International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

https://gssrr.org/index.php/JournalOfBasicAndApplied/index

Design of a Bandpass Filter with an Absorptive Stopband for Multifeed Antenna Systems

Joe Zeidan[a*], Stephane Bila[b], Abdallah Nasser[c], Aurelien Perigaud[d], Olivier Tantot[e]

[a,b,c,d,e]*University of Limoges, CNRS, XLIM UMR 7252, 123 av. Albert Thomas, 87060 Limoges, France*

[a]*Email: joe.zeidan@ua.edu.lb*

[b]*Email: stephane.bila@xlim.fr*

[c]*Email: abdallah.nasser@altran.com*

[d]*Email: aurelien.perigaud@xlim.fr*

[e]*Email: OlivierTantot@xlim.fr*

Abstract

This paper presents a filtering solution for enhanced multiband and multisource antenna systems used for space applications. Covering a large surface of the Earth necessitates numerous apertures closely spaced over a reflector antenna. Since these multi-feed systems generally employ multiple bands and multiple polarizations, these architectures induce significant coupling and consequently influence the effectiveness of the solution. The approach of signal retransmission with a controlled phase is proven to be efficient despite a delay concern. On the other hand, as shown in this paper, dissipating the reflected signal can also provide an adequate solution. For this second approach, we have synthesized a two-band filter, one passing the signal, the other absorbing it. This behaviour fits the desired antenna performance and improves the isolation between the two channels. We have designed such a filter and a comparison was made between the two approaches to investigate and derive the efficiency and benefit of each solution. A resized version of the microwave filter with dual behaviour has been manufactured and characterized for experimental verification.

Keywords: Multifeed antenna; microwave filter; filter synthesis; absorptive filter.

Received: 4/13/2024
Accepted: 6/13/2024
Published: 6/23/2024

----

* Corresponding author.

1. Introduction

Antenna systems for multimedia satellite communications illuminate the Earth's surface in order to create a regular grid of contiguous spots. This illumination can be achieved by using several reflector antennas illuminated by focal horn-type sources in order to achieve sufficient performance in terms of EOC gain, isolation between beams, etc. Previous studies [1] have shown the possibility of removing this barrier by fictitiously interlacing the primary sources using an antenna with an electromagnetic band gap correctly dimensioned. The scheme in Figure 1 was based on the use of two frequency bands (250 MHz each at Ka-band) operating on orthogonal polarizations (H and V). To optimize the performance of this antenna system, bandpass filters have been synthesized by an original approach in order to conventionally transmit the signal in each passband but also to present optimal phase conditions in the adjacent band in order to radiate energy in a controlled manner [2]. The approach shown in Figure 1 requires controlling the out-of-band phase of the filter. The optimal phase for re-radiating the signal in phase, depends on various parameters, in particular on the distance between sources.

