Design of wide band bow-tie slot antennas for multi-frequency operation in CMB experiments

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Abstract This report presents two proposals of antenna designs suitable to be included in arrays for multi-frequency operation in the ranges from ∼10 to ∼60 GHz and from ∼130 to 300 GHz, both aimed to be applied in Cosmic Microwave Background (CMB) experiments. The antennas exhibit small sizes and wide bandwidth approaching 131% and 79% respectively. The radiation characteristics for a single element and the total directivity for configurations of 5x5 and 15x15 elements array were simulated by means of HFSS (Ansoft) software.

1 Introduction

Many new experiments for astrophysical studies based on CMB observation require multi-band measurements. As an example, the detection of clusters of remote galaxies can be performed by comparing CMB photon fluxes at 150 and 220 GHz, using the model of spectral deformation of the Planck law due to the Sunyaev-Zeldovich (SZ) effect [1]. Up to now, these requirements can be met by means of optical filtering, defining appropriate photometric bands, but it generally consumes a higher surface of the available focal plane. A proposal to overcome this problem had be shown using multi-frequency detector arrays composed by antenna-coupled bolometers associated with millimeter circuits and microstrip transmission lines [2]. On the other hand, the anomalous microwave emission is being studied as additional component of the diffuse galactic foregrounds. Previous studies have demonstrated its evidence emitting in the frequency range from 11 to 17 GHz [3], and recently had been measured at frequencies of ∼31 GHz [4] although it can be observed up to 60 GHz but at lower emissivity levels.

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Usually the array systems that operate in different bands are designed using separate antennas for each band. With the advent of the new technologies now it turns to be possible and desirable to design a single antenna that operates in several bands for a same set-up system. Therefore a wideband antenna that covers the desired range is required.

In this report we propose two designs of antennas suitable to be included in arrays for multi-frequency operation in the ranges from ∼10 to ∼60 GHz and from ∼130 to 300 GHz respectively, aiming towards astrophysics applications. Both designs were based on a previous model reported by Evangelos S. et al. [5]. Each single element design exhibit a wide bandwidth of ∼131% and ∼79% with $VSWR < 2$. The return loss, the antenna impedance and the far field radiation patterns are presented. The total directivity for configurations of 5x5 and 15x15 elements array is also presented. The simulation results computed by means the commercial software HFSS (Ansoft) provide a good expectative for the fabrication of the prototypes.

2 Antenna design

The proposed designs consists of a bow-tie slot antenna fed by a Co-Planar Wave guide (CPW) printed on Alumina/A996 with $3\mu m$ gold electroplated substrate with 0.254 *mm* of thickness, relative permittivity of 10, and conductor loss (tan δ) of 0.001. The geometry and parameters of the proposed antenna are shown in Fig. 1. For design I, a=0.15, b=1, c=0.22, d=0.27, e=0.1, f=0.2, g=6.5, h=4.85, i=0.2, j=0.45, and k=0.254. For design II, a=0.05, b=0.2, c=0.72, d=0.23, e=0.05, f=0.05, g=1, h=0.79, i=0.02, j=0.09 and k=0.254. All dimensions are in *mm*. The substrate sizes are 10x12 mm^2 and 2x2 mm^2 respectively.

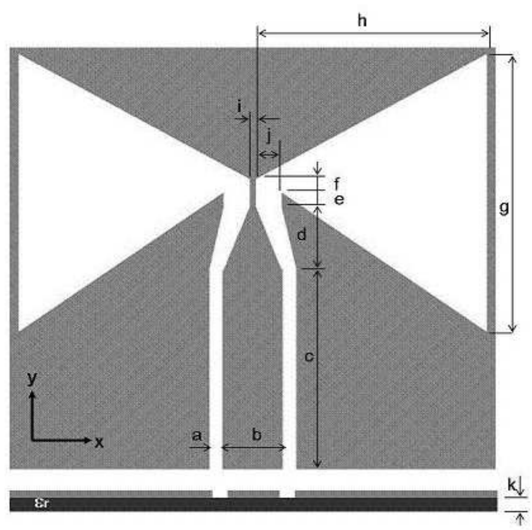

Fig. 1. Schematic geometry and antenna parameters.

