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Microwave Applications Group (GAM) Annual Research Report 2016/2017

Head of the Group research report

The Microwave Applications Group (GAM), that was set up in 1997, focuses its research activities on the development of techniques for analysis and design of passive components implemented in different technologies: coaxial, waveguide, planar and hybrid ones (such as substrate integrated waveguides, SIWs, and alternative realizations like empty and coaxial SIWs) and employing conductors, dielectrics, periodic structures (EBGs) and/or tuning elements (varactors and micro-electro-mechanical systems as MEMs).

During the 20 years of joint activity of this group (GAM), the number of members and achievements has grown steadily. Nowadays the group is composed by 14 members including academic staff (Dr. Vicente Boria -Head of the Group-, Dr. Héctor Esteban, Dr. Santiago Cogollos, Dr. Pablo Soto, Dr. Ana Vidal, Dr. Carmen Bachiller and Dr. José Vicente Morro), researching staff (presently 2 post-docs: Dr. Stefano Sirci and Dr. Ana Rodríguez, and one guest senior researcher Dr. Marco Guglielmi), technical staff (Màriam Taroncher, Marta Reglero) and management staff (María Bayarri). The group has a strong and long-lasting collaboration with Dr. Jorge D. Martínez (a very active researcher of the UPV Institute on Instrumentation for Molecular Imaging, I3M). There are also several (international and national) students doing their PhD or Master thesis within the group, as well as invited researchers doing stages during different periods.

The GAM is one of the co-founder research groups of the UPV Institute on Telecommunications and Multimedia Applications (iTEAM), as well as of the spin-off company Aurora SAT (which is presently located in the UPV Scientific Park facilities). Moreover, it was strongly involved in the creation of the Valencia Space Consortium (VSC), a regional public consortium for promoting and leading Space-related scientific, technological and dissemination activities, and where Prof. Vicente E. Boria is presently the Chairman of its Executive Commission.

As a result of the research activity developed over the last years, the group has obtained financial support for teams with proven scientific-technical quality and has participated in numerous projects at international, national and regional level. Among all of them, we first highlight an international project funded by the European Commission within Marie Curie – Career Integration Grant Program (Acronym: SIWTUNE, Ref: FP7-PEOPLE-2012-CIG, PCIG11-GA-2012-322162), lasted 4 years and recently concluded in February 2017. During the last year (2016), we have also completed an R&D project funded by Ministerio de Economía y Competitivad, Spanish Government (Acronym: RECOMPENSE, Ref: TEC2013-47037-C5-1-R), and we have just started a new one as a follow-up of the main research lines of the group (Acronym: COMPASSES, Ref: TEC2016-75934-C4-1-R). In addition, we are still developing the 2nd phase of a regional project for groups developing high-quality research activities, which is granted until the end of 2018 (Acronym: FUTUR-SAT, Ref: PROMETEOII/2015/005) and it is jointly developed with the Electromagnetic Radiation Group (GRE) of iTEAM.

Apart from receiving public funding, the GAM activities are also funded through technology transfer contracts with industries and organizations, mainly subscribed with the European Space Agency (ESA) and with national companies of great relevance in the space communications sector (such as Thales Alenia Space and EADS-CASA).

Regarding the training capacity of the group, we should mention that up to three PhD doctoral theses have been publicly defended in the last year -receiving all of them the maximum degree of "Cum Laude"-, and the senior group members are presently supervising another six more in different research areas. In addition, the group is strongly involved in the organization of a course on passive microwave components course for space communications systems, taught by people of renowned experience and relevance in the sector. Two editions of this course have already been celebrated, and it is expected to continue this activity in collaboration with ESA and the European Microwave Association (EuMA).

Since June 2010, the group actively collaborates with the European High Power RF Space Laboratory, which is the ESA Laboratory specialized

in RF breakdown phenomena (Multipactor, Corona and power handling) and passive inter-modulation (PIM). The laboratory relies on two class 10000 (ISO 7 category) clean rooms with a total working area of 200 m2. The facility includes seven high vacuum chambers and several dedicated state-of-art high power RF tests beds, operating over a wide frequency range from 435 MHz up to 30 GHz. Together with other UPV research groups, the GAM also participates in the joint Laboratory for High Frequency LTCC Circuits (LCAF), which is operating since 2013. This laboratory is located within a clean room class 10000/1000, and has unique national equipment for the manufacture of circuits in LTCC technology.