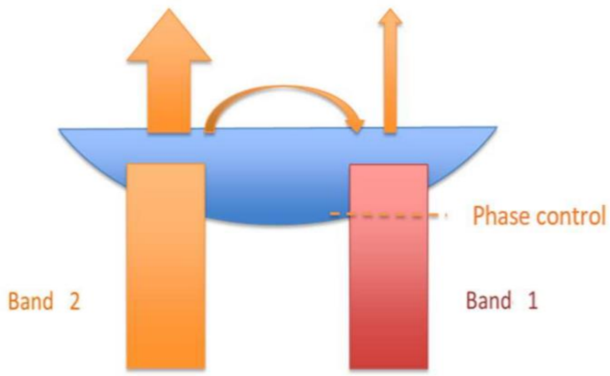

Figure 1: Radiation of the reflected signal with a controlled phase

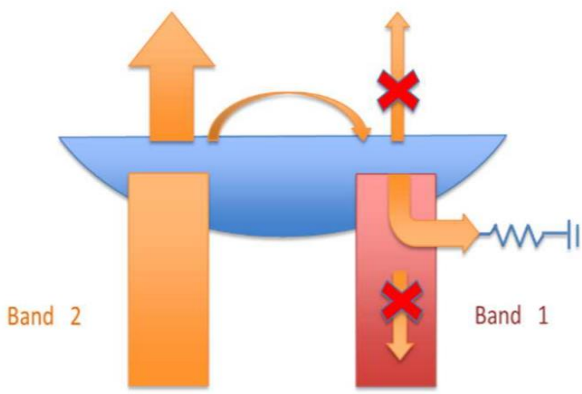

Figure 2: Dissipation of the signal in neighboring channels

The methodology proposed here consists on replacing bandpass filters with other filters having the additional property of absorbing in the bands of the neighboring channel. In this way, the energy in the adjacent bands is not re-radiated but dissipated as depicted in Figure 2. Therefore, the current approach should allow the sources to be brought closer in the antenna system. Such filters allow to transmit the signal within a frequency band, without reflecting the signal on any other frequency band. Several processes to synthesize these filters have been presented in the literature, mainly on planar technologies [3] along with reconfigurable and adaptive filters[4,5].It is important to note that dissipating filters can be seen as a special case of lossy filters [6].

2. Synthesis of bandpass filters with absorptive stopbands for a multi-feed antenna

2.1. Objective

The objective of this study is to develop new architectures of microwave filters, capable of transmitting the signal on a given frequency band and of dissipating the signal in other frequency bands. Studies reported in [7,8] demonstrate the usage of a matched multifeed antenna with a 4 reuse scheme that consists of two linear polarization and two 250 MHz frequency channels. As already mentioned the problem relies on the coupling between the neighboring openings, which can reduce the performance of the antenna system. However, this problem can be minimized by introducing bandpass filters at the feeds of the antenna. With an appropriate control of the reflected signal in other filtered apertures, the efficiency of the overall system can be optimized. However, this approach requires to set a certain spacing between feeds. In this case, the proposed device would make it possible to absorb the signal from one or more neighboring channels, without transmitting energy to the source, nor reflecting it towards free space. Thanks to this type of device, it becomes possible, for example, to bring the sources closer by controlling their coupling. The typical role of filters is either to transmit or to reflect the signal, but here, the filter will be used also to dissipate the reflected signal within particular frequency bands.

2.2. Muli-feed antenna

A 14-port antenna described in [2] is employed for analyzing the potential interest of such filters. The arrangement of the 14 feeds is depicted in Figure 3. Our approach consists to connect to the same antenna, classical bandpass filters, i.e. rejecting the signal in all stopbands and bandpass filters capable of absorbing the signal in certain stopbands.

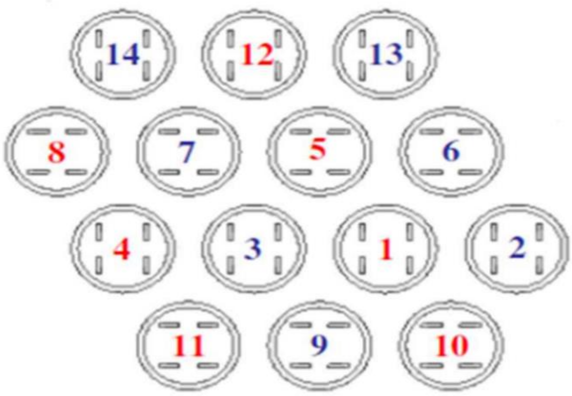

Figure 3: Antenna feeds with two polarizations (horizontal and vertical polarizations) and two frequency bands (pass-band #1 for aperture 1,4,5,8,10,11,12; pass-band #2 for aperture 2,3,6,7,9,13,14)

According to our specifications, we aim for filters with 125- MHz distinct passbands between 29.5 and 30 GHz. Classical (only) bandpass filters and bandpass filters with absorptive stopbands, whose coupling diagram is given in Figure 4, are synthesized. Their scattering parameters are displayed in Figure 5.

