Microwave Applications Group (GAM)

HEAD OF THE GROUP RESEARCH REPORT

Over the past year (September 2021 to July 2022), the group has continued working on two projects awarded with national and regional public funds, respectively. Both projects are in the final phase of their whole execution periods, and promising results are being obtained during their development.

In addition to these two R&D projects, the group has national and regional public funding to train new researchers and PhD students, who are already collaborating with the group in its different technology transfer activities and present research lines.

Furthermore, GAM continues involved in two European Union projects and grants, which are developed in collaboration with other European universities and industries, for the training of young scientists and performing research activities in the satellite communications sector.

Apart from public funding, the GAM activities are also financed through several technology transfer agreements with different industries and organizations, mainly subscribed with the European Space Agency (ESA) and many other space-sector companies.

Regarding to the training capacity of the group, it is worth mentioning that two doctoral thesis have been successfully defended during the last year. Meanwhile, other pre-doctoral students continue developing their investigation with the supervision of group senior members. In some cases, our doctorate students have performed short-term research stages in centers of excellence on topics related to their PhD thesis works. During the next years it is hoped that we can continue sending students to carry out the planned stays, and to host several foreign students doing part of their research work together with us.

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 (high-frequency components) and the space sector. A complete list of research activities and further details about the group can be found at the following links: 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 (microwave and millimetre-wave) 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, diplexers, 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 and private funding, through European, national and regional projects as well as through research contracts with industries, making feasible to keep on producing new and relevant results in the R&D topics mentioned above.

1.1.- Ongoing projects

GUIDESAT Project: Advanced Design of New High Frequency Components in Compact Waveguide Technologies for Future Telecommunications Satellites

Retos Investigación: Proyectos I+D+i 2019

Programa Estatal de I+D+i Orientada a los Retos de la Sociedad, Ministerio de Economía y Competitividad, Gobierno de España. 01/06/2020 – 31/05/2023

The most relevant European satellite communication systems and applications are currently supporting a huge number of services of modern Digital Society. Among them, we highlight the global navigation system GALILEO, meteorological and Earth Observation programs like COPERNICUS, nanosatellites for scientific missions and big constellations of small satellites for implementing the upcoming "Internet of Satellites", as well as large Telecommunication satellites in geostationary orbit. Thanks to these satellite payloads, many civil and military applications and a wide variety of sectors are being benefitted globally.

With the aim of keeping the growing rate of such applications, all cited space programs are already deploying their future evolutions. Among them, one can find the Galileo second generation project, the next generations of meteorological (METEOSAT and METOP) satellites, the near future SENTINEL missions, the coming breed of small platforms for Starlink and OneWeb constellations, and the new large multi-beam space platforms operating in the millimetre wave (and sub-millimetre wave) frequency ranges (up to some terahertz). All these next-generation satellites will need more advanced communication payloads based on novel equipment with more stringent requirements.

The main aim of this coordinated project is to address all identified challenges by designing novel passive components and antennas for next-generation satellite communication systems, including their prototyping and experimental validation. For that purpose, the four sub-projects will closely work on all available high-frequency technologies: i.e. more classical ones based on planar circuits and waveguides, more recent integrated planar waveguides with/without dielectric substrate, and the promising concept of gap waveguides. Advanced materials (such as bioplastics, artificial materials, liquid crystals, and also gallium nitride and graphene for terahertz frequencies), as well as manufacturing techniques (classical milling, 3-D fabrication methods, LTCC and micromachining processes), will be also investigated.

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.

SPACE – VLC Project: Advanced technological demonstrators for emerging and inclusive space applications in the microwave and millimeter wave bands

Prometeo – 2019

Subvenciones para la realización de proyectos de I+D+i para grupos de investigación de excelencia PROMETEO 2019, Conselleria de Innovación, Universidades, Ciencia y Sociedad Digital, Generalitat Valenciana. 01/01/2019 – 31/12/2022

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.

