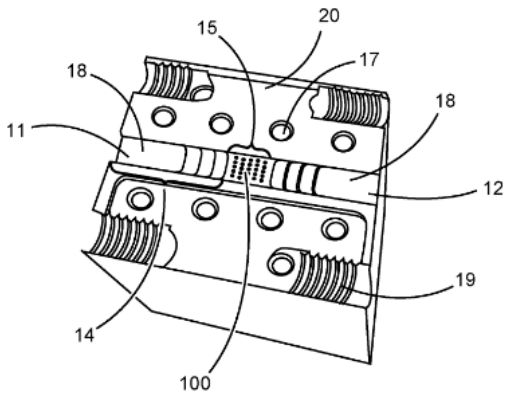
Chad Bartlett - ESR 6 CAU: High-frequency waffle-iron filters

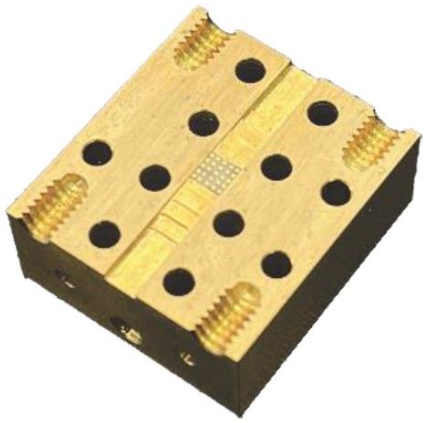
In ESR6's Innovation Triangle, a novel technique for the miniaturization of high-frequency waffle-iron filters has been proposed. The proposed component integrates standard rectangular waveguide technology with unique PCB based via-chips to form a low-cost waffle-iron filter that does not require the stringent milling of waffle-iron teeth and is suitable for very high frequency applications (i.e., >75 GHz). As an additional benefit of the design, the via-chips can be exchanged easily and cost effectively to avoid the reproduction of components that do not meet the required filter specifications. The key advantages can be viewed as low cost, simple milling requirements, and high-power handling.

The concept has been developed within the **TESLA consortium** with our industry partner **TESAT Spacecom**. The concept has passed from being a rough draft, to being an exceptionally desirable patent (WO2022084449A1), and then finally sold on June 9, 2022. The added value of the innovation provides market opportunities for commercialized products, new enterprises and novel research paths for both the aerospace and telecommunication sectors alike.

TESLA has allowed for a novel waffle-iron filter technique to be developed with the aim of overcoming challenges in the next generation of satellite equipment and has been conducted within **ESR6's Innovation Triangle Initiative**, which comprised of the collaborative efforts between **TESAT Spacecom**, **Kiel University (CAU)**, and **ESR6** as an early-stage researcher. The filing and final sale of the patent to industry denotes a remarkable career milestone as an early-stage researcher and exhibits a key exploitable result for the TESLA project and its EU beneficiaries.



Via-Chip Based Waffle-Iron Filter Schematic Design



Prototype of a 90 GHz Via-Chip Based Waffle-Iron Filter During Assembly

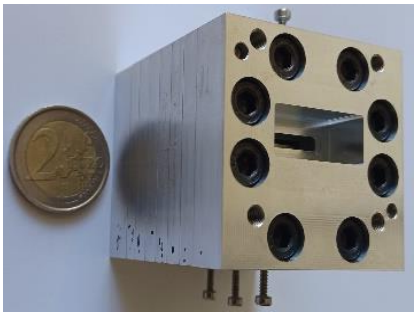
Abdul Rehman - ESR 12 UNIPG: Wide Stopband Miniaturized Filter For Space Applications

With the advent of 5G and of IoT applications, satellites are necessary to provide seamless connectivity to the end users. In the coming years, space technologies have the potential to impact the telecom industry on a larger scale. Large constellations of satellites are driving high importance on the cost. Parameters like size and weight of components impacts the cost and volume of satellite payloads. Bandpass filters are the bulkiest part in satellite transceivers. To reduce the cost and volume of the satellite payload communication system, bandpass filters with small footprints and wide stopbands are required. Wide stopband filters allow us to avoid the use of lowpass filters or at least reduce their dimensions.

Waveguide bandpass filters with small footprints (using miniaturized transverse magnetic -TM- cavity) and with wide stopband rejection performance have been designed in **ESR12's Innovation Triangle** within the **TESLA Innovation Triangle Initiative**. Low cost, small size, and high-power handling capability with wide stopband rejection performance makes these filters attractive for space applications. As part of the activities of **ESR12's Innovation Triangle**, he participated in a project with **RF Microtech** (where he also did a secondment). This project was a contract with **European Space Agency** (ESA), that also included the design of compact, broadband filters for C band applications using dielectric materials.