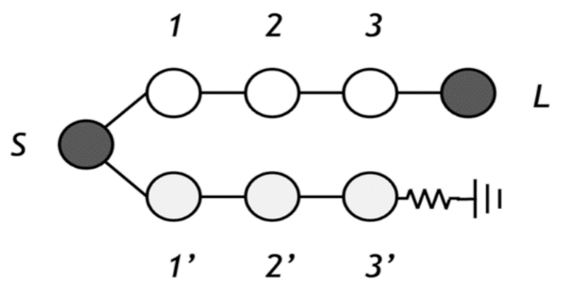

Figure 4: Coupling diagram of the bandpass filter with absorptive stopband

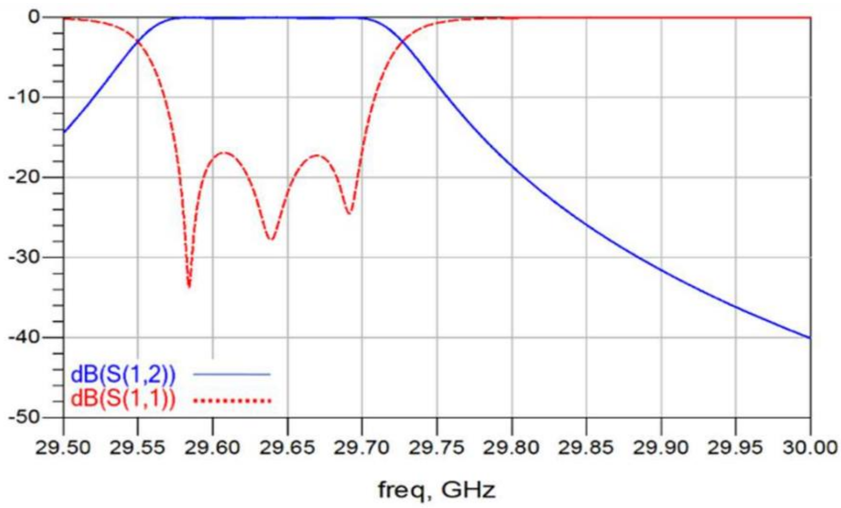

Figure 5 (a): Scattering parameters for 3 poles only bandpass filter (passband #1)

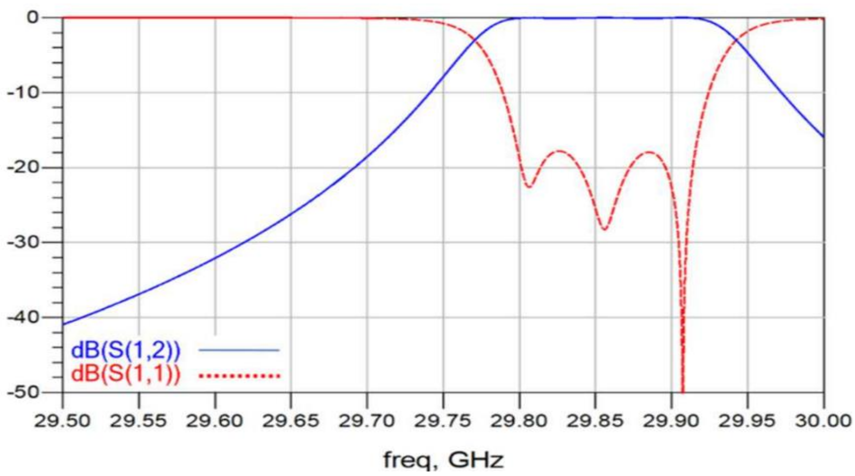

Figure 5 (b): Scattering parameters for 3 poles only bandpass filter (passband #2)