It is fair to say, from the facts described above, that the quality of the group is improving 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.html.

1.- Project activities

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

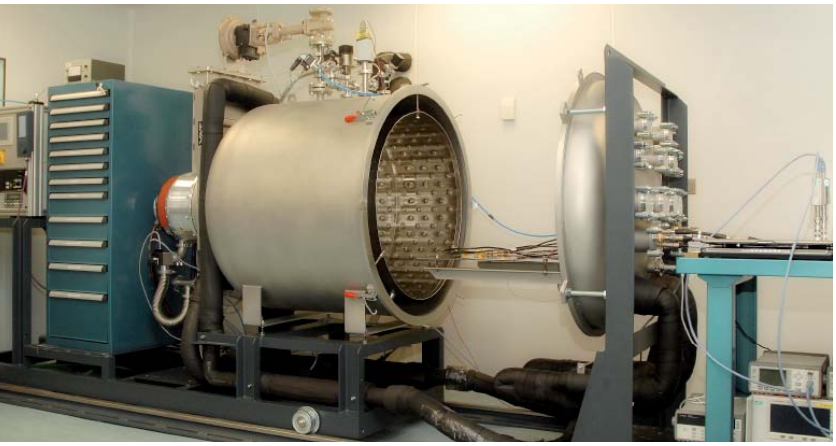


Figure 1. Experimental facilities for manufacturing circuits (left), and measuring high-power effects (right).

- Analysis and design of high frequency passive circuits (microwaves and millimetre waves) 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, and its application to the rigorous 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.
- Practical design of components (circuits and antennas) for radio communication systems (wireless, space and mobile systems) operating in the high bands of the frequency spectrum (i.e. microwaves, millimetres waves and sub-millimetres waves).

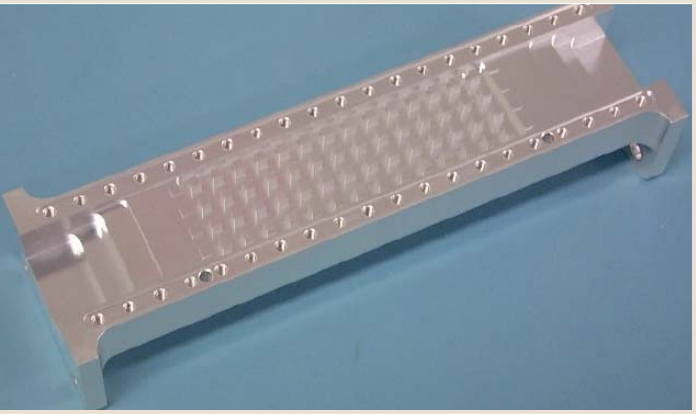
Along the past years, the group has obtained practical experience in the design of multiple passive components for high-frequency (microwave and millimetre waves) applications in different technologies. These components include tuneable coupled cavity filters for space and LMDS systems, dual-mode circular-guide filters with elliptical irises and tuning screws for satellite payloads, compact solutions of evanescent and double-corrugated mode filters, passive components (filters and multiplexers) considering typical mechanizations effects (rounded corners), and passive devices (filters, couplers and diplexers) in several hybrid technologies (e.g. in SIW, coaxial SIW, ESIW and ESICL).

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

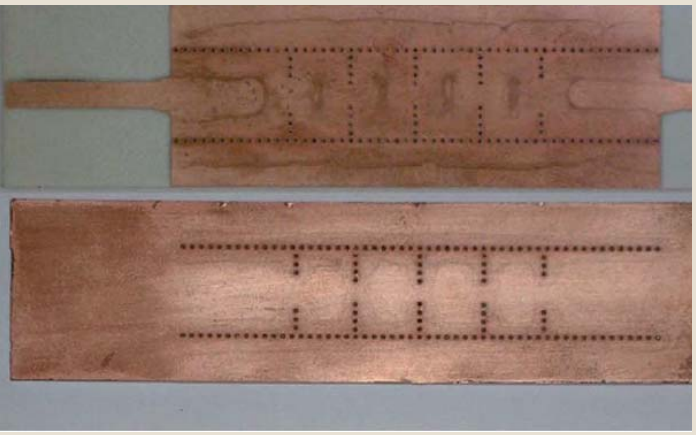
1.1.- Ongoing projects

COMPASSES project: Demostradores Tecnológicos de Filtros y Multiplexores con Respuestas Selectivas y Sintonizables en Nuevas Guías Compactas para Aplicaciones Espaciales

