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# Full-Metal High Gain Antenna for SatCom Applications at K/Ka band

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**Abstract**—This communication introduces a high-gain antenna designed for satellite communications (SatCom) in the K/Ka band, covering the frequency range 17-31 GHz. The antenna is based on a long slot array, fed by a corporate feed network (CFN). The CFN is tapered to reduce (<-23 dB) sidelobe levels (SLL) in the radiating plane orthogonal to the long slots across the entire frequency band. Additionally, a pillbox coupler serves as a line source generator to illuminate the CFN, featuring an integrated parabolic reflector illuminated by a displaceable H-plane horn in its focal plane. The antenna is fabricated using computer numerically controlled (CNC) milling technology in Aluminum to minimize losses. The total size of the antenna is  $44.5 \times 33.1 \times 6.2 \lambda_0^3$  with  $\lambda_0$  the wavelength at 31 GHz. The antenna exhibits a minimum measured realized gain of 34.3 dBi at 17 GHz. The antenna can steer its main beam along the slot plane to cover a field of view exceeding  $50^\circ$  in elevation by displacing the H-plane horn in the focal plane of the pillbox coupler.

## I. INTRODUCTION

Low Earth Orbit (LEO) Satellite communication (SatCom) terminals in K/Ka band operate in the frequency bands 17.7-21.2 GHz and 27.5–31 GHz for the down and up link channel, respectively **Erreur ! Source du renvoi introuvable.** To maintain a robust link with rapidly moving satellites certain key features in SatCom terminals have to be secured, among them, broad operating band, high gain, wide field of view, and low sidelobe levels (SLL) [2],[3].

Long slot antennas can satisfy such key features particularly when fed in parallel by a corporate feed network (CFN). The CFN can also control the SLL of the radiated energy along the plane orthogonal to the slot plane. However, the CFN only controls the SLL along the plane perpendicular to the slots. The SLL along the slot plane can be controlled by a line source generator. The line source generator also enables beam steering in elevation along the slot plane. In this communication, a pillbox quasi-optical system is implemented to feed the CFN.

The pillbox coupler comprises an integrated parabolic reflector that is fed by a movable H-plane horn positioned in the focal plane of the reflector. Beam steering is achieved by adjusting the position of the horn along the focal plane of the parabola [4]. While long-slot arrays inherently provide linear polarization, the introduction of circular polarization is attainable by incorporating a polarizer over the radiating aperture [5] or using multi-mode slots.

In [5], we proposed an 8-long slots antenna array. The antenna was fabricated in PCB technology. The beam scanning was limited to  $\pm 24^\circ$  in elevation. There was no tapering applied to the CFN. None the less, in [5], we validated the fabrication of such arrays and their feed network in multilayer PCB technology using a recently introduced contact-less transition in [6]. In [7], we built upon our antenna in [5] to have a more directive beam with a minimum measured realized gain of 30.8 dBi at 17 GHz. The full antenna was fabricated by using CNC milling and PCB technology. The proposed prototype presented a new concept of folding a CFN to reduce the number of substrate layers by 65% and introduced an innovative simple mechanism to combine two different fabrication technologies for loss reduction. The SLL of the far-field radiation patterns in both principal planes was less than  $-18$  dB for broadside radiation, and a field of view of  $\pm 42^\circ$  in elevation was achieved.

In this paper, we further build on our previously presented prototypes to reduce the losses and achieve a higher gain and efficiency. The structure presented in this work is fabricated in CNC milling technology of Aluminum to adopt empty guiding structures to boost the gain and efficiency of the antenna. The radiating aperture has an effective area that is equal to our proposed prototype in [7] for an easy comparison between both works. The CFN is also tapered in the same manner and uses the same quasi-optical beamformer. The final antenna has a minimum measured realized gain of 34.3 dBi at broadside compared to a 30.8 dBi for the design in [7] corresponding to an increase in gain of 3.5 dB directly related to low losses of the metallic structure.

## II. ANTENNA DESIGN

The proposed design can be separated into two main blocks: a tapered CFN feeding 32 long slots antenna array, and a pillbox beamformer acting as a source generator to feed the CFN. The first block is shown in Figure 1. The CFN consists of a parallel-plate waveguide (PPW) in Aluminum and air. The PPW height is 3.556 mm operating with its principal Transverse Electromagnetic (TEM) mode. The minimum thickness of any metallic plate is 3mm to ease the fabrication process and ensure a rigid structure with no bending of the plates. The CFN is tapered to achieved a SLL lower than  $-23$  dB across the full band in the radiation plane orthogonal to the slots. The second block is a pillbox coupler feeding the CFN. More information

about both the tapering procedure and the pillbox coupler can be found in detail in [7] and not mentioned here for brevity.

