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# BOW-TIE SLOT ANTENNA FOR 29 TO 45 GHz BAND

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## Abstract

We propose a bow-tie slot antenna fed by a microstrip to CPW transition to operate in the mm wave-band from 29 to 45 GHz. The measured results exhibit a maximum impedance bandwidth of 43% for VSWR<2, and an average gain of 10 dB. The antenna is suitable for the integration with microstrip circuits and mm-wave MMIC. The antenna is mounted on a mechanical structure with a movable reflector plane which provides the adjustment for the return losses. The whole design facilitates the cooling process when this antenna is used in low temperature experiments.

## 1. Introduction

According to the emergence of the miniature new technologies in communications and electronics, planar antennas are widely investigated in a large brand of applications because they facilitate the integration with printed circuits where low profile, weight, size and cost are required. On the other hand, it is also desirable to design a single antenna that operates in several bands, as broad as possible, with the same setup connected to active or passive elements. Bow-tie slot antennas are promising candidates for this trend due to their advantages in uni/bi-

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directional radiation patterns with low radiation losses, wide operation bandwidth, and good impedance matching. Many bow-tie slot configurations can be found in the literature, most of them directly fed by a coplanar waveguide (CPW) transmission line [3, 4]. The antenna proposed in this paper utilizes the combination of both, a microstrip line with a CPW thus forming a transition to feed it. This facilitates its incorporation to systems composed by the emerging front-end monolithic microwave integrated circuits (MMIC).

Our investigation is aimed towards the mm wave-band in the range from 25 to 45 GHz, whose application will be used as a feasibility study to the phase II of the "QUIJOTE CMB experiment" [5] designed to study the anisotropies of the Cosmic Microwave Background (CMB). For our convenience, we analyzed the antenna performance in the unidirectional case by introducing a movable metallic reflector plane below the substrate and varying gradually its distance. In this paper, the radiation characteristics for a single element of this type of antenna and the coupling between two identical elements aligned in the *x*-*y* directions are presented.

## 2. Antenna Design

Figure 1 shows the geometry and parameters of the bow-tie slot antenna, where $a = 0.05$, $b = 0.25$, $c = 8$, $d = 5$, $e = 2.38$, $f = 0.12$, $g = 5.525$, $h = 0.05$, $i = 0.125$, $j = 0.05$, and $k = 7.6$. All dimensions are in mm. The bottom ground plane only covers the microstrip line section (*c* dimension). Figure 2 shows the experimental setup. The design was realized on an alumina substrate of $25.4 \times 25.4\,\text{mm}^2$ with a $3\,\mu$m-thick electroplated gold metallization, 0.254 mm thickness, relative permittivity of 10, and loss tangent of 0.001. The antenna is mounted on a metallic structure made of brass material in which the microstrip ground plane is attached with Epo-Tek H20E (Silver conductive epoxy). The widths of the microstrip line and gaps of the CPW were calculated as in previous paper [2] to provide characteristic impedances of around $Z_0 = 50$ Ohm respectively to reduce mismatch losses in the transition from microstrip to a 50 Ohm 2.4 mm coaxial connector. A movable reflector plane is placed below the substrate in order to vary vertically the reflection distance. The mechanical mount establishes the basic mechanical principles to build antennas which require a variable bandwidth, and it is designed to be used in direct contact with metal surfaces, as well as with the cold plate of cryostats when a low temperature experiment is required to facilitate the cooling process.

