Wideband Sub-6 GHz Self-Grounded Bow-Tie Antenna with New Feeding Mechanism for 5G Communication Systems

Mohammad Alibakhshikenari[1], Bal Singh Virdee[2], and Ernesto Limiti[1]

[1] Electronics Engineering Department, University of Rome "Tor Vergata", Via del Politecnico 1, 00133 Roma, ITALY
[2] London Metropolitan University, Center for Communications Technology,
School of Computing and Digital Media, London N7 8DB, UK

Abstract— **This paper presents a self-grounded directional Bow-Tie antenna with a novel feed structure for sub-6 GHz applications in 5G communication systems covering 3.35-4.4. The antenna consists of two petal shaped metal structures that are interconnected to each other with a microstrip line. The petals are anchored on a common ground-plane. The feed mechanism used to excite the petals is by EM coupling from a single open-circuited microstrip line implemented behind the ground-plane. The couples EM energy is controlled via an I-shaped slot printed on the ground-plane. The proposed antenna offers good impedance matching across its operating frequency range with VSWR<2 and exhibits an average gain of 20 dBi.**

Keywords— **Bowtie antenna, feeding mechanism, self-grounded, single-polarized.**

I. Introduction

Wideband antennas are essential for modern and emerging communications, MIMO and radar (or sensor) systems. Such antennas support a large frequency range which makes them popular for developing compact multiband and multi-standard wireless systems. Wideband antennas enable mutiple applications to be integrated on a single device. Although there are numerous types of wideband antennas available today however the self-grounded bow-tie antenna offer the advantages of structural simplicity and compactness [1], [2]. These types of antennas are excited using a wideband balun [3], [4] which, however, can be challenging to design and implement in practice.

In this paper a simple solution has been devised to circumvent the issue encountered in the design of wideband balun. This is based on microstrip line coupling with the bow-tie's petals through an I-shaped slot etched in the ground-plane. The proposed technique reduces the complexity of the feed structure design and simplifies the manufacturing process. Radiation characteristics of the antenna was optimized by adjusting the geometry of two identical petals which are anchored to a common ground plane. The conceptual realization presented here is of a single-port single-polarized bow-tie antenna fed by the proposed feed mechanism which is optimized for a normal directive beam. The antenna is shown to have an excellent impedance match and a directive beam with a fractional bandwidth of 27%. The results presented reveal that each petal of the bowtie antenna has a directivity similar to that of the theoretical Huygens source, which makes it an interesting candidate achieving the best available MIMO coverage of small antennas [5].

II. Antenna Geommetry

To realise directional radiation from a bow-tie antenna its radiating structure needs to resemble the shape of an eagle's wings, as illustrated in Fig.1, where the radiating elements are connected to the ground at the outer end of the antenna. This type of configuration reduces the size of wideband antenna with minimal degradation in the operating frequency band. Fig.2 shows how the bow-tie dipole is translated to a self-grounded bow-tie antenna.

The geometry of the single-port single-polarized self-grounded bowtie antenna is shown in Fig.3. The structure is based on the designs presented in [3], [4]. The antenna is essentially constructed from two petal shaped metal structures that are interconnected to each other with a bend microstrip line. The petals are anchored on a common ground-plane. The feed mechanism proposed here to excite the petals is realised using an open-circuited microstrip line implemented on the opposite side of the ground-plane. The petals are electromagnetically coupled to the open-circuited microstrip line via an I-shaped slot printed on the ground-plane. In this way, both petals are excited equally by a single-microstrip fed line. The proposed technique gets rid of using a balun. The profile of the petals and I-shaped slot were modified to match them to the feed line to achieve optimum wideband antenna performance. The antenna is constructed on FR4 lossy dielectric substrate with thickness of 0.8 mm, dielectric constant of ε_r = 4.3, and tanδ= 0.025. The antenna design was analysed using CST Microwave Studio, which is a commercially available full-wave 3D EM software [5].

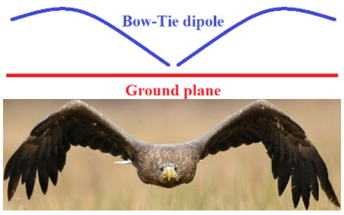

Fig.1. Eagle configuration of bow-tie.

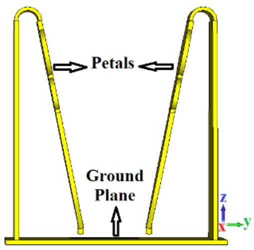

Fig. 2. Conversion from bow-tie antenna to self-grounded bow-tie antenna.

Design parameters that describe the proposed bow-tie antenna are: angle θ, the location, length and width of the microstrip line on bottom of ground-plane, the width of the ground-plane, the length and width of the microstrip line on top of the ground-plane connecting the two petals, the radius of curvature of the bowed section of the petal, the profile of the petals, the configuration, dimensions and location of the slot on the ground-plane. The dimensions and configuration of the two petals are identical.

We have applied the optimizer facility available in CST Microwave Studio to optimize the geometry of the antenna through the above defined parameters. The optimization criterion set in CST Microwave Studio was reflection-coefficient of less than -12 dB between 3.35 and 4.4 GHz. Fig.4 shows the reflection-coefficient for the proposed self-grounded bow-tie antenna with single-port. In this case the input port impedance is 50 ohm. It can be observed that in this preliminary investigation the antenna has the excellent reflection coefficient performance, which is almost below -10 dB over the band of 3.35 GHz to 4.4 GHz, which corresponds a fractional bandwidth of 27%.

