Microwave Applications Group (GAM)

HEAD OF THE GROUP RESEARCH REPORT

Over the past year (September 2020 to July 2021), the group has continued working on two projects awarded with national and regional public funds, respectively. Both projects are in the middle of their whole execution periods, and they are beginning to show promising results.

In addition to these two projects, the group has also obtained national and regional public funding to hire new researchers and PhD students, who are already collaborating with the group in its different 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 space 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 space-sector companies.

Regarding to the training capacity of the group, it is worth mentioning that two doctoral theses 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, and despite the situation derived from COVID19, our doctorate students have performed short-term research stages in centers of excellence on topics related to their PhD thesis works. It is hoped that with the improved situation 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

Figure 1: SELECTOR Project Logo

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

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-itn.hw.ac.uk/

Figure 2: TESLA Network Logo

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

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, 14 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, IEEE Transactions on Antennas and Propagation, IET Proceedings on Microwave, Antennas and Propagation, IET Electronics Letters and Radio Science).

At the same time, and despite restrictions due to the pandemic, the group has presented up to 6 scientific communications in prestigious international conferences (such as the 2020 European Microwave Conference -EuMC-, the 17th European Radar Conference and the XXXV Simposium Nacional de la Unión Científica Internacional de Radio -URSI-), most 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:

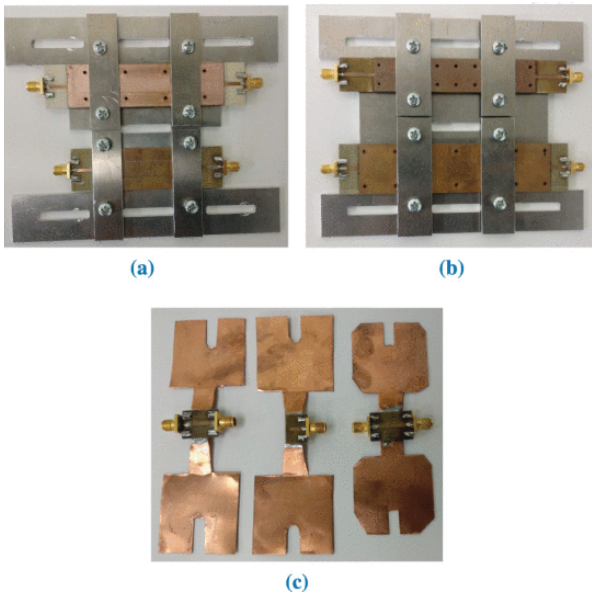


Figure 3: (a) ADLS and SIW filters on aluminium jigs, (b) ESIW and ESICL filters on aluminium jigs, and (c) TRL CalKit elements on copper thermal bridge

Thermal Stability Analysis of Filters in Substrate Integrated Technologies Under Atmospheric Pressure and Vacuum Conditions, Vicente Nova, Carmen Bachiller Martin, Juan Angel Martínez, Héctor Esteban González, José Manuel Merello, Ángel Belenguer Martínez, Oscar Monerris, Vicente E. Boria, IEEE Access, vol. 8, pp. 118072 - 118082, Jun. 2020 Q1

In this work the same filter is implemented on four different Substrate Integrated technologies (including completely and partially filled with dielectric, as well as empty - no dielectric - versions). The four filters are designed, manufactured, and measured at different temperatures according to the thermal testing standards for space applications. The thermal study is performed under atmospheric pressure conditions and, for the first time, under high vacuum conditions.

