MICROWAVE APPLICATIONS GROUP

HEAD OF THE GROUP RESEARCH REPORT

Over the past year (June 2017 to May 2018), the group has continued working on its two projects awarded with national and regional public funds, respectively. It is expected that at the end of this year, 2018, when it ends the execution of the regional project, all its main objectives will be achieved.

In addition to these two projects, the group has also obtained national public funding to hire some new researchers and PhD students, who are already collaborating with the group in its different research lines through formation grants and funds for hiring technical and support staff.

Apart from receiving public funding, the GAM activities were also funded through at least five technology transfer contracts with industries and organizations, mainly subscribed with the European Space Agency (ESA).

Regarding the training capacity of the group, we should mention that one PhD doctoral thesis has been publicly defended in the last year -receiving the maximum degree of "Cum Laude"-, and the senior group members are presently supervising another ten more in different research areas.

It is fair to say, from the facts described above, that the quality of the group is growing year by year, therefore becoming a reference in the framework of their research areas and the space sector. More details about the group can be found at: http://gam.webs.upv.es/, or http://www.iteam.upv.es/group/gam/.

1. - PROJECT ACTIVITIES

The main research lines in which the GAM group is currently working are listed below:

- Analysis and design of high frequency (microwaves and millimetre waves) passive circuits implemented in guided, planar, and hybrid (waveguides integrated in dielectric and empty substrates, such as SIW, coaxial SIW, ESIW and ESICL) technologies, using micro-electro-mechanical systems (MEMs), as well as periodic materials (EBGs) and metamaterials.
- Electromagnetic study of dispersion/transmission problems in open space, in connection with the analysis and design of antennas and scattering (radar and remote-sensing) applications.
- Development of algorithms based on artificial intelligence techniques, for the automated synthesis and design of high frequency passive components (e.g. filters and multiplexers).
- Practical design of components (circuits and antennas) for high-frequency communication systems (e.g. wireless, space and mobile systems), including the modelling and experimental validation of high-power effects for satellite applications.

In all these research lines and activities, the group has obtained relevant public funding, through both national and regional projects, making feasible to keep on producing new and relevant results in these R&D topics.

1.1. - ONGOING PROJECTS

COMPASSES Project: Technological Demonstrators for Filters and Multiplexers with Selective and Reconfigurable Responses in New Compact Waveguides for Space Applications

Currently, space communication systems provide a large number of services to our modern Digital Society. For this purpose, on-board payloads operating at lower microwave bands have been used and, since 2006, new satellites offering communication services in the Ka-band are available. Even though all these satellites are continued to be employed, recently, new emerging applications of space communications are forthcoming.

As relevant players in the space sector have pointed out, future space communications must respond to the following new scenarios: data transmission from small platforms (pico- and nano-satellites with scientific and technological missions) in C-band (6 GHz), global Internet Access (from and to the entire planet) through mega-clusters of micro-satellites operating in Ku-band (12-14 GHz), civil and military -security and defence- applications with variable demand of performance (through reconfigurable payloads operating in high frequency bands as Ka, Q, V and W), and new remote sensing services in the sub-millimetre wave range (between 100 GHz and 1 THz).

To meet these emerging applications, future satellites will incorporate new and advanced communication payloads, whose equipment and subsystems (passive components such as filters, diplexers and multiplexers, as well as antennas) are going to require specific technological solutions that best fit to each particular scenario. Therefore, small satellite platforms will need more compact devices and with low manufacturing costs, payloads of next telecommunication satellites (in Ka, Q and V bands) will have to incorporate flexibility (capacity of reconfiguration of operational frequencies and bandwidths, as well as of coverage), whereas components of future space communications operating at higher frequencies (between 100 GHz and 1 THz) will need of manufacturing techniques with higher accuracies.

This joint project aims to offer solutions (through the design, implementation and experimental validation of specific technology demonstrators) to these challenges for the high-frequency equipment (passive components and antennas) of future satellite applications.

This project has been funded by the Programa Estatal de I+D+i Orientada a los Retos de la Sociedad, Ministerio de Economía y Competitividad, Gobierno de España.