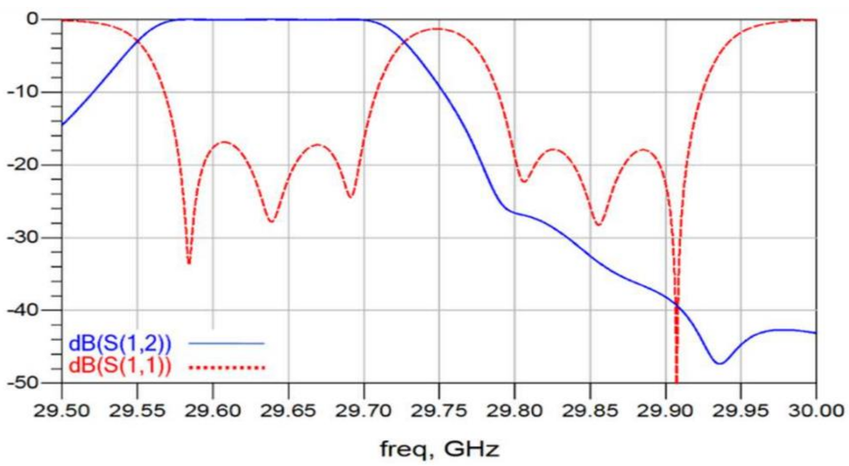

Figure 5 (c): Scattering parameters for 3 poles bandpass filter with absorptive stopband (passband #1)

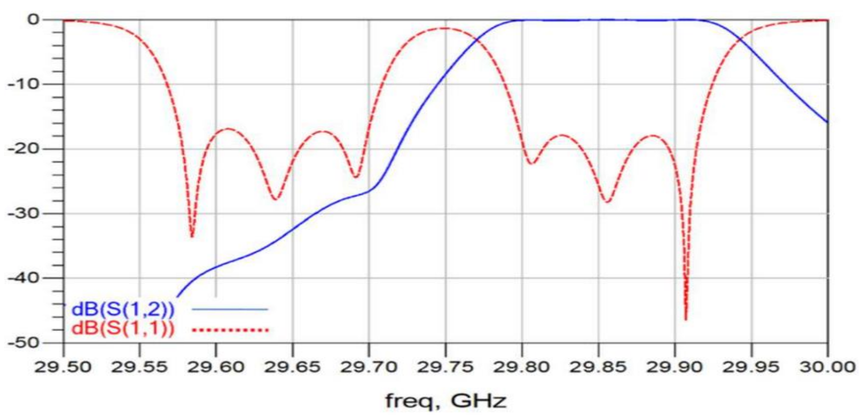

Figure 5 (d): Scattering parameters for 3 poles bandpass filter with absorptive stopband (passband #2)

Those filters are then connected to the multifeed antenna and simulated using ADS. A comparison is made between two antennas the first connected to two regular passband filters visualized in Figure 5 a) and b) (without absorption) and the second connected to two passband filters with absorptive bands Figure 5 c) and d).

