3D-Printed Double-Ridged Waveguide Array Antenna targeting High-Efficiency Ku-band SatCom on The Move Applications

Francesco Filice
STMicroelectronics, Crolles, France
Polytech'Lab, Université Nice-Sophia, Valbonne, France
francesco.filice@st.com

Nour Nachabe, Cyril Luxey
Polytech'Lab, Université Nice-Sophia, Valbonne, France
nour.nachabe@etu.univ-cotedazur.fr
cyril.luxey@unice.fr

Frédéric Gianesello
STMicroelectronics, Crolles, France
frederic.gianesello@st.com

***Abstract*— On-going research about Low Earth Orbit (LEO) mobile satellite communications (Sat-Com-on-The-Move) push towards the designs of low-cost and low-profile user terminals. This paper proposes initial results about a wideband double-ridged waveguide antenna to be further integrated in a mobile-user terminal array-antenna, operating in Ku- Band (10.75 – 14.5 GHz). The design of a 2×2 sub-array covering the Ku- band with an efficiency above 70% is proposed to be later used as a unit cell in a larger array. Fabrication with 3D-printing technology is envisaged in order to assess the performance of this design.**

Keywords*— *Ku- Band, LEO, Sat-Com-On-The-Move, mobile user terminal antennas, double ridged waveguide antenna, 3D-printing

I. INTRODUCTION

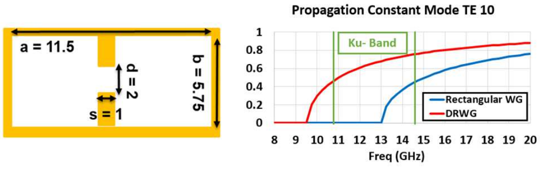
Large-scale development of LEO Sat-Com-On-The-Move is an objective of leading companies in aerospace and satellite communication market. While fabrication and deployment costs of required satellite constellations is being reduced, the challenge is to develop low-cost and low-profile user terminals able to meet the needs of the consumer mass-market [1]. Commercial existing antenna-solutions target military and professional customers and therefore uses motorized reflectors [2], which results in too bulky and expensive systems. Compact terminals implementing slotted-waveguide array are already available [3], but the intrinsic bandwidth limitations of this solution forces to split reception (Rx) and transmission (Tx) in two distinct arrays, which doubles the occupied size (and cost) of the antenna-solution.

A compact wideband radiating unit-cell, allowing to integrate both Rx and Tx within the same antenna and offering acceptable performance, would represent a major step. Despite the fact that microstrip antenna would achieve these performance with the best cost and form factor, the high attenuation losses of the microstrip feeding network prevent to use this solution in an array configuration. Open-ended waveguides (WGs) offer a reasonable solution but they would not meet the form factor required to create a satisfying scanning array at these frequencies. Indeed, such elements would be too large, implying a large element spacing that would create grating lobes when scanning.

Hence, we propose to design a Double-Ridged WaveGuide (DRWG) antenna to fulfill those goals. The design and the simulation of a single double-ridged waveguide (DRWG) antenna are presented in the first section of this paper. The second section is dedicated to the design and the simulation of a 2×2 sub-array along with its relative feeding network. The paper ends by conclusions and perspectives.

II. DOUBLE-RIDGED WAVEGUIDE ANTENNA DESIGN

A DRWG is designed by adding two ridges on the bottom and top walls of a regular rectangular waveguide. The parameters are the width a and the height b of the initial rectangular waveguide, the ridge width s and the distance between the two ridges d ([4], Fig.1 a) with optimized dimensions). Ridges widen the impedance bandwidth and shift the fundamental mode cut-off frequency to lower values, as shown in fig.1 b). The optimization of the DRWG results in a waveguide able to work at Ku- band and having a smaller section than a traditional waveguide by 63%. The proposed DRWG is further simulated in an open-ended configuration. Fig.3 shows the obtained broadside realized gain of about 3.3 dBi, the directivity of about 4.8 dBi and the total efficiency around 70% within the whole Ku-band. The losses are mainly due to mismatch loss (return loss ~ 5 dB) while the simulated attenuation of the designed DRWG is about 0.32 dB/m.



a) *b)*

Fig. 1 a) Top view of the DRWG with dimensions [mm], b) Mode TE10 propagation constant for DRWG and initial rectangular waveguide.

