A Dual Band Circularly Polarized SIW Interleaved Antenna Array

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Abstract—The design of a new dual band slot antenna for Substrate Integrated Waveguide (SIW) technology is presented. The antenna element operates in two bands suitable for emerging High Throughput Satellite Systems terminals; namely the K band (19.2-20.2 GHz) and the Ka Band (29-30 GHz). The inclined slotted antenna elements are first designed separately for each band and then in conjunction. These slot antenna pairs can be subsequently utilized for the formation of circularly polarized interleaved antenna arrays. Simulated axial ratio and impedance bandwidth cover the required bandwidths of 1 GHz in each band.

Index Terms—SIW, Circular Polarization, Satellite communications.

I. INTRODUCTION

High Throughput Satellite Communications Systems in the Ka band are expected to fulfill the European Digital Agenda for broadband everywhere by 2020 [1]. There are several satellite systems in development that aim to deliver broadband communications. For example, the Inmarsat Global Xpress [2] has already started offering Ka Band satellite communications on mobile platforms. Global Xpress is a GEO (Geostationary Earth Orbit) system that is going to utilize 3 satellites and another one for redundancy. The frequency plan for the system follows the FDD (Frequency Division Duplex) approach (Uplink 29-30 GHz, downlink 19.2-20.2 GHz).

Mobile platforms can include a lot of different scenarios; from cars to manpack. Earth stations in terms of satellite communications are categorized as Onboard Aircrafts (AES), Onboard Vessels (ESV) and Mobile Platforms (ESOMPs). ESOMPs in particular can be used in a harmonized way in terms of regulatory constraints according to a recent report by CEPT/ECC [3].

Considering the different frequency bands for uplink and downlink, the reflector antennas currently in offer utilize dual band feeders. However, reflector antennas are bulky for a widespread adoption and lightweight antennas are needed [4]. Planar antennas can offer an attractive alternative. Antenna designs operating in K-Ka bands have been presented in the literature mostly as reflectarrays [5]-[6].

In this work, planar antenna elements are proposed based on SIW technology. SIW is considered as a technology that offers the benefits of waveguide technology along with the integration potential of planar technology [7]. The slots pair introduced in [8]-[9] for waveguides, is adapted for SIW. For the array topology, an interleaved arrangement [10][11] is adopted.

Section II presents the slot antenna geometry and the interleaved array. Section III describes the design procedure. Section IV presents some preliminary results on the antenna elements. Conclusions and future work are drawn in Section V.

II. ANTENNA GEOMETRY

A. Single Band Slot Pair

The antenna is composed by two slots orthogonal to each other [8]. The geometry along with the relevant parameters are shown in Fig. 1. Slots with the same dimensions (L, W) are placed a distance d_s apart along the waveguide length and are offset by x in the lateral dimension.

![Slots pair geometrical parameters.](image-url)
B. Dual Band Slot Pairs

The conceptual steps in forming the elementary antenna to operate in two bands is shown in Fig. 2. Each band can be designed separately and then combined to form the dual band antenna.

![Fig. 2. (a) Conceptual steps for the dual band operation (b) Actual achieved arrangement](image)

C. Interleaved Array

Having the element of Fig. 2 in place, arrays can be formed (Fig.3). Furthermore, since the antenna element can be considered as two separate antenna elements, interleaved arrays are also possible.

![Fig. 3. Conceptual steps for the interleaved array development](image)

III. DESIGN PROCEDURE

The design procedure for the determination of the slot dimensions follows [8] utilizing the SIW-waveguide equivalence [7]. The simulations were carried out using a widely used simulator (ANSYS HFSS v.15.1). The procedure is shown in Fig.4.

![Fig. 4. Design procedure to find the slot pair dimensions in each band](image)

The center frequency of each band is used as the design frequency. A typical design plot is shown in Fig.5 for the K band considering that the most important parameter that controls the slot excitation strength is the length. As described in Fig.4, the magnitude $S_{21}$ is recorded as a function of slot length $L$. For each slot length, several values of $S_{21}$ are possible under combinations of the other four geometry parameters.
The procedure is repeated separately for each band. When the two single band pairs are brought together, each pair acts as a scattering element for the other. As a final step for the interleaved array, the design is done with both pairs present. The aim is to bring as close as possible the two pairs (Fig.2).