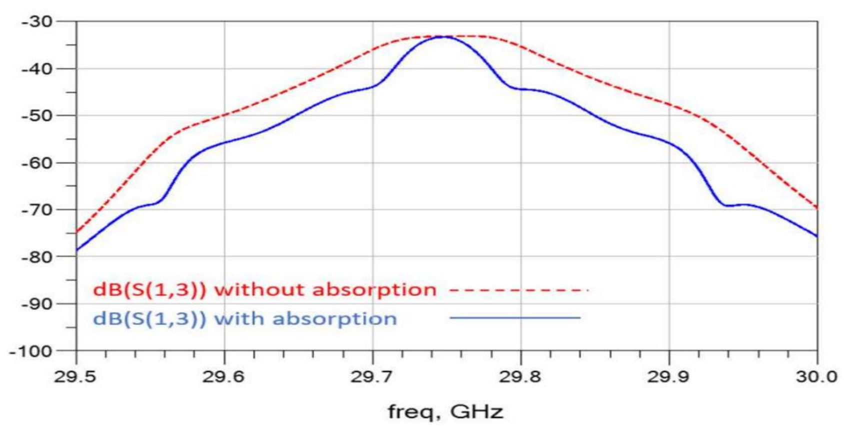

Figure 6 (a): Transmission between port 1 and 3

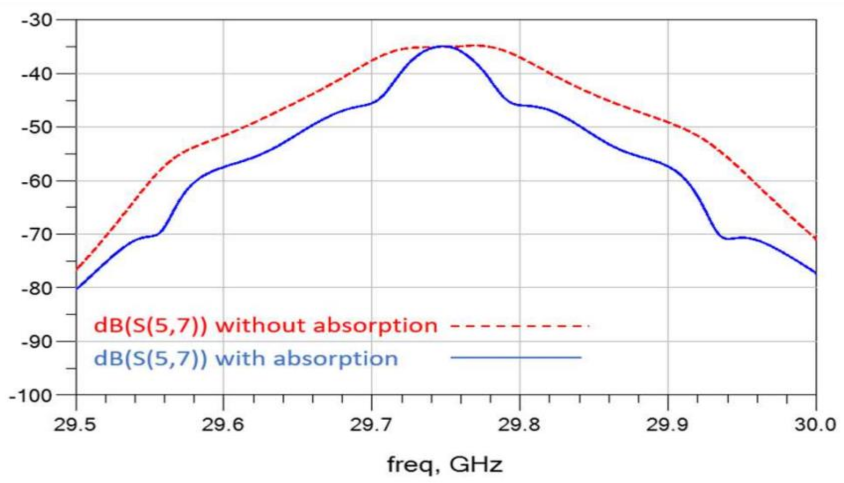

Figure 6 (b): Transmission between port 5 and 7

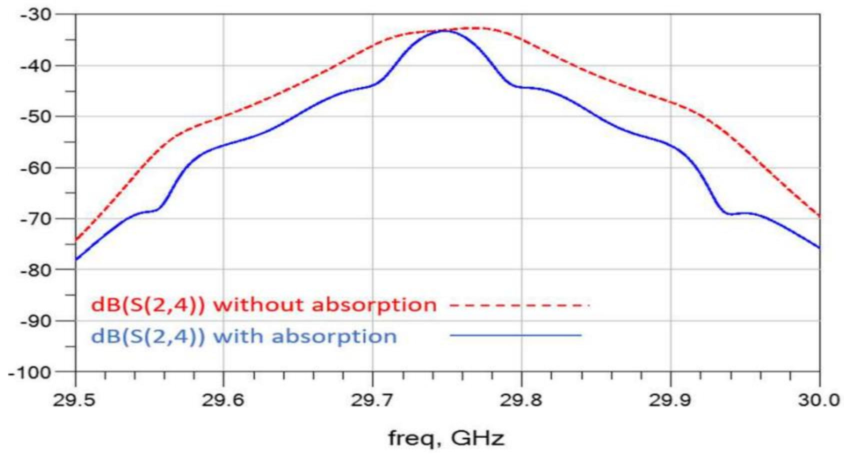

Figure 6 (c): Transmission between port 2 and 4

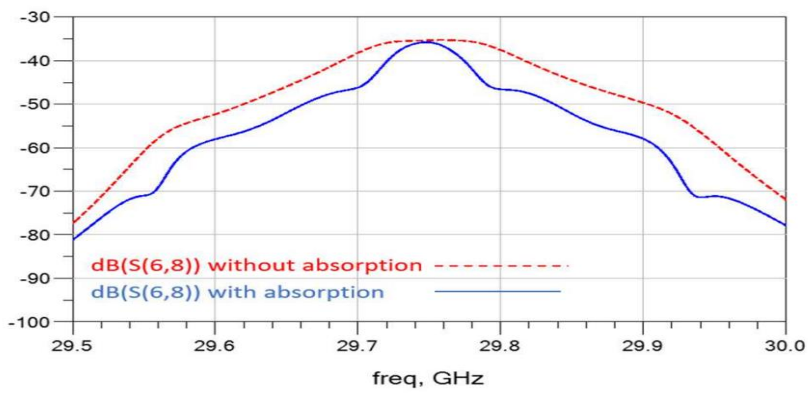

Figure 6 (d): Transmission between port 6 and 8

By comparing the transmission between ports located at the center of the antenna #1 and #3 having the same polarization but transmitting on a different pass-band in Figure 6 a), it is noticeable that a significant isolation over each of the two passbands is spotted. Similarly, Figure 6 b) at aperture #5 transmitting on the first pass band and aperture #7 transmitting on the second passband while both having the same polarization we can also spot a more important isolation that exceed 7 dB at certain frequencies. The consistency of this isolation is shown in Figure 6 c) and Figure 6 d), consecutively for apertures #2 and #4 then #6 and #8. Such response can potentially be used to further bring sources together while limiting the couplings between them.

3. Design and fabrication of bandpass filters with absorptive stopbands.