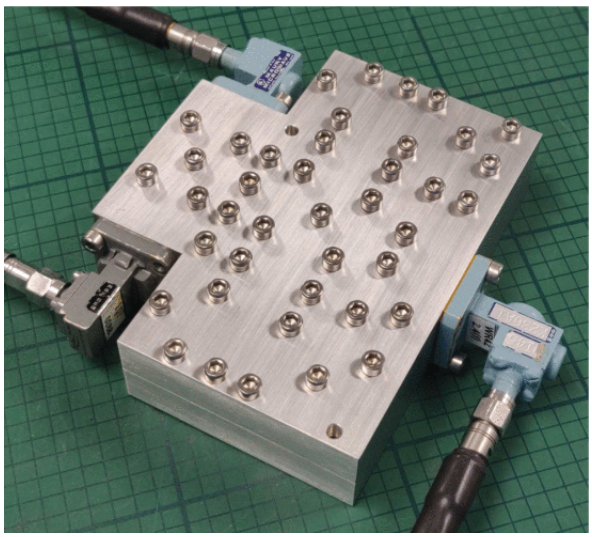


Figure 4: Diplexer breadboard

Waveguide Quadruplet Diplexer for Multi-Beam Satellite Applications, Javier Ossorio García, Juan Carlos Melgarejo Lermas, Santiago Cogollos, Vicente E. Boria, Marco Guglielmi, IEEE Access, vol. 8, pp. 110116 - 110128, Jun. 2020 Q1

The objective of this paper is to describe the design of an innovative low-cost diplexer for Ka-band multi-beam satellite applications. The device is based on the use of two quadruplets to implement several transmission zeros (TZs) thus obtaining high-selectivity quasi-elliptic transfer functions. The resulting diplexer is particularly flexible in terms of layout, does not require tuning and has an excellent high-power behaviour. We also compare the simulations with the measurements obtained with a manufactured breadboard.

A New Family of Multiband Waveguide Filters Based on a Folded Topology, Juan Carlos Melgarejo, Santiago Cogollos, Marco Guglielmi, Vicente E. Boria, IEEE Transactions on Microwave Theory and Techniques, vol. 68, issue 7, pp. 2590 - 2600, May 2020 Q1

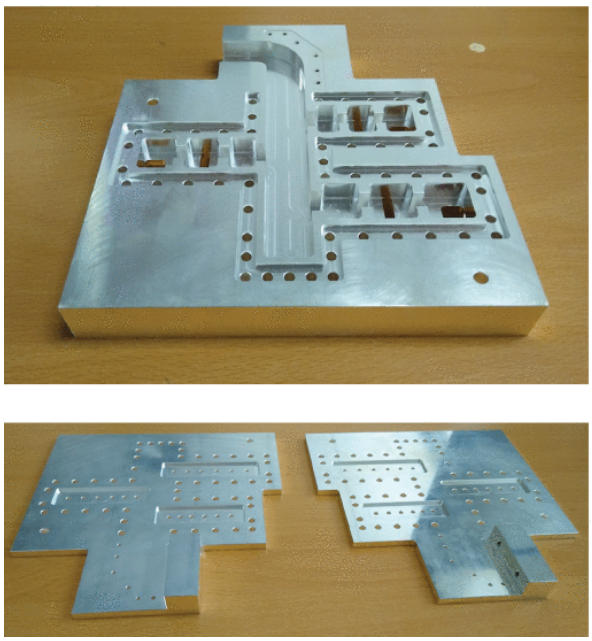


Figure 5: Top: body of the triband filter. Bottom: top and bottom covers of the filter

A new family of multiband waveguide filters based on a folded topology is described. The design of the multiband filter is based on the aggressive space mapping (ASM) technique and can consider manufacturing details, such as round corners and tuning elements. The structure is validated by designing, manufacturing, and measuring a triband filter. The agreement between simulations and measurements is shown to be excellent, thereby validating both the filter topology and the design process.

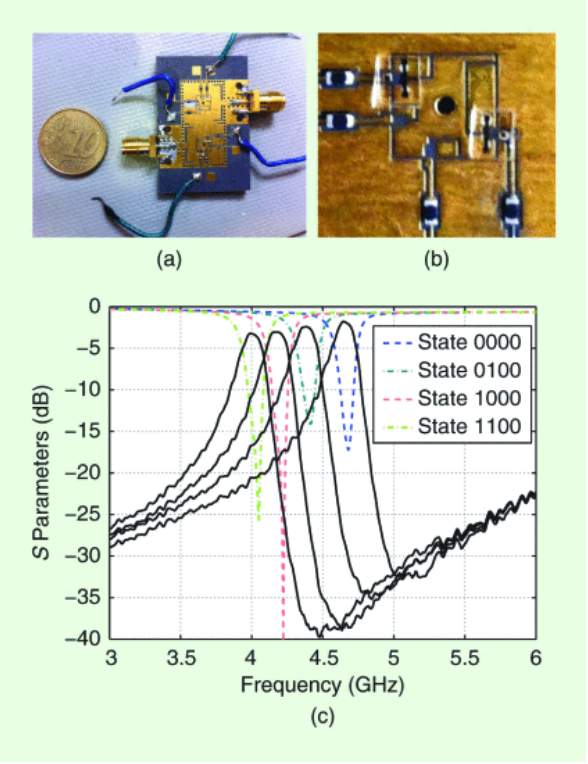


Figure 6: (a) The discretely tunable filter with four assembled RF MEMS resistive switches. (b) A close-up image of the MEMS assembly on one resonator. (c) The preliminary measurements for the four frequency states.