3 Simulation results

All parametric variables were controlled in the HFSS design environment considering open radiation type boundaries for the substrate's surrounding box, and using an excitation wave port of 50 Ohm. Fig. 2 shows the antenna impedance in terms of real and imaginary parts. It exhibits two out-of band resonances at $\sim$47 and $\sim$58 GHz for design I, whereas in design II, the resonance appears at $\sim$135 GHz. The return loss and VSWR are shown in Figs. 3 and 4. In one of them we observed that the antenna operates over a wide range that extend from $\sim$12 to $\sim$58 GHz giving a bandwidth of 131%, whereas the other extends from $\sim$130 to more than 300 GHz, for our purposes we considered 300 GHz as limit, hence we got a bandwidth of 79%, both cases exhibit a $VSWR < 2$. The Fig. 5 shows the computed radiation patterns at the operating band center frequencies, 35 and 215 GHz respectively. At these frequencies the antennas have beamwidths of $\sim 90^{o}$ and $\sim 105^{o}$ in the E-plane and of $\sim 45^{o}$ and $\sim 60^{o}$ in the H-plane. We observed that at frequencies of 42 GHz and 173 GHz the antennas have the best matched hence we computed its total directivity considering arrays of 5x5 and 15x15 elements giving the maximum radiation intensity (U) of 57.2 and 1577.4 $\frac{W}{sr}$, with peak directivity of 31.8 and 103.5 respectively, their corresponding radiation patterns are shown in Fig. 6.

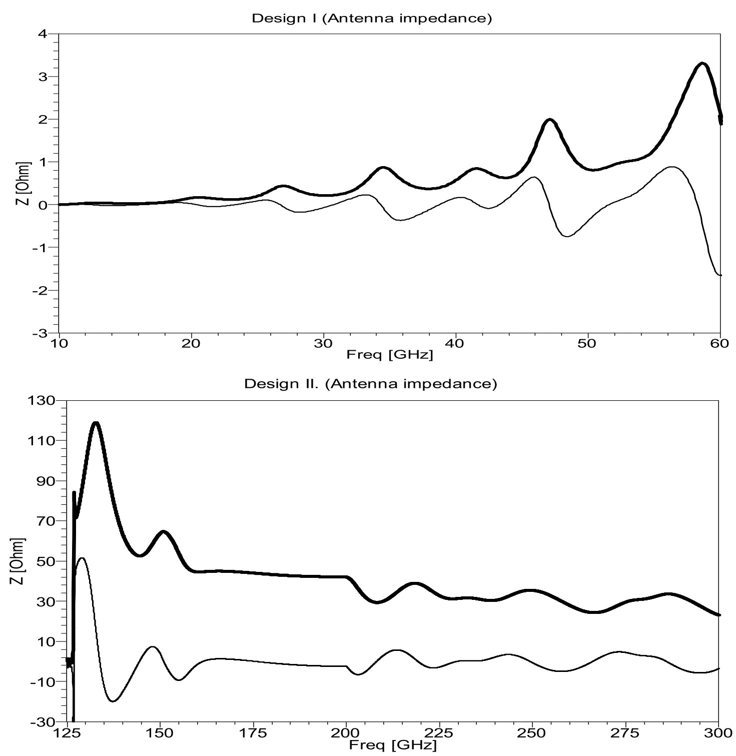

Fig. 2. Computed complex impedance.

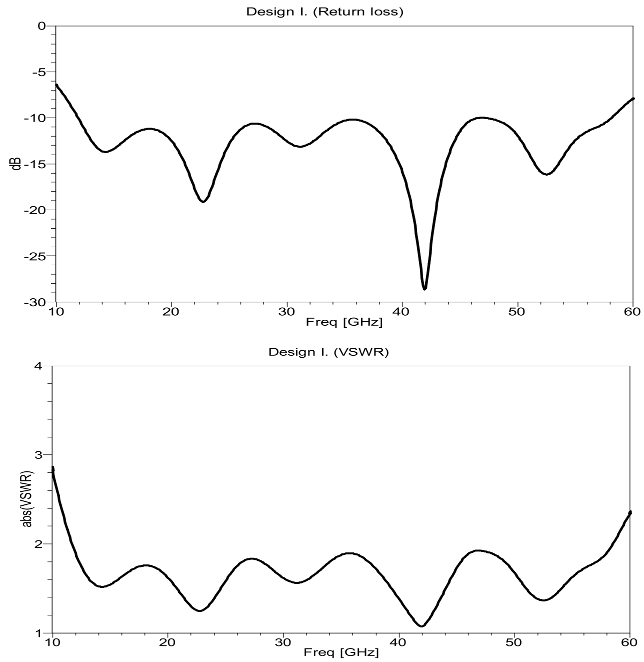

Fig. 3. Return loss and VSWR for design I.