To meet all these emerging applications, future satellites will incorporate new and advanced communications payloads, whose equipment and subsystems (passive components such as filters, with various responses and functions, diplexers and multiplexers, as well as antennas) will require technological specific solutions, better adapted to each specific scenario. Thus, this R&D project aims to offer solutions (through the design, implementation and experimental validation of specific technological demonstrators) to these great challenges in new high-frequency equipment (passive components and antennas) for future space applications. In order to achieve this, the most appropriate technologies (more classic ones such as planar and waveguides, or more recent ones such as the hybrid guided-planar SIW and its novel embodiments without dielectric substrate -ESIW and ESICL-, or guides with corrugated walls also known as groove gap waveguide), the materials (dielectrics, ferrites and liquid crystal) and novel manufacturing techniques (LTCC and additive manufacturing) will be considered in each application.

SELECTOR Project: SMT Compatible Electromechanical Relay for Compact Redundancy Ring

www.selectorspace.eu

H2020-RIA (Research and Innovation Action) Program. 01/01/2019 – 31/12/2021

Figure 1: SELECTOR Project Logo.

SELECTOR project (funded as an H2020 Research and Innovation Action) is focused on the development of innovative passive components to increase the number of freely accessible space qualified passive components; thus, contributing to the European policy about "Reaching non-

dependence in certain technologies that will open new markets to industries and will increase the overall competitiveness of the European Space sector".

SELECTOR aims at developing Surface Mount Technology (SMT) compatible electromechanical switches for space sector high miniaturization. These devises called "Miniature Electro-Mechanical Relay" (MEMR), already exist for microwave industrial ground application like Automatic Test Equipment. SELECTOR will deliver MEMR as part of ESA portfolio European Preferred Part List (EPPL) so that this high integration, high performance passive component be available with non-restriction for the whole European industry. SELECTOR will also demonstrate a whole new approach of self-redundant microwave equipment called "Meta-equipment" based on microwave specific SMT board level assembly and MEMR components to minimize cost and improve integration. This demonstrator will address Very High Throughput Satellites (VHTS) emerging applications, where the new paradigm is the introduction of digital technologies dealing with very high number of RF chains. New evolution toward RF high power and high frequency capability will be implemented to open-up new sector of application within Space satellites (Navigation, earth observation), but also non-space sectors.

In the framework of this project, the GAM group is directly involved in the (theoretical and practical) evaluation of the new developed passive components in terms of high-power and high-frequency space applications.

TESLA Project: Advanced Technologies for future European Satellite Applications

https://tesla.unilim.fr/

H2020-MSCA-ITN-2018 (Marie Skłodowska-Curie Innovative Training Networks) Program. 01/01/2019 – 31/12/2022

Figure 2: TESLA Network Logo.

Space sector is key and strategical asset for Europe to face global challenges, which must continue to be developed to have a prominent role in the world, contributing to the independence security and prosperity of Europe. Since satellite payload RF components and systems are essential for delivering mission objectives and supporting ground equipment, new technologies and techniques are required to respond to emerging satellite applications and technology challenges.

To this end, TESLA ETN (European Training Network) will create a multidisciplinary research environment to develop the Advanced Technologies for future European Satellite Applications. It will set up collaborations with senior staff in academic and industrial sectors to conduct top research into new and enabling technologies for satellite flexible payloads, big constellation systems, satellite high-speed communications and remote sensing, as well as large satellite platforms. TESLA will also implement a unique research program, with the objective to push the next generation of creative, entrepreneurial and innovative satellite communication developers, to enhance the European space economy and business through outreach activities for a wider economic and social impact.

2.- Research results

As a result of the joint research activity developed by this group in its research lines, during the last year of activity, 12 articles have been published in scientific journals with a high impact index (such as IEEE Transactions on Microwave Theory and Techniques, IEEE Access, IEEE Microwave and Wireless Components Letters, and IEEE Journal of Microwaves).

At the same time the group has presented up to 7 scientific communications in prestigious international conferences (such as the 2021 IEEE MTT-S International Microwave Symposium -IMS-, 2021 IEEE MTT-S International Microwave Filter Workshop -IMFW-, 2021 51st European Microwave Conference -EuMC-, 2021 18th European Radar Conference -EuRAD-), some of them in on-line format.

Finally, due to the research activity of the group developed in collaboration with companies and administrations of the aerospace sector, it has recently participated in the development of one new patent (see more details in section 2.2. of this report).