When Compactness Meets Flexibility: Basic Coaxial SIW Filter Topology for Device Miniaturization, Design Flexibility, Advanced Filtering Responses, and Implementation of Tunable Filters, Jorge Daniel Martinez, Stefano Sirci, Vicente E. Boria, Miguel Angel Sanchez-Soriano, IEEE Microwave Magazine, vol. 21, issue 6, pp. 58 - 78, May 2020 Q2

Optimized SIW filters can reach a Q factor of 200-800 using low-loss substrates and standard fabrication procedures. Furthermore, packaging and electromagnetic (EM) shielding, power-handling capabilities, and low-cost batch manufacturing are other broadly recognized strengths of this approach. However, SIW filters are still larger than most of their planar counterparts; in addition, advanced topologies are not always easy to accommodate, and filter reconfigurability usually leads to very complex implementation. In this work, a more compact solution based on the novel coaxial SIW topology is successfully used for the implementation of several filters.

Microstrip to Ridge Empty Substrate-Integrated Waveguide Transition for Broadband Microwave Applications, David Herraiz, Héctor Esteban, Juan Angel Martínez, Angel Belenguer, Vicente Boria, IEEE Microwave and Wireless Components Letters, vol 30, issue 3, pp. 257 - 260, Feb. 2020 Q1

The empty substrate-integrated waveguide (ESIW) is of low cost and low profile and can be integrated into a printed circuit board. To increase the operational (monomode) bandwidth of the rectangular waveguides, a metal ridge can be inserted (leading to the ridge waveguide). Extrapolating this idea to the ESIW, a study of possible ridge ESIW (RESIW) geometries has been performed, and a novel transition from microstrip line to RESIW is proposed.

2.2.- Patents

During this year the following patent has been registered:

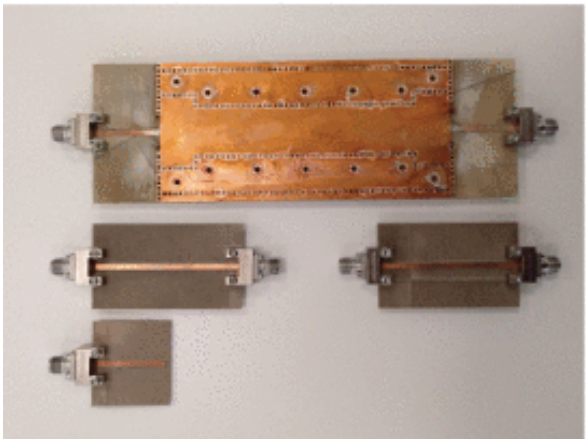
Marco Guglielmi, Vicente E. Boria

Dielectric Tuner

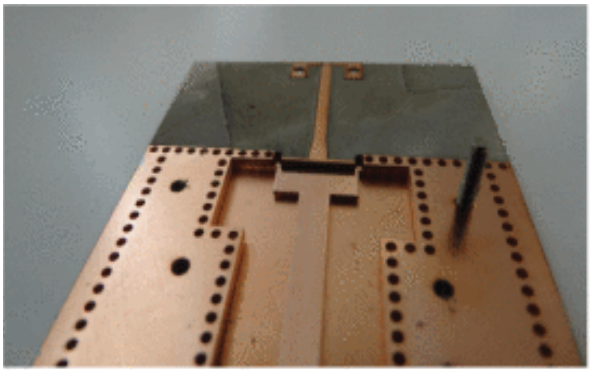
Pub. No.: P202030640

Pub. Date: 25/06/2020

National concession date: 02/02/2021



(a)



(b)

Figure 7: Back-to-back manufactured prototype. (a) TRL calibration kit and assembled prototype (b) Detailed view of transition