The initial dimensions of the slots pair for each band are given in Table I with reference to Fig. 2. The substrate used is Arlon (ε\textsubscript{r}=3.38, h=0.51mm, tanδ=0.0025). The SIW width is 6.27mm with vias of diameter of 0.6 mm and spacing 1.4mm.

| No | Parameter | 19.7 GHz | 29.5 GHz |
|----|-----------|----------|----------|
|    |           | Isolated | Both     | Isolated | Both     |
| 1  | L(mm)     | 4.6      | 4.5      | 3.23     | 3.6      |
| 2  | W(mm)     | 0.3      | 0.3      | 0.3      | 0.2      |
| 3  | x(mm)     | 1        | 1        | 1        | 0.95     |
| 4  | d\textsubscript{s}(mm) | 2.5      | 2.5      | 1.7      | 1.5      |
| 5  | ϕ\textsubscript{s}(°) | 56       | 56       | 36       | 56       |

In the traveling wave array design, each element requires a different value of S\textsubscript{21} in order to synthesize a Taylor or other aperture distributions [12]. Towards this end, design plots such as the one in Fig.5 permit the mapping of S\textsubscript{21} to slot length for each array element.

IV. PRELIMINARY PERFORMANCE RESULTS

Axial ratio results are shown for the two bands in Fig.6a for the K-band and in Fig. 6b for the Ka band. Overall the axial ratio is below the 3 dB throughout the bands of interest.

Correspondingly for the impedance, the S\textsubscript{11} plots for the two bands are shown in Fig. 8. In both bands, good matching is achieved. For comparison, the axial ratio when the slot pair operates isolated is included.
V. CONCLUSIONS

The design of slot antennas that operate in the K and Ka bands has been presented. The antenna element for each band consists of inclined orthogonal slot pairs that generate circular polarization. Preliminary results on axial ratio and impedance satisfy the 2GHz total bandwidth requirements. These elements can be used to form interleaved subarrays that can satisfy requirements for mobile platforms. Results on a linear interleaved array will be presented in the conference.

REFERENCES

[1] European Commission, A Digital Agenda for Europe, August 26, 2010.
[2] Y.Koulikova and L.Roberti, “Global Xpress:Global Mobile Broadband”, ITU Regional Seminar on Prospects for use of the Ka-band by satellite communication systems” Almaty, Kazakhstan, 5 - 7 September 2012.
[3] European Communications Committee, “The Use of Earth Stations on Mobile Platforms Operating with GSO Satellite Networks in the Frequency Range 17.3-20.2 GHz and 27.5-30.0 GHz”, Report 184, February 2013.
[4] Inmarsat, “New Lightweight antenna to bring fast in-flight broadband connectivity to smaller Business Aviation aircraft”, Press Release, 20th May, 2015.
[5] J-M Baracco et al. “Dual frequency Ka-band reflectarray for ground terminal application.” Antennas and Propagation (EuCAP), 2014 8th European Conference on, 2014.
[6] R. Deng, Y. Mao; S. Xu, and F. Yang, "A Single-Layer Dual-Band Circularly Polarized Reflectarray With High Aperture Efficiency,” IEEE Transactions on Antennas and Propagation, vol.63, no.7, pp.3317-3320, July 2015.
[7] M Bozzi, A Georgiadis, and Ke Wu. "Review of substrate-integrated waveguide circuits and antennas," IET Microwaves, Antennas & Propagation, 5.8 (2011): 909-920.
[8] G. Montisci, "Design of circularly polarized waveguide slot linear arrays." IEEE Transactions on Antennas and Propagation,54(10), 2006, 3025-3029.
[9] Montisci, Giorgio, Michela Musa, and Giuseppe Mazzarella. "Waveguide slot antennas for circularly polarized radiated field." IEEE Transactions on Antennas and Propagation, 52.2 (2004): 619-623.
[10] F. Hyjazie, P. Watson, H. Boutayeb. "Dual Band Interleaved Base Station Phased Array Antenna With Optimized Cross-Dipole and EBG/AMC Structure". IEEE APS 2014, Jul 2014, United States.
[11] Guo, Hua, C. J. Guo, and Jun Ding. "Pattern Synthesis of Dual-band Shared Aperture Interleaved Linear Antenna Arrays." Radioengineering 23.3 (2014).
[12] H.Boutayeb, and K.Wu. "Analysis and Design of Millimeter-Wave Circularly Polarized Substrate Integrated Travelling-Wave Antennas." Progress In Electromagnetics Research C, 49 (2014): 67-77.