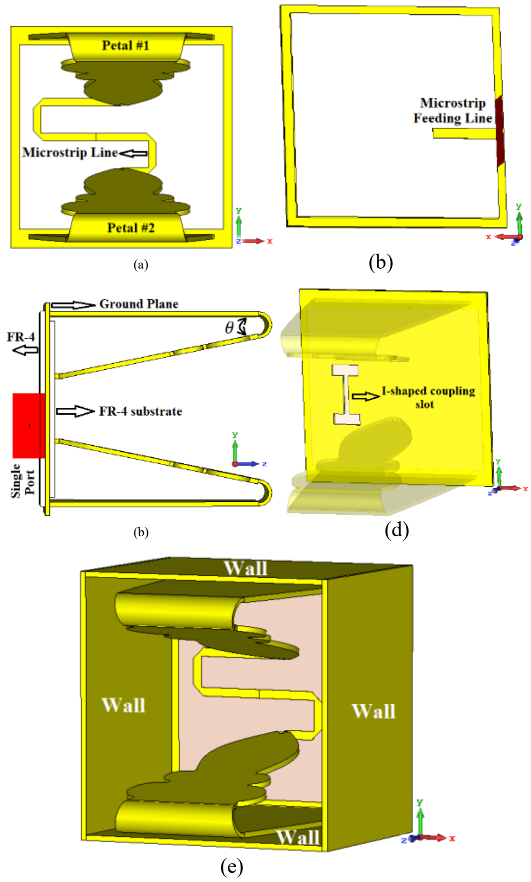

Fig.3. Proposed single-port single-polarized bow-tie antenna, a) top view, b) bottom view, c) side view, d) isometric view showing the I-shaped coupling slot etched on the ground plane, and e) whole structure enclosed by four walls.

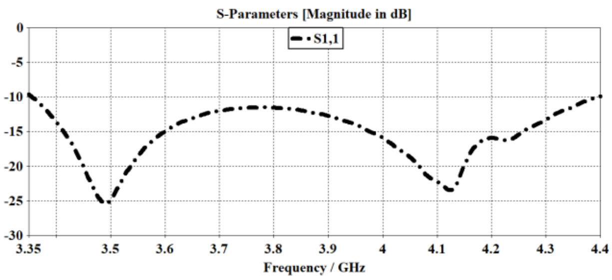

Fig.4. Reflection coefficient (S_{11}<-10) for the proposed bow-tie antenna excited using the proposed mechanism.

The proposed bow-tie antenna was used to implement 8×8 array. The co- and cross-polar radiation patterns of the array in E- and H-planes at various spot frequencies in the operating range are shown in Fig.5. The radiation characteristics show the antenna is highly directive in both planes over 3.35–4.4 GHz. It is also noticed that, the radiation patterns are symmetrical. The radiation gain is about 20 dBi over the frequency band. The maximum beam directions are along the normal of the antenna ground-plane at all frequency points.

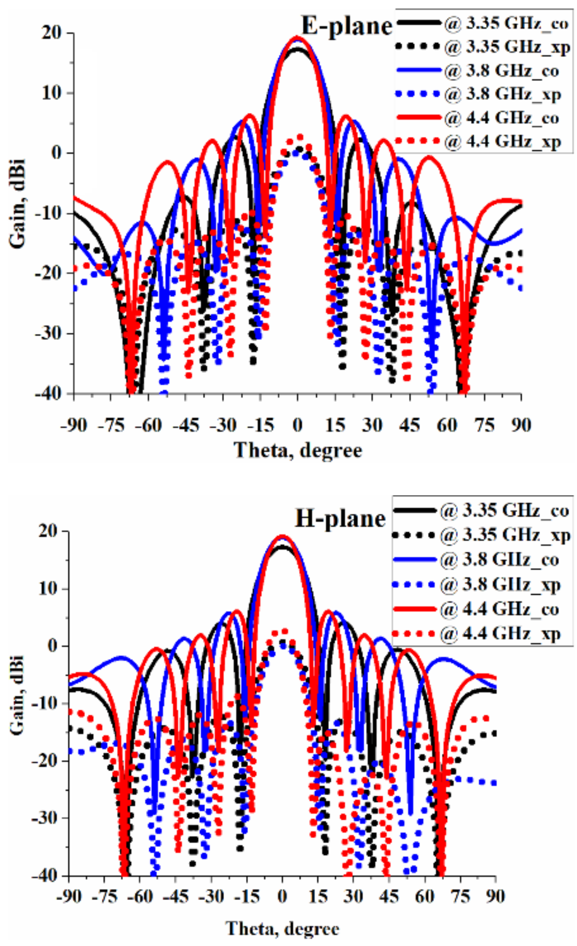

Fig.5. Co- and cross (x) - polar radiation patterns of the proposed bow-tie antenna in E- and H-planes at spot frequencies in the operation band. The patterns are for 8×8 bow-tie antenna arrays.

III. Conclusion

The feasibility of a new and simple feed mechanism is conceptionally validated in the realization of a low-profile and directional wideband self-grounded Bow-Tie antenna. The proposed feed mechanism is implemented with a single open-circuited microstrip line that couples EM energy to the Bow-tie structure through a slot etched in the ground-plane. This technique gets rid of baluns and therefore reduces the complexity of the feed structure design and simplifies the manufacturing process. The resulting antenna offers good impedance matching across its operating frequency range with VSWR<2 and exhibits an average gain of 20 dBi.

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