FUTUR-SAT Project: Advances in Microwave and Millimetre Wave Components (Circuits and Antennas) for Future Space Communication Systems

Space communication systems, which currently operate in the lower microwave bands, provide key scientific, technological and social services, as well as critical security and defence applications. Since 2006, space communications offer broadband (10 Gbps), TV and video on demand, deep space communications and military applications. Today, the 2nd generation of Ka-band satellites, currently under development and with transmission rates greater than 100 Gbps, will be able to offer advanced mobile communications services, navigation and Earth observation systems, with huge civil, security and defence purposes.

All these future spectral requirements lead to the possibility of using higher frequency bands, such as Q- and V-band (40-60 GHz), which are currently being explored. However, the correct operation of these new services involves many technological challenges in the design of satellite payloads

At these frequencies, losses are high and require transmitting signals with power levels up to 500 W per channel. In addition, new space platforms must handle a large number of channels with very high bandwidths. The reduction of the physical dimensions of the components that integrate these satellites should be also considered, which will have implications in the managing of power levels, and in the precision of the manufacturing processes. Furthermore, the future space communications systems must provide reconfiguration capability of their parameters such as operating carrier frequencies, bandwidths and coverage, as well as to provide adaptive gain controls for atmospheric and environmental conditions changes.

This project aims to offer innovative solutions to all of these technological challenges that future space communications systems must face, more specifically in the area of advances in the development of components (passive circuits and antennas) in the microwave and millimetre wave bands that integrate the payloads and communication modules of the satellites.

This project has been funded by the Programa PROMETEO FASE II para grupos de Investigación de Excelencia, Consellería de Educación, Investigación, Cultura y Deporte, Generalitat Valenciana.

2.- RESEARCH RESULTS

As a result of the joint research activity developed by this group in all these research lines, during the last year of activity, more than 15 articles have been published in scientific journals with a high impact index (such as IEEE Transactions on Microwave Theory and Techniques, IEEE Microwave and Wireless Components Letters, IEEE Transactions on Antennas and Propagation, IET Proceedings on Microwave, Antennas and Propagation, IET Electronics Letters and Radio Science).

At the same time, the group has presented more than 20 communications in prestigious international conferences (such as IEEE-MTT Int. Microwave Symposium, IEEE-AP Int. Symposium on Antennas, European Microwave Conference on Numerical Electromagnetic Modeling and Optimization for RF, Microwave, and Terahertz Applications (NEMO), the 9th International Workshop on Multipactor, Corona and Passive Intermodulation (MULCOPIM'17), the European Microwave Week 2017, and the 2017 ESA Microwave Technology and Techniques Workshop, some of them as invited papers.

Finally, because of the research activity of the group in collaboration with companies and administrations of the aerospace sector, it has recently participated in the development of two patents.

Some of the most outstanding results are described below:

The Microwave Application Group (MAG), in collaboration with the Universidad de

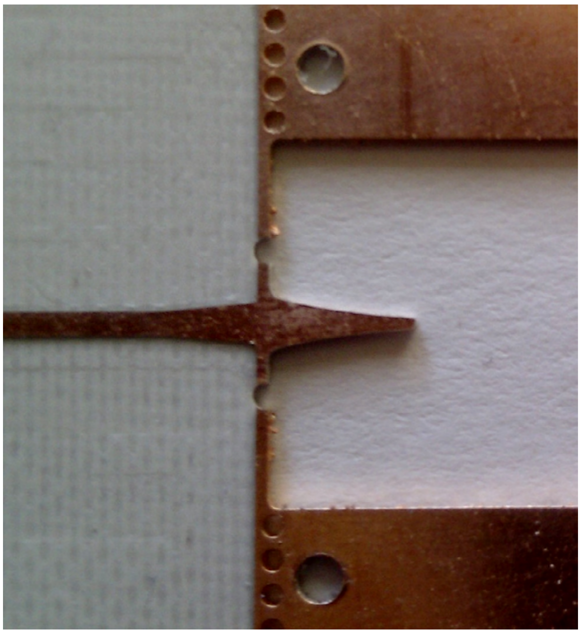

Figure 1: Transition detail from microstrip to ESIW

Castilla-La-Mancha, has developed new empty transmission lines integrated in a planar circuit board. These are the empty substrate integrated waveguide (ESIW), and the empty substrate integrated coaxial line (ESICL). Both lines are low profile, and low cost, and can be manufactured with standard planar circuit machinery. At the same time, they outperform the substrate Integrated waveguide in terms of losses and quality factor in resonators, due to the absence of dielectric. In order to validate the two transmission lines for high performance and high frequency communication systems, in the last year some communication devices have been successfully implemented, such as a narrow-band high-Q filter in ESICL [1], a folded filter in ESIW [2], and a Moreno cross guide coupler [3] in ESIW. Besides, new empty transmission lines have been developed: an E-plane ESIW [4] for implementing traditional E-plane devices, and a decoupled ESIW [5] that allows the polarization of liquid crystal inside the ESIW. Finally, the transition from microstrip to ESIW has been improved (see Figure 1) [6] so that now the insertion losses and reflection levels have both been decreased.

[1] Borja, A. L., Belenguer, A., Esteban, H., and Boria, V. E. (2017). Design and Performance of a High-Q Narrow Bandwidth Bandpass Filter in Empty Substrate Integrated Coaxial Line at $ K_ {u} $-Band. IEEE Microwave and Wireless Components Letters, 27(11), 977-979.

[2] Ballesteros, J. A., Diaz-Caballero, E., Fernandez, M. D., Esteban, H., Belenguer, A., and Boria, V. (2017, October). Performance comparison of a four-pole folded filter realized with standard and empty substrate integrated waveguide technologies. In European Microwave Conference (EuMC), 2017 47th (pp. 412-415). IEEE.

[3] Miralles, E., Belenguer, A., Esteban, H., and Boria, V. (2017). Cross-guide Moreno directional coupler in empty substrate integrated waveguide. Radio Science, 52(5), 597 603.

[4] Belenguer, A., Cano, J. L., Esteban, H., Artal, E., and Boria, V. E. (2017). Empty substrate integrated waveguide technology for E plane high-frequency and high-performance circuits. Radio Science, 52(1), 49-69.

[5] Sánchez, J. R., Bachiller, C., Esteban, H., Belenguer, A., Nova, V., and Boria, V. (2017). New decoupled empty substrate integrated waveguide realisation. Electronics Letters, 53(17), 1203-1205.

[6] Esteban, H., Belenguer, A., Sánchez, J. R., Bachiller, C., and Boria, V. E. (2017). Improved low reflection transition from microstrip line to empty substrate-integrated waveguide. IEEE Microwave and Wireless Components Letters, 27(8), 685-687.

The Microwave Application Group (GAM) and Aurora Software and Testing, S.L (AURORASAT),

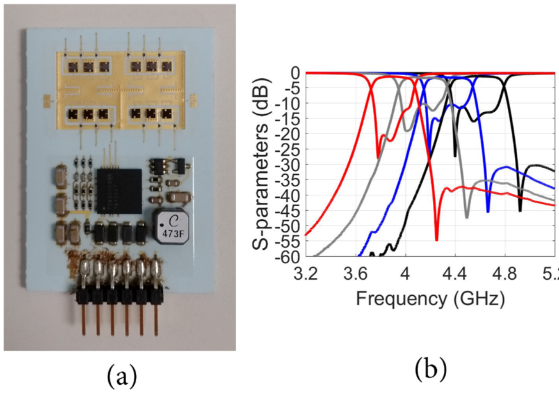

Figure 2: (a) RF MEMS reconfigurable coaxial SIW filter and (b) measured results.

