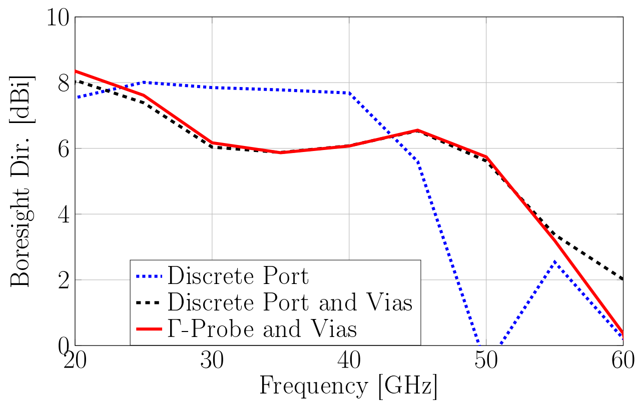

Fig. 3. The comparison of the boresight directivity for three different excitations.

we compare these two ideally excitations with a practical feeding structure, using the Γ-shaped probe. We can see that the reflection coefficient is below -8 dB over the frequency band of $22-57$ GHz.

Fig. 3 illustrates the boresight directivity of three different excitations. As can be seen, the stability of the boresight directivity can be increased by adding the rows of via holes. Also we can see that the directivity is almost the same for structures comprised of bowties and vias, when the discrete port excitation is implemented by Γ-shaped probe.

The simulated radiation patterns of the antenna in 45°-plane (D-plane) at three different frequencies are shown in Fig. 4. We see that the radiation pattern is stable over $20-50$ GHz. Also, the symmetry in co-polar and cross-polar components of the radiation pattern implies the good performance of the feeding network to excite the bowtie, differentially.

IV. Conclusion

We have presented an ultra-wideband bowtie antenna for mm-wave applications. The feeding mechanism of the pro-

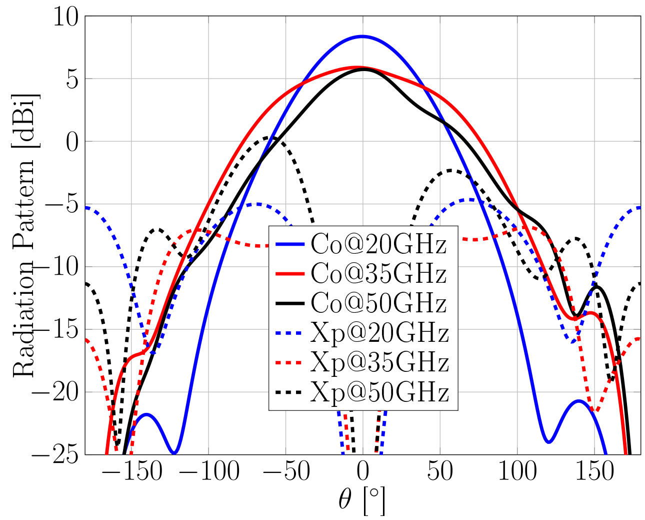

Fig. 4. The Radiation pattern of the proposed antenna in 45°-plane (D-plane), at three different frequencies of 20 GHz, 35 GHz and 50 GHz.

posed antenna is similar to MED structures, implemented by multilayer PCB and via holes. The bandwidth of $2.6:1$ was achieved in terms of reflection coefficient better than -8 dB. The radiation pattern was stable and the directivity was between $5.8-8.3$ dBi over the frequency band of $20-50$ GHz. The antenna can further be optimized to achieve better performance, considering the manufacturing limitation. It's worth to mention that the structure has the capability to be further modified as an element for wideband wide-scan arrays for mm-wave applications.

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