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



a)



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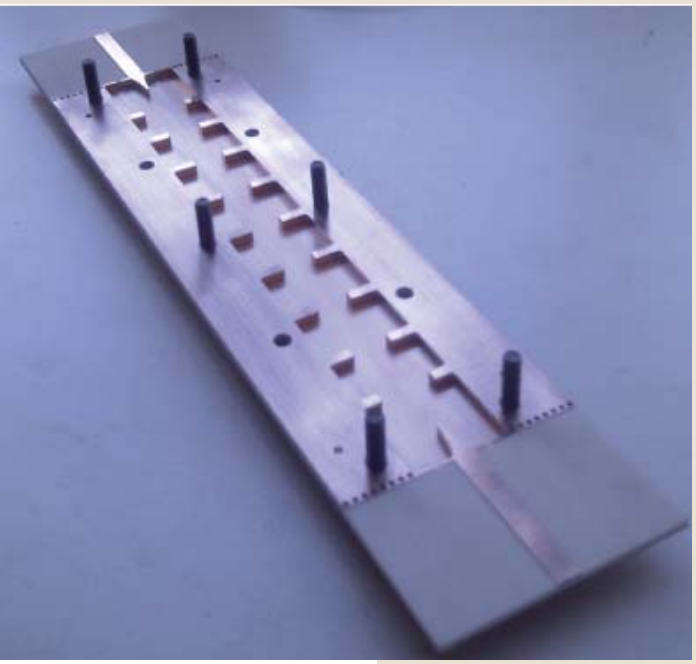

c)

Figure 2. Examples of high frequency passive components designed by the group in different technologies: double-corrugated low-pass filter in a), filters in substrate integrated (SIW) technology in b) and in empty substrate (ESIW) in c)

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: Avances en Componentes (Circuitos y Antenas) de Microondas y Ondas Milimétricas para Futuros Sistemas de Comunicaciones Espaciales

Space communications 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 10 years of activity, more than 100 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, and Radio Science).

At the same time, the group has presented more than 150 communications in prestigious international conferences (such as IEEE-MTT Int. Microwave Symposium, IEEE-AP Int. Symposium on Antennas, European Microwave Conf., PIERS, and ICEAA), 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.

2.1.- Featured publications

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

M. Orellana J. Selga, P. Vélez, M. Sans, A. Rodriguez, J. Bonache, V. E. Boria, F. Martín, "Design of Capacitively Loaded Coupled-Line Bandpass Filters With Compact Size and Spurious Suppression," in IEEE Transactions on Microwave Theory and Techniques, vol. 65, no. 4, pp. 1235-1248, April 2017.

DOI: 10.1109/TMTT.2016.2638843

This paper is focused on the synthesis of capacitively loaded coupled lines for the design of bandpass filters with compact size and spurious suppression. The filters consist of cascaded pairs of coupled lines periodically loaded with patch capacitors. The loading capacitances provide a slow-wave effect to the coupled lines useful for filter miniaturization, whereas periodicity introduces bandgaps that can be controlled in order to achieve spurious suppression. Filter design is achieved following an automated process based on aggressive space mapping (ASM) optimization. The two reported examples, demonstrate the potential of the proposed ASM-based design approach, as well as the effectiveness of the loading capacitances to reduce filter size and reject the spurious bands. Significant size reduction in both filters is achieved, whereas the out-of-band rejection is better than 30 and 45 dB in the third-order and fifth-order filters, respectively, up to at least 4f0.

M. Á. Sánchez-Soriano, S. Sirci, J. D. Martínez and V. E. Boria, "Compact Dual-Mode Substrate Integrated Waveguide Coaxial Cavity for Bandpass Filter Design," in IEEE Microwave and Wireless Components Letters, vol. 26, no. 6, pp. 386-388, June 2016.