2.1.- Featured publications

Some of the most recent and relevant publications of the GAM group in the last year are briefly summarized next:

High Power RF Discharge Detection Technique Based on the In-Phase and Quadrature Signals, Oscar Monerris-Belda, Raúl Cervera, Miguel Rodríguez, Elena Díaz-Caballero, Carlos Alacide, John Petit, Vicente E. Boria, Benito Gimeno, David Raboso, IEEE Transactions on Microwave

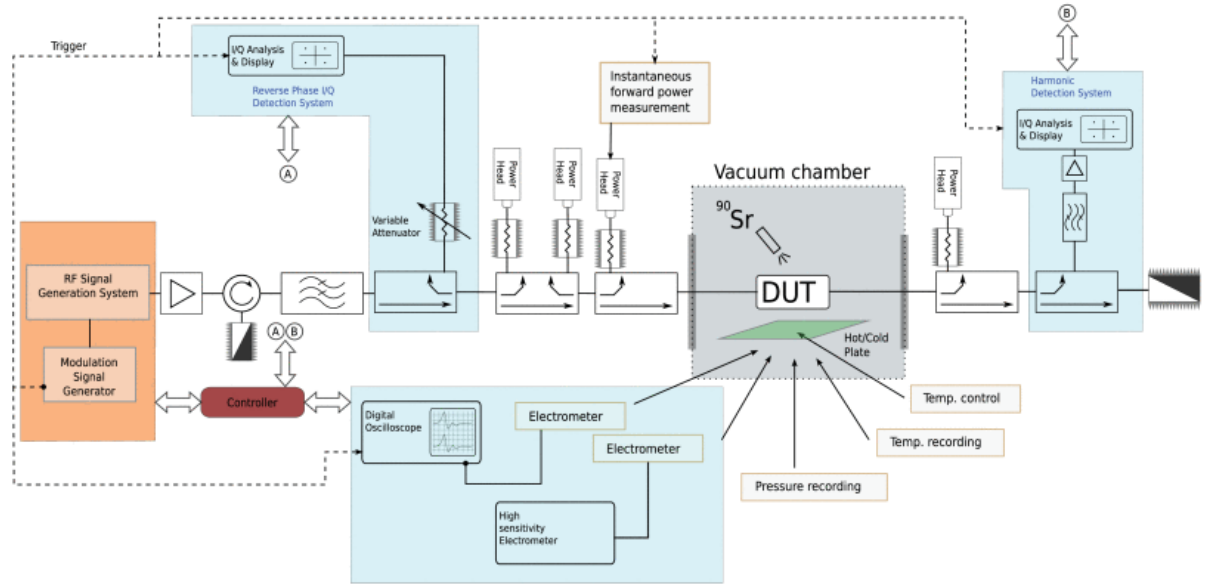


Figure 3: Schematic of the test bed used for the IQ validation test campaign.

Theory and Techniques, Vol. 69, no. 12, pp. 5429-5438, Dec. 2021, Q1

This work presents a novel RF breakdown detection system, which monitors the same parameters as the microwave nulling system but with several advantages. The proposed technique is broadband and uses a larger analysis bandwidth, thus reducing the cases in which a small response is difficult to be classified. It also represents a major step forward in high power testing as it runs without human intervention, warning the operator or decreasing the RF power automatically.

Hybrid Wideband Staircase Filters in Rectangular Waveguide With Enhanced Out-of-Band Response, Joaquin F. Valencia Sullca, Marco Guglielmi, Santiago Cogollos, Vicente E. Boria, IEEE Transactions on Microwave Theory and Techniques, pp. 3783 – 3796, Vol. 69, Issue 8, Aug. 2021, Q1

The objective of this article is to describe the design of a new family of wideband filters in a rectangular waveguide based on hybrid couplings and a staircase configuration. The design of several hybrid filter prototypes is discussed in detail, and finally, simulations and measurements for an eight-pole filter prototype are also compared, showing very good agreement, thereby fully validating both the design procedure and the new filter topology that we propose.