A prototype is designed and fabricated at lower frequency, for sake of simplicity. The passbands are set to 100 MHz at 8.15 GHz and 8.4 GHz respectively.

3.1. Design

The filter is implemented with dual-mode cylindrical cavities as depicted in Figure 7. The structure is primarily dimensioned with a horizontal access for providing a 3 pole filter response with a center frequency at 8.15 GHz. The same structure, with a vertical access, is then dimensioned for providing a filter response with a center frequency at 8.4 GHz. Finally, the access port is turned at 45 degrees to excite both polarizations, i.e. both frequency bands, at the same time. After adjusting the dimensions of the structure, a duplexer response as shown in Figure 8 is obtained. One output access can be connected to a dissipative load to absorb the signal.

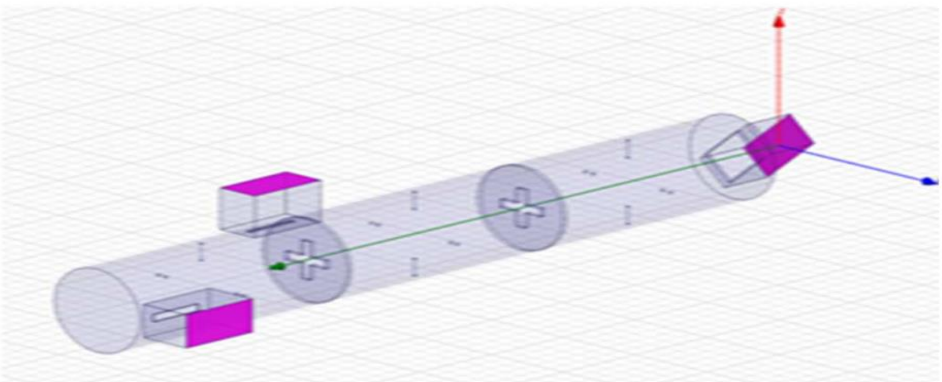

Figure 7: Implementation of the band pass filter with absorptive stopband in dual-mode cylindrical cavities

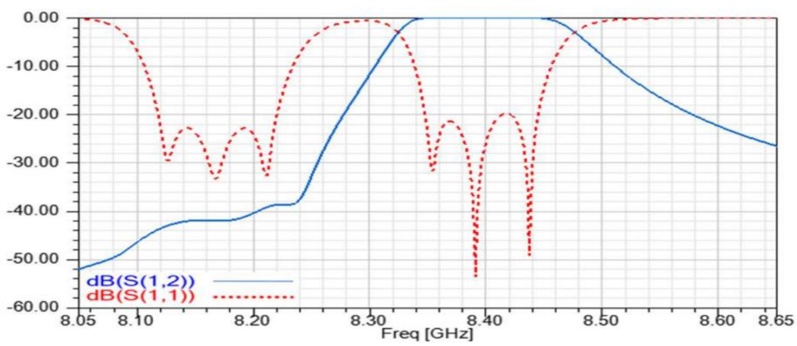

Figure 8: Scattering parameters simulated by HFSS channel #2 transmitted and channel #1 dissipated

3.2. Fabrication and test

The filter has been fabricated by 3D plastic additive manufacturing. The structure is shown in Figure 9.