DOI: 10.1109/LMWC.2016.2558651

This letter proposes a new compact filtering building block. It consists of two via holes embedded into a substrate integrated waveguide (SIW) cavity connected to capacitive metal patches at the top layer. This topology provides two coaxial modes performing a doublet filtering configuration. The proposed dual-mode SIW coaxial cavity is studied in detail and guidelines for the filter design are given. As will be shown, the proposed building block presents a high degree of design flexibility, which allows for the design of multiple kind of bandpass filter (BPF) responses, including both narrow- and wide-band BPFs along with transmission zero generation. As a verification, several filters are designed and implemented at 8 GHz.

C. Bachiller, H. Esteban, F. Díaz, J.V. Morro, V.E. Boria, "Radio-Frequency Performance Comparison of Several H-Plane Rectangular Waveguide Filters Loaded With Circular Dielectric Posts," in IET Proceedings on Microwaves, Antennas and Propagation, vol. 10, no. 5, pp. 536-545, April 2016.

DOI: 10.1049/IET-MAP.2014.0738

The study presents a radio-frequency performance comparison between several H-plane geometry filters based on rectangular waveguide technology. The basic all-metal filter of resonant cavities is compared with filters loaded with circular dielectric resonators, either in propagative or evanescent mode. The use of these resonators is claimed to reduce the length of the filter, increase the rejection band until the first spurious frequency and to improve the voltage magnification factor (VMF), at the cost of increasing the losses. Therefore, in order to properly assess and quantify the possible advantages of these filters, an accurate analysis of six of them has been developed. All the filters have been designed to have the same electrical response, and the length, losses, rejection band, VMF, and fabrication cost for all the filters are compared.

C. Carceller, P. Soto, V. E. Boria and M. Guglielmi, "Design of Hybrid Folded Rectangular Waveguide Filters With Transmission Zeros Below the Passband," in IEEE Transactions on Microwave Theory and Techniques, vol. 64, no. 2, pp. 475-485, Feb. 2016.

DOI: 10.1109/TMTT.2015.2510644

The design and physical implementation of hybrid folded rectangular waveguide filters providing multiple transmission zeros (TZs) below the passband are considered in this paper. These structures offer great flexibility to locate the TZs in a wide frequency range. Different implementations have been considered, each one offering certain advantages in terms of ease of manufacture, number of TZs, and their separation from the passband. A simple design procedure is also described. Measurements of a manufactured five-pole filter prototype and simulations fully validate the novel configurations proposed in this study.

A. Berenguer, V. Fusco, D. E. Zelenchuk, D. Sánchez-Escuderos, M. Baquero-Escudero and V. E. Boria-Esbert, "Propagation Characteristics of Groove Gap Waveguide Below and Above Cutoff," in IEEE Transactions on Microwave Theory and Techniques, vol. 64, no. 1, pp. 27-36, Jan. 2016.

DOI: 10.1109/TMTT.2015.2504501

Recently, gap waveguides have been shown as a potential alternative to conventional waveguides in the millimetre-wave band. Until now, groove gap waveguide (GGW) has been studied through direct correspondence with rectangular waveguide with the same physical dimensions. However, there have been observed differences in the above cut off propagation characteristics between these two waveguide types. Furthermore, the behaviour of GGW below cut off remains unknown. This work presents a discussion of both below and above cut off propagation characteristics of GGW, and introduces a simple model that explains the observed GGW behaviour and establishes well its propagation characteristics. Two thru-reflect-line calibration kits have been manufactured, and the measurements have good agreement with the proposed analysis model results.

2.2.- Patents

In the last year, one patent has been processed, and it has been requested an international extension of another one, with the following data:

A. Belenguer, A. Lucas, H. Esteban, V.E. Boria
STRUCTURE FOR THE TRANSITION OF TWO SIGNAL TRANSMISSION LINES IN A PCB
Pub. No.: WO/2016/156642
Pub. Date: 06.10.2016
International Application No.: PCT/ES2016/070210
International Filing Date: 23.03.2016

A. Belenguer, E. Díaz, H. Esteban, V.E. Boria
DEVICE FOR CALIBRATING NETWORK ANALYSERS
Pub. No.: WO/2016/051008
Pub. Date: 07.04.2016
International Application No.: PCT/ES2015/070721
International Filing Date: 02.10.2015