in the framework of the ESA project RFQ/3-14301/15/NL/PA, have demonstrated the possibility of designing high selectivity RF MEMS reconfigurable coaxial SIW filters with wide tuning range and improved Q-factor. They can be used in a great variety of applications in order to increase flexibility and miniaturization, while reducing manufacturing costs. Thus, a discretely tunable 4-pole bandpass filter, which can be switched between four different frequencies has been designed, manufactured and tested. Specifically, the filter must cover the C-band between 3.7 GHz and 4.5 GHz with four equally spaced frequency responses showing constant FBW while providing more than 15% of tuning range. A potential application for such tunable components would be the implementation of flexible wideband receivers, especially for the uplink C-band for satellite applications. The basic building block of the proposed tunable filter is based on a coaxial topology implemented in SIW technology [1]. The use of the multi-layer LTCC technology enables us to implement a monolithic integration of the tuning element control unit and the reconfigurable filter, as shown in Figure 2. This solution helps the designers to improve the overall EM performance of the component while achieving a remarkable miniaturization degree. In order to allow for digital frequency tuning of the filter, embedded loading capacitive patches are introduced by inserting electrically isolated bit capacitances at the top metal layer of the filter layout, as proposed in [2]. These bit capacitances are connected and disconnected from the remaining filter metallization, thus performing the filter frequency tunability, by using RF MEMS resistive switches from AirMems [3]. In this context, the RF MEMS switch AIM-OS100310 is fabricated on a high resistivity silicon substrate. The device is wafer-level packaged, and hermetically sealed with a temperature resistant material, which provides a great easiness of integration into RF circuits. It is a single pole, single throw MEMS resistive switch. Due to its high linearity level and very low power consumption, this switch represents a good solution for many wireless infrastructure applications.

[1] S. Sirci, J.D. Martínez, M. Taroncher, and V.E. Boria, ''Varactor-loaded continuously tunable SIW resonator for reconfigurable filter design'', 41st EuMW 2011, Manchester (UK), Oct. 2011, pp. 436–439.

[2] S. Sirci, J.D. Martínez, R. Stefanini, P. Blondy and V.E. Boria, "Compact SMD packaged tunable filter based on substrate integrated coaxial resonators", in Proc. IMS IEEE MTT-S, Jun. 2014.

[3] AirMems AIM-OS100314SPST RF MEMS Switch Data Sheet, Limoges (France).

2.1.- FEATURED PUBLICATIONS

Some of the most recent and relevant publications of the R&D group in the last year are briefly summarized next.

New Decoupled Empty Substrate Integrated Waveguide Realisation, J.R. Sánchez, C. Bachiller, H. Esteban, A. Belenguer, V. Nova, V.E. Boria, Electronics Letters, vol. 53, pp. 1203-1205, Aug. 2017.

DOI: 10.1049/el.2017.1240

A novel decoupled empty substrate integrated waveguide (DESIW), which enables AC/DC decoupling in any device that is integrated in it is presented. The decoupling strategy is performed throughout a micro-milling square pattern of easy implementation that increases the insertion losses compared with the standard ESIW. However, the DESIW related losses are still tolerable, allowing the employment of the new periodic structure in many practical applications. In particular, it can be used for the design and manufacturing of reconfigurable devices which need a bias voltage on the whole device, or just on some of its particular areas. A broadband transition from DESIW to microstrip planar lines has been also successfully designed. The new line has been manufactured and measured.

Advanced Compact Setups for Passive Intermodulation Measurements of Satellite Hardware, D. Smacchia, P. Soto, V.E. Boria, M. Guglielmi, C. Carceller, J. Ruiz-Garnica, J. Galdeano, D. Raboso, IEEE Transactions on Microwave Theory and Techniques, vol. 66, pp 700-710, Feb. 2018.

DOI: 10.1109/TMTT.2017.2783383

Guideline for the practical development of novel advanced test beds for passive intermodulation (PIM) measurements. The proposed test beds show high performance and are flexible, allowing for the measurement of several PIM signals of different orders, with two or more input carriers. In contrast to classic test beds for satellite hardware an integrated solution involving the minimum number of hardware pieces is proposed. The result is a lower number of flanged interconnections, thus reducing residual PIM level and insertion losses. In addition, return loss degradation and harmful spurious generation in the interconnections are also avoided. Measurement test beds for conducted and radiated PIM are discussed, highlighting the benefits and drawbacks of each configuration. Design guidelines for the key components are fully discussed. Finally, excellent experimental results obtained from low-PIM measurement setups, working from C-band to Ka-band, are shown, thus fully confirming the validity of the proposed configurations.