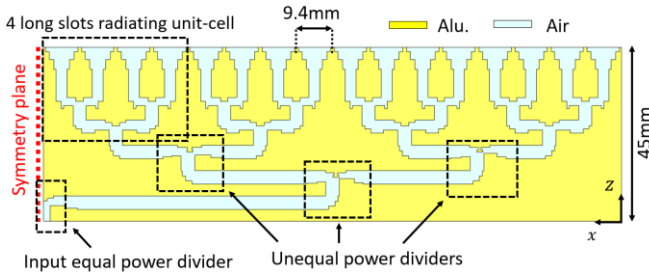


Figure 1. 2D view of one half of the CFN and the long slot radiating aperture. The antenna is symmetric across  $x$ - $z$  plane.

The long slots antenna array is realized by 32 slots. The periodicity between the slots is 9.4mm or  $1\lambda_0$  where  $\lambda_0$  is the free space wavelength at 31 GHz. The CFN is based on 1:2 PPW power dividers to feed the 32 slots from the input port of the CFN. As shown in Figure 1, the CFN is symmetric across the  $zy$  – plane. The central power divider divides the power equally between the two halves of the antenna. Afterwards, 3 unequal power dividers are designed in the next two stages to taper the antenna aperture and reduce the SLL to  $-23$  dB. The full thickness of the CFN and the slots is less than  $5\lambda_0$ . The full width of the antenna array and CFN is  $33.1\lambda_0$  along the  $x$  direction. Along the  $y$ -direction the size of the antenna corresponds to the diameter of the pillbox coupler and is equal to  $44.5\lambda_0$ .

### III. SIMULATED AND MEASURED RESULTS

The full antenna is electrically large to be simulated with our computational resources at IETR. Similar to our models in [5] and [7], a slice of the CFN along with the antenna array is simulated in a periodic environment. A reflection coefficient better than  $-15$  dB across the whole band was observed. In the E-plane ( $zx$  – plane orthogonal to the slots), a SLL lower than  $-23$  dB was achieved from 17 to 31 GHz. The half-power beam width (HPBW) ranged from  $3.6^\circ$  at 17 GHz to  $2.1^\circ$  at 31 GHz. The simulated HPBW is around  $2.6^\circ$  with a SLL that is better than  $-24$  dB across the full band.

A prototype has been fabricated and validated experimentally at IETR. A minimum gain of 34.3 dBi has been obtained at 17 GHz. The gain increases steadily to reach a 36.3 dBi at 21.5 GHz for the down-link frequency band. The measured and simulated normalized far-field radiation patterns are reported at 17 GHz in E-plane in Figure 2. The measured HPBW is  $3.6^\circ$  agreeing with the simulations, with the SLL remains better than  $-18$  dB. The deviation is attributed to fabrication tolerances affecting the power division and phase stability between the output ports in the unequal power dividers. In the H-plane, the measured and simulated HPBW are in excellent agreement, with a SLL lower than  $-25$  dB. At the time of editing this contribution, measurements were still running for

the up-link frequency band and scanning. More results will be presented at the conference.

### IV. CONCLUSION

A high-gain long slot antenna array suitable for SatCom applications has been introduced operating in K/Ka-band with a single radiating aperture. The long slot antenna array and its CFN have been fabricated in Aluminum using CNC milling technology. A tapered CFN is implemented to reduce the SLL ( $< -23$  dB) across the full band of operation with a total thickness of 45 mm. A pillbox coupler is used to illuminate the CFN. Its thickness is less than 15 mm. A fractional bandwidth of 58% (17–31 GHz) is achieved by combining the two parts. A field of view of  $\pm 50^\circ$  is expected. The measured peak gain of the antenna is 36.3 dBi at 21.5 GHz in the down-link frequency band of Satcom links. The antenna is still under measurements, and more results will be presented at the conference.

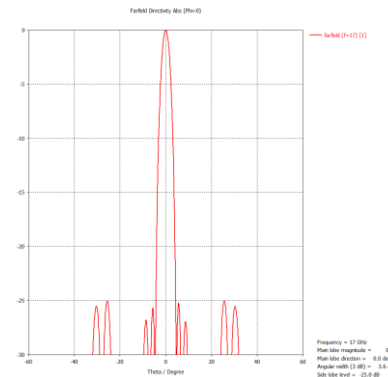


Figure 2. Measured versus simulated far-field radiation patterns in E-plane ( $zx$  – plane in Fig. 1) at 17 GHz.

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