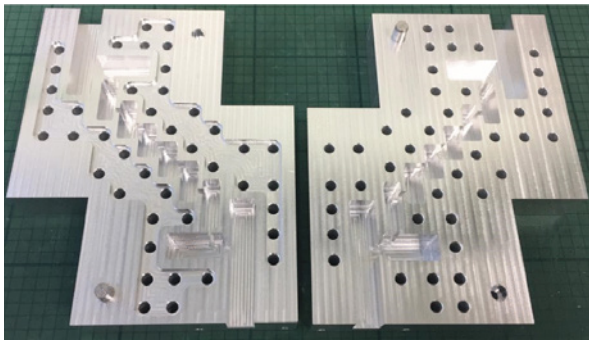
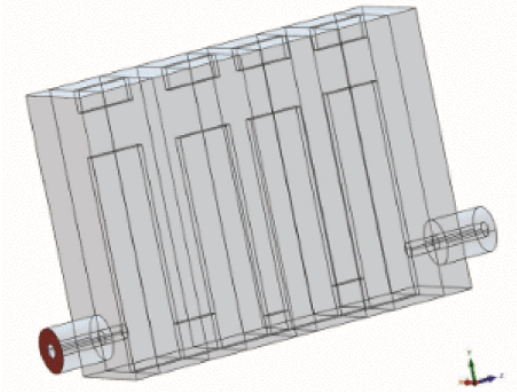


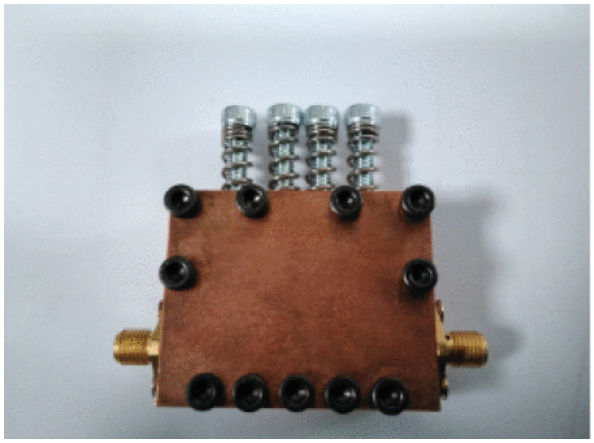
Figure 4: Manufactured prototype in aluminum (no silver plating).

Inline Combline Filters of Order N With up to N + 1 Transmission Zeros, José Joaquín Vague, David Rubio, Miguel Angel Fuentes, Santiago Cogollos, Mariano Baquero, Vicente E. Boria, Marco Guglielmi, IEEE Transactions on Microwave Theory and Techniques, pp. 3287 – 3297, Vol. 69, Issue 7, July 2021, Q1

In this article, we describe several alternative inline implementations for combline filters with transmission zeros (TZs) located both below and above the passband. Good agreement between the measured and simulated results is demonstrated, thereby fully validating the new filter concepts.



(a)

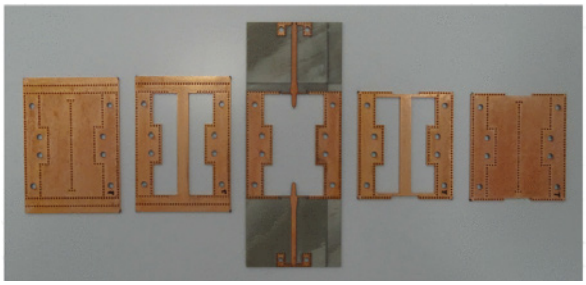


(b)

Figure 5: Four-pole filter with TZs above the passband. (a) Inner view designed with FEST3D. (b) Photograph of the manufactured prototype.

Microstrip to Double Ridge Empty Substrate Integrated Waveguide Transitions Based on Exponential and Superelliptical Dielectric Taper, David Herraiz, Héctor Esteban, Darío Herraiz, Ana Vidal, Angel Belenguer, Vicente E. Boria, IEEE Access, vol. 9, pp. 165745-165753, Dec. 2021

The operational (monomode) bandwidth of the ESIW can be increased with the Single Ridge ESIW (SRESIW). However, the bandwidth can be further increased with the Double Ridge ESIW (DRESIW). In this paper, a brief study of possible DRESIW geometries has been performed, and