Novel Planar and Waveguide Implementations of Impedance Matching Networks Based on Tapered Lines Using Generalized Superellipse, S. Cogollos, J.J. Vague, V.E. Boria, J.D. Martínez, IEEE Transactions on Microwave Theory and Techniques, vol. 66, pp. 1874-1874, April 2018.

DOI: 10.1109/TMTT.2018.2791952

For the practical implementation of RF and microwave impedance matching networks, a widely employed solution is based on tapered lines. This paper shows a simple method to design smooth tapers that take into account the dispersion of the line and the required design bandwidth simultaneously. A planar taper has been designed in microstrip technology with the same length of classical ones but improving their performances. A waveguide prototype has also been designed with similar performance to a commercial one but with one third of its length. Both tapered structures have been obtained through the optimization of very few parameters using the same design strategy. As a result, the reflection coefficient of the tapers can be optimally adapted to a given specific mask using the prescribed value of physical length. Experimental results for both tapers are included for the validation of the proposed topologies and the related design method.

Exploring the Tuning Range of Channel Filters for Satellite Applications Using Electromagnetic-Based Computer Aided Design Tools, J. Ossorio, J.J. Vague, V.E. Boria, M. Guglielmi, IEEE Transactions on Microwave Theory and Techniques, vol. 66, pp. 717-725, Feb. 2018.

DOI: 10.1109/TMTT.2017.2769083

The objective of this paper is to use electromagnetic-based computer-aided design (CAD) tools to investigate the maximum tuning range of channel filters, typically used in satellite payloads. Both circular and rectangular waveguide technologies are investigated. The results of the investigation show that single-mode rectangular waveguide implementations offer substantially wider tuning range, as opposed to classical dual-mode circular waveguide implementations. In addition to simulations, measurements are also presented indicating very good agreement with theory, thereby fully validating the CAD procedure.

Compact Wideband Balanced Bandpass Filters With Very Broad Common-Mode and Differential-Mode Stopbands, M. Sans, J.Selga, P.Vélez, J. Bonache, A.M. Rodriguez, V.E. Boria, F. Martín, IEEE Transactions on Microwave Theory and Techniques, vol. 66, pp 737-750, Feb. 2018.

DOI: 10.1109/TMTT.2017.2785246

Compact balanced bandpass filters based on a combination of multisection mirrored stepped-impedance resonators and interdigital capacitors are presented in this paper. The considered filter topology is useful to achieve wide bandwidths for the differential mode as well as very efficient common-mode suppression. By conveniently adjusting the transmission zeros for both operation modes can be extended up to significantly high frequencies. Filter size and this performance are the main relevant characteristics of the proposed balanced filters. The potential of the approach is illustrated by the design of a prototype order-5 balanced bandpass filter, with central frequency f_0 = 1.8 GHz, 48% fractional bandwidth (corresponding to 55.4% -3-dB bandwidth), and 0.04-dB ripple level. The designed filter is as small as 0.48λg x 0.51λg, where λg is the guided wavelength at the central filter frequency, and the differential-mode stopband extends up to at least 6.5 GHz with more than 22-dB rejection.

2.2.- PATENTS

In the last year, the processing of the next two patents has been advanced:

M. Guglielmi, V.E. Boria, M. Baquero, G. Toso, P. Angeletti

BELOW CUTOFF ARRAYS

Pub. No.: P201730838

Pub. Date: 26/06/2017

International Patent Extension Application 09/01/2018

V.E. Boria, M. Baquero, D. Sánchez-Escuderos, M. Guglielmi

THE WAVEGUIDE CROSSOVER FILTER

Pub. No.: P201830106

Pub. Date: 07/02/2018

2.3.- AWARDS

Elevation to Fellow of the IEEE is an honor reserved for a select group of engineers each year. The number of Fellows elevated in any year cannot exceed one-tenth of 1% of the total voting membership. This highest grade of membership in the IEEE is conferred by the IEEE Board of Directors in recognition of an individual's outstanding record of accomplishments in any IEEE field of interest. And this year, with the IEEE Microwave Theory and Techniques Society (MTT-S) as the evaluating Society, 1 of the honorees awarded the status of member of the IEEE has been the head of or group, Vicente E. Boria Esbert, for his contributions to high-power microwave filters and multiplexers