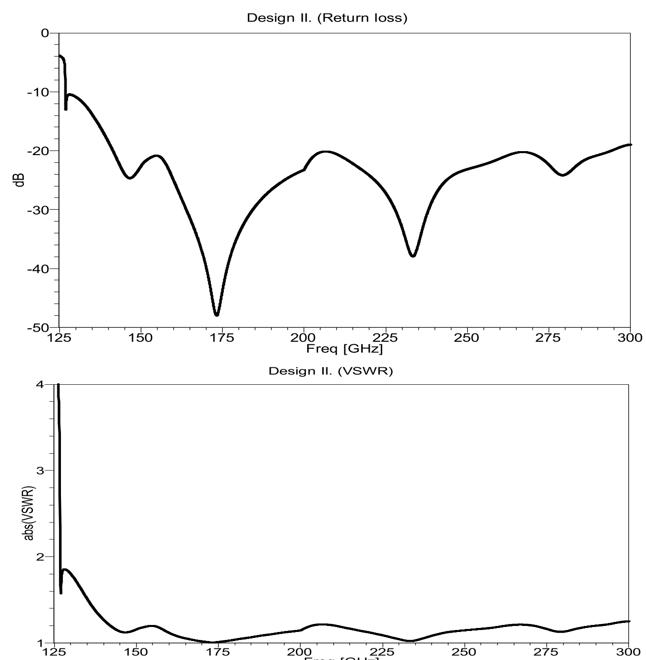

Fig. 4. Return loss and VSWR for design II.

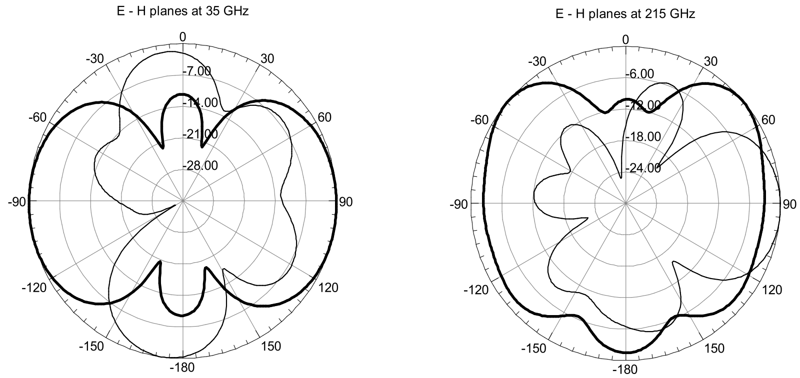

Fig. 5. E-H plane radiation patterns at 35 and 215 GHz.

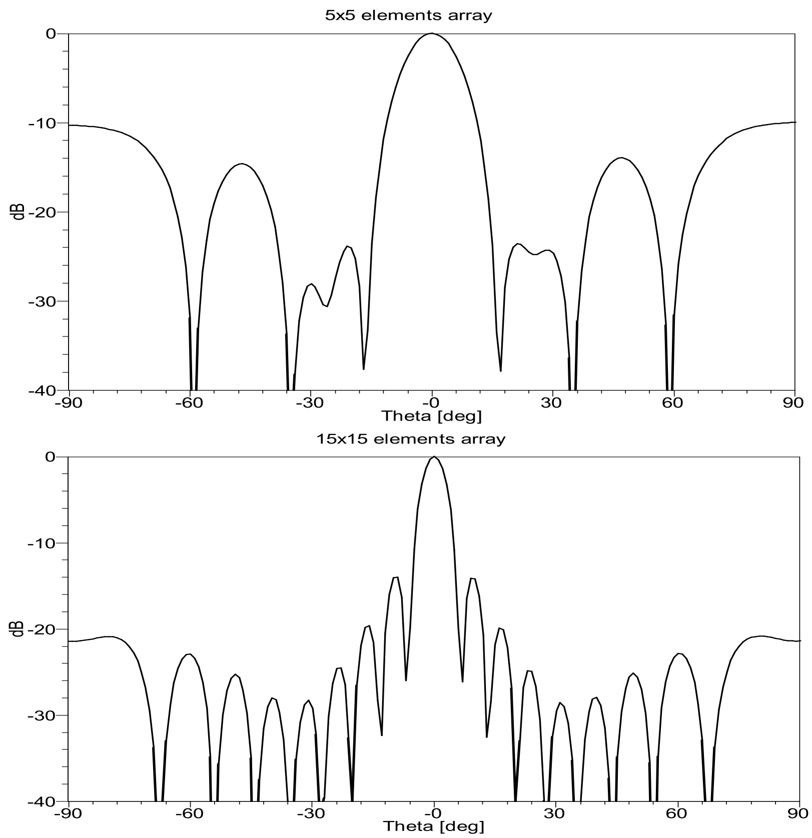

Fig. 6. Total directivity at 42 and 173 GHz.

4 Conclusions

This report gives a first estimation of the performances expected for wide band slot antennas operating simultaneously at different band frequencies required for the study of CMB. The concept is currently under test to validate the design tool. The simulations results provide good expectative for the fabrication of the prototypes.

References

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