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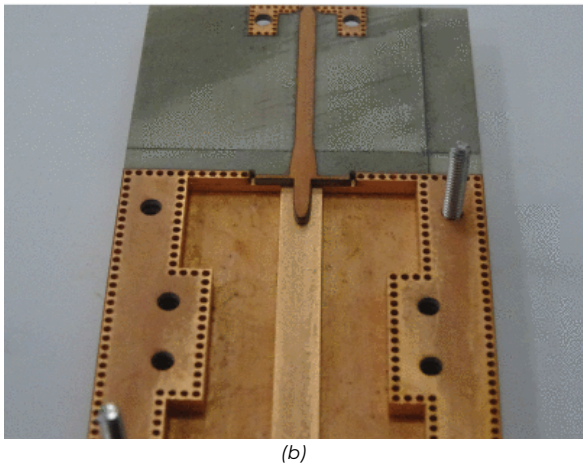
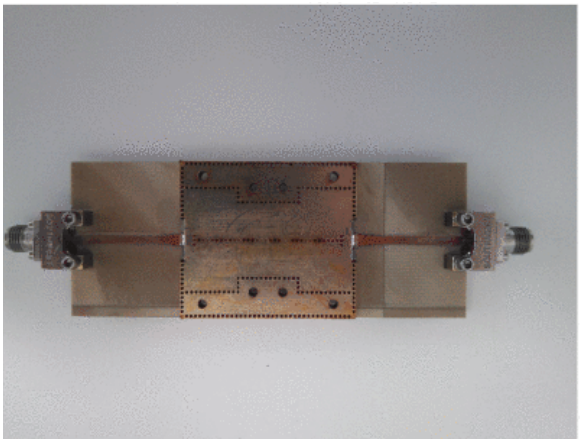


(b)



(c)

Figure 6: Back-to-back manufactured prototype of the superellipse microstrip to DRESIW transition.

two transitions from microstrip line (MS) to DRESIW with a dielectric taper geometry based on different equations are proposed.

Inductive Cascaded Quadruplet with Diagonal Cross-Coupling in Rectangular Waveguide, Santiago Cogollos, Richard J. Cameron, Marco Guglielmi, Juan Carlos Melgarejo, Vicente E. Boria, IEEE Access, vol. 10, pp. 45241-45255, April 2022

The objective of this paper is to show how inductive quadruplets with diagonal cross-couplings can be used as building blocks for filters in rectangular waveguide. The results show excellent agreement with simulations, thereby fully validating both the new family of filter structures and the related design procedures.

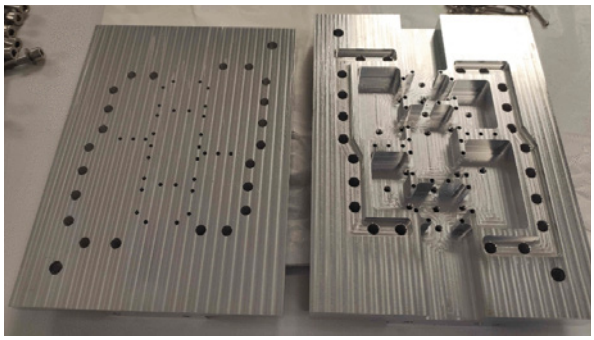


Figure 7: Manufactured 7-4 symmetric filter. Top cover (left) and body (right).

Multipactor Threshold Estimation Techniques Based on Circuit Models, Electromagnetic Fields, and Particle Simulators, Pablo González, Carlos Alcaide, Raúl Cervera, Miguel Rodríguez, Óscar Monerris, John Petit, Ana Rodríguez, Ana Vidal, Joaquín Vague, José V. Morro, Pablo Soto, Vicente E. Boria, IEEE Journal of Microwaves, vol. 2, no. 1, pp. 57-77, Jan. 2022

This paper describes the different techniques available to predict the multipactor threshold

power for radio frequency (RF) and microwave passive hardware under continuous wave (CW) excitation, from cumbersome particle simulations to fast approximate methods based on circuit models. The techniques are applied to both wideband and narrowband application examples. The predictions have been compared with measured thresholds of manufactured samples obtained with a novel multipactor test bed, thus allowing to highlight the advantages and limitations of each technique and particle simulator.

		Coaxial line	Combline filter	
Frequency (GHz)		1.575	1.548	1.575
Measured		220 W	12.0 W	17.9 W
Circuit Approach	Predicted	353.4 W	14.5 W	20.4 W
	Delta	2.06 dB	0.82 dB	0.57 dB
SPARK3D	Predicted	251.8 W	12.1 W	19.9 W
	Delta	0.59 dB	0.04 dB	0.46 dB
CST-PS	Predicted	238 W	9.5 W	14.1 W
	Delta	0.34 dB	-1.01 dB	-1.04 dB

Table 1: Comparison between Predicted and Measured Multipactor Thresholds for the Coaxial Transmission Line and the 3-Pole Combline Filter Samples.