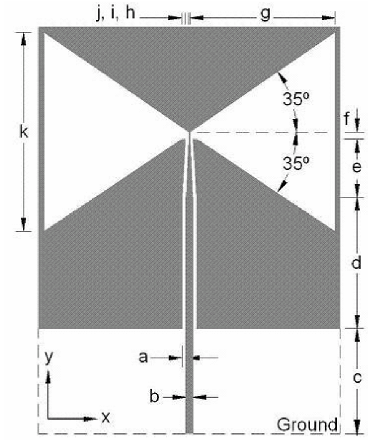


**Figure 1.** Antenna geometry (not to scale) and parameters.

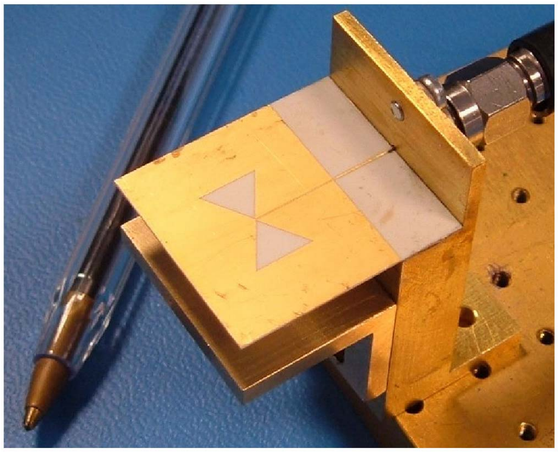

**Figure 2.** Experimental setup attached to a metal base.

## 3. Measured Results

All measurements presented in this paper were made using a PNA-E8364A vector network analyzer. The measured return loss of a single element bow-tie slot antenna before introducing the reflector plane is depicted in Figure 3. The antenna exhibits a broadband behaviour from 27 to 45 GHz with return losses better than 10 dB in almost the total bandwidth. Figure 4 shows the return losses using the reflector plane; the antenna presents small variations in the measurements compared with the previous ones, but we observe an improvement when the reflector plane distance is minimized to zero, thus giving in consequence a maximum frequency range for operation from 29.1 to 45.2 GHz.

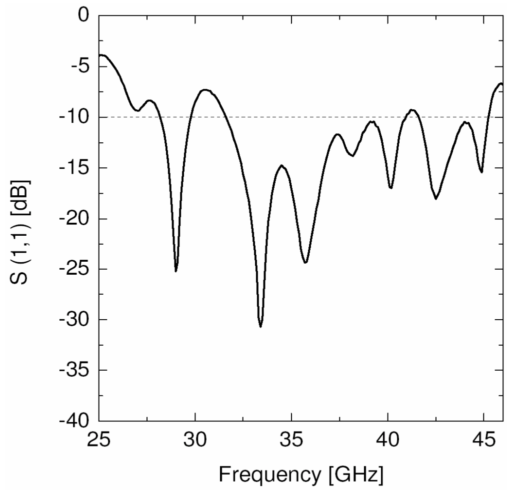


**Figure 3.** Measured return loss without reflector plane.

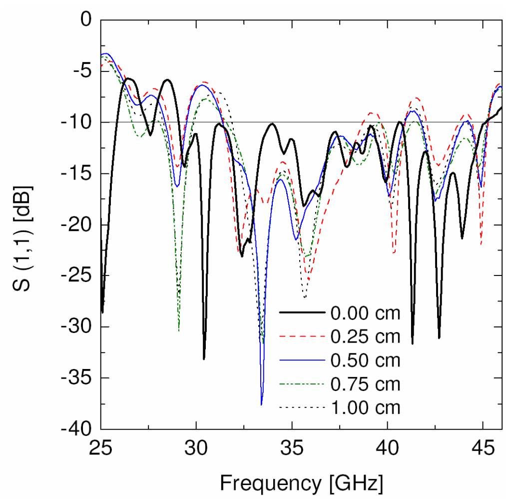


**Figure 4.** Measured return losses varying the reflector plane distance.

The gain $G_A$ of the bow-tie slot antenna was measured using the comparison method with a standard horn as follows:

A different bow-tie antenna unit was used as fixed antenna in the transmitter side, while in the receiver side a standard horn antenna was used as reference and then replaced by the bow-tie antenna under test. Special care was taken to place both, reference and antenna under test, in the same position. Received power at the coaxial connector antenna terminals was recorded, and bow-tie antenna gain obtained according to (1),

$$G_A = G_{REF} + \Delta P_R \tag{1}$$

with $\Delta P_R = P_A - P_{REF}$, where $G_{REF}$ is the standard horn antenna gain, from the manufacturer data, $P_{REF}$ is the received power with the standard horn antenna and $P_A$ is the received power with the bow-tie antenna under test.

Figure 5 shows the experimental arrangement for measuring the gain. The picture shows the horn antenna used as reference and a bow-tie used as transmitter. Test results in the 32 to 36 GHz band are shown in Figure 6. The antenna gain achieves a maximum of approximately 13 dB, and then it falls off towards the edges of the antenna bandwidth. The average gain over the full operating frequency range is around 10 dB.

Far field radiation patterns were manually measured, taking values of the radiated power every five degrees in a scanned angle interval from – 45º to 45º for both the E-plane and the H-plane. Test results at 33 GHz are shown in Figure 7. We observed large side lobes in the H-Plane that may be due to the attachment and the field reflection from the metal mount.