Figure 9: Filter fabricated by plastic additive manufacturing

The structure has been metallized and characterized. The measured scattering parameters are given in Figure 10.

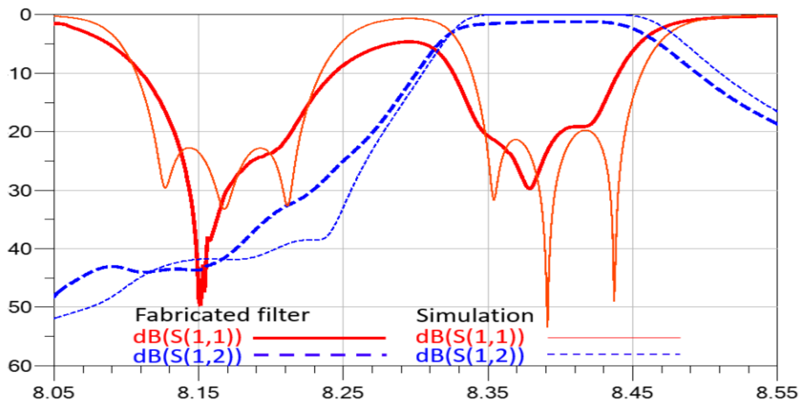

Figure 10: Measured scattering parameters of the fabricated filter

4. Conclusion

A bandpass filter with absorptive stopband has been proposed for matching a multifeed antenna system. Dissipating the signal coupled by neighbouring apertures provide greater isolation. Such a filter has been designed and fabricated using dual-mode cavities.

References

[1] H. Chreim et al., "An Enhanced Ka -Band Reflector Focal-Plane Array Using a Multifeed EBG Structure," in IEEE Antennas and Wireless Propagation Letters, vol. 9, pp. 1152-1156, 2010.

[2] U. Naeem et al., "A simplified methodology for matched filter design with constraints - filter-antenna subsystem for space application," 2010 IEEE MTT-S International Microwave Symposium, Anaheim, CA, 2010, pp. 1664-1667.

[3] Juseop Lee, Tsung Chieh Lee, William J. Chappell, Lumped-element realization of absorptive bandstop filter with anomalously high spectral isolation, IEEE Transactions on Microwave Theory and Techniques, Vol 60, Issue 8, pp 2424–2430, août 2012.

[4] M. Fan, K. Song, L. Yang and R. Gómez-García, "FrequencyReconfigurable Input-Reflectionless Bandpass Filter and Filtering Power Divider With Constant Absolute Bandwidth," in IEEE Transactions on Circuits and Systems II: Express Briefs, doi: 10.1109/TCSII.2021.

[5] R. Gómez-García, J. -M. Muñoz-Ferreras and D. Psychogiou, "Adaptive Multi-Band Negative-Group-Delay RF Circuits With Low Reflection," in IEEE Transactions on Circuits and Systems I: Regular Papers, doi: 10.1109/TCSI.2021.

[6] A. Basti, A. Périgaud, S. Bila, S. Verdeyme, L. Estagerie and H. Leblond, "Design of Microstrip Lossy Filters for Receivers in Satellite Transponders," IEEE Transactions on Microwave Theory and Techniques, vol. 62, no. 9, pp. 2014-2024, Sept. 2014.

[7] L. Llombart, A. Neto, G. Gerini, M. Bonnedal and P. De Maagt, "Leaky wave enhanced feed arrays for the improvement of the edge of coverage gain in multibeam reflector antennas", IEEE Trans. Antennas Propag., vol. 56, no. 5, pp. 1280-1291, May 2008.

[8] H. Chreim, R. Chantalat, M. Thévenot, U. Naeem, S. Bila, S. Verdeyme, et al., "Analysis of capabilities to achieve overlapped radiating apertures by using a multi-feed EBG structure loaded by passive filtering functions", EuCAP, 2010-Apr.-11-16