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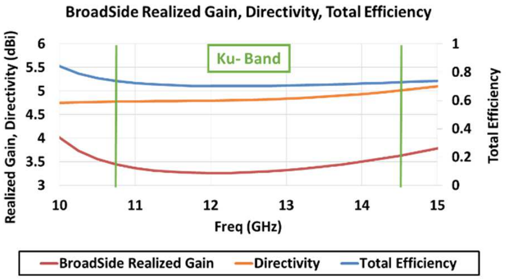

Fig. 3 Simulated broadside realized gain, directivity and total efficiency of an open-ended DRWG.

III. 2X2 SUB – ARRAY DESIGN

The proposed DRWG design is leveraged in order to create a 2×2 sub-array. A four-way power divider was designed, consisting of a cavity with ridges coupling the power into the four outputs. Several views of the optimized design are shown in fig. 4 a) and simulated performance are plotted in fig.4 b): matching remains below –10 dB along the whole operating band and the signal is equally split between the four outputs with equal phase. A standard waveguide input is required in order to allow test and measurements, so we designed a WR-75 to DRWG transition and added a standard WR-75 flange. The unit-cell will be leveraged to create a large array, targeting an electronic beam steering of ±45° in elevation at 14.5 GHz. A 12.1 mm ($0.6*\lambda_{14.5GHz}$) center-to-center pitch is required as condition to avoid grating lobes. Hence, a DRWG taper is used to connect the power divider to each DRWG unit-cell and set the correct inter-element distance. The complete design is shown in Fig.5, while the simulation results are shown in Fig.6.

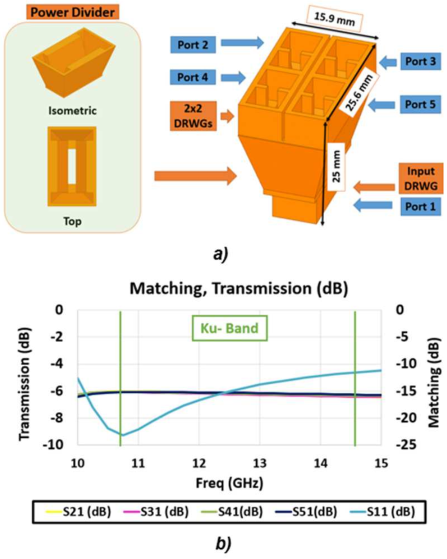

Fig. 4 a) Several views of the 2x2 sub-array with power divider and input DRWG, b) Simulated matching and Sij of the 2x2 sub-array.

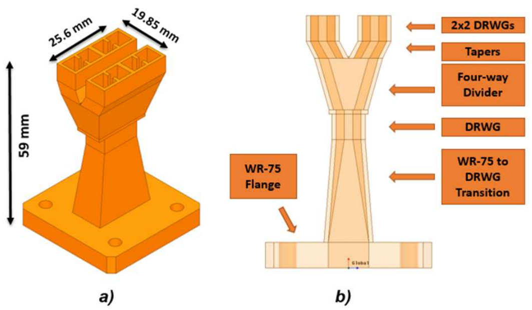

Fig. 5 a) 3D-view and (b) Transparent Side-view of the 2x2 sub-array with complete feeding network.

The broadside realized gain stays between 8 and 10.5 dBi, while the directivity varies between 10 and 12.5 dBi. Matching stays between -4 and – 6 dB and still needs to be improved.

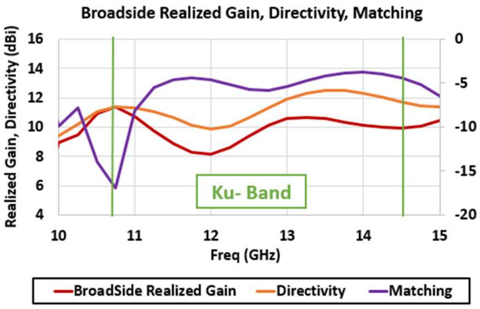

Fig. 6 a) Simulated broadside realized gain, directivity and matching of 2x2 sub-array with feed network.

IV. CONCLUSION

A DRWG antenna with an efficiency above 70% was proposed to address Sat-Com-On-The-Move applications at Ku- band. A 2×2 sub-array was designed to be used as a unit-cell for a further large scanning array. Fabrication, test and measurements of the proposed design are envisaged in order to validate those obtained results and will be presented during the conference.

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