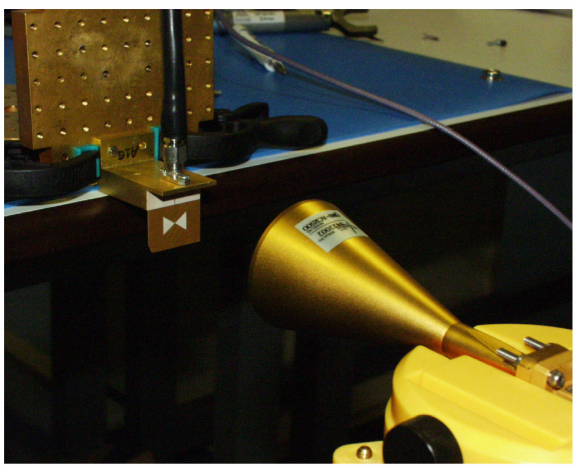

**Figure 5.** Experimental arrangement for measuring the antenna gain.

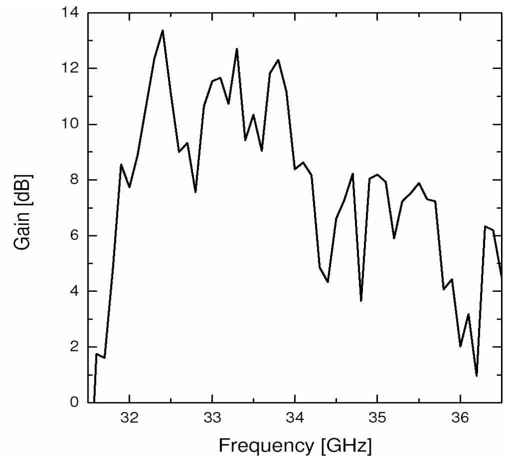


**Figure 6.** Measured antenna gain versus frequency.

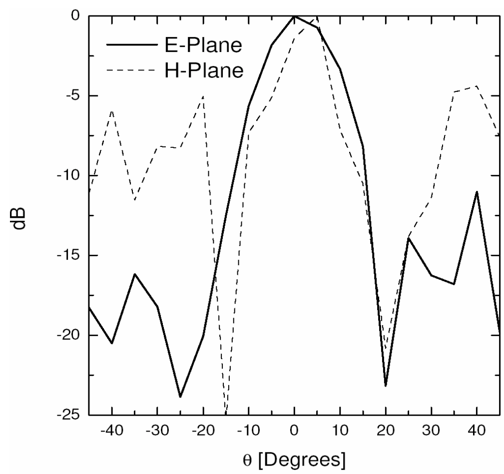


**Figure 7.** Measured radiation patterns at 33 GHz.

The coupling between two identical elements was measured in the *x*-*y* directions whose configurations are shown in the insets of Figures 8-9. Each element operates independently and they are separated by a distance of 25 mm and 36 mm in the *x* and *y* directions, respectively. The measurements show an average coupling of around –30 dB for both configurations, which are good enough in order to satisfy some requirements in array systems. Computed and simulation results for this type of antennas [1, 2] have demonstrated that an array with more than four elements may improve the radiation patterns, increasing the gain by a factor of two and providing side lobe levels lower than –20 dB.

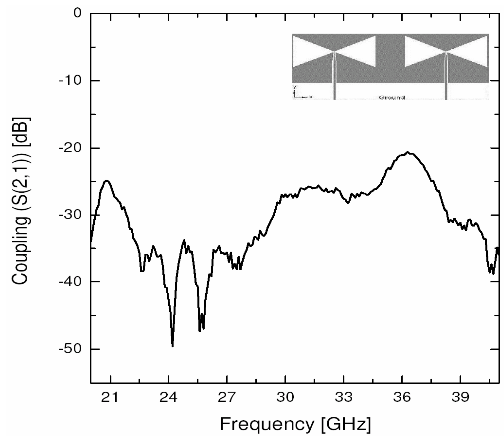


**Figure 8.** Measured coupling between two identical elements separated 25 mm.

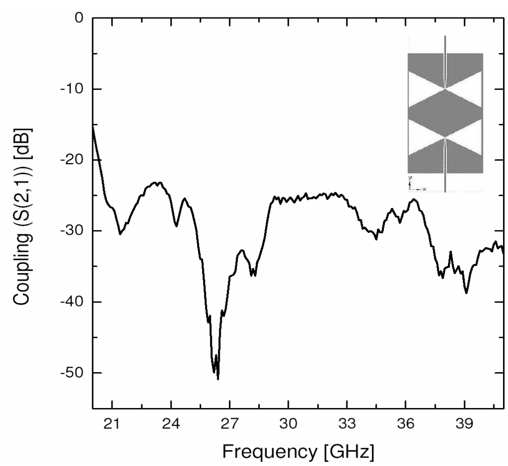


**Figure 9.** Measured coupling between two identical elements separated 36 mm.

## 4. Conclusion

In this paper, a compact design of bow-tie slot antenna is presented. The antenna exhibits an average gain of 10 dB, and 26% bandwidth operation frequency. The low levels of the measured coupling between two element configurations satisfy the requirements in array systems. The design and the measured results provide good solution for integration with mm-wave integrated circuits, as well as other communications applications. The mechanical mount provides the basic principles to build antenna systems in which adjustments for the return losses are required.

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