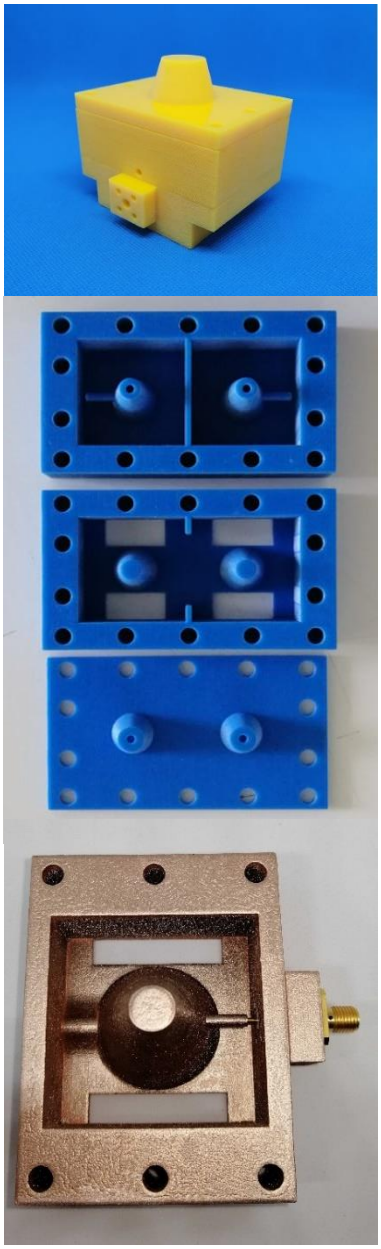
Summary of the product performance:

Center Frequency = 9.2 GHz
Filter order = 6th order
F.B.W = 4%
R.L (meas) = 18 dB
I.L (meas) = 0.5 dB
Upper stopband rejection (meas) > 27dB = 20GHz



Enrique López Oliver – ESR13 UNIPG:

3-D-Printed Conical Resonator Filter For Future Space Applications



A new type of filter based on conical resonators is proposed in **ESR13's Innovation Triangle** as an alternative to current combline filters for the next generation of satellites.

Nowadays, onboard filters pose significant engineering challenges due to an already tight spectrum and a very confined space. Additionally, size and mass are essential characteristics that affect the overall price of the satellite. In that regard, traditional combline filters are bulky and heavy, so their use can be very costly for the space segment. Therefore, the objective was to obtain a new class of filters implemented through 3-D printing techniques and overcome these problems while maintaining performance and adding new capabilities. The following achievements were obtained with respect to traditional combline filters:

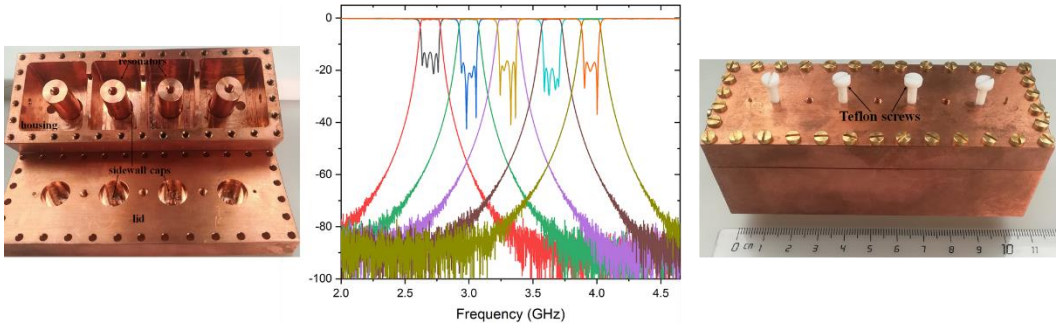
- A new resonator design based on conical posts allows designing filters in different physical arrangements: vertically, horizontally, or a combination of both.
- An achieved volume reduction for conical filters of about 30% and a wider spurious-free range while maintaining the same quality factor as classical combline filters.
- Filter designs oriented toward 3-D printing techniques, with the advantage of a cheaper manufacturing cost and smaller mass.

Overall, the high flexibility of the proposed filter leads to more freedom when arranging the physical space. In addition, the smaller mass and volume also lead to a cost-effective solution that could be particularly interesting for future systems implemented with 3-D printing techniques.

The particular shape of the structure was also considered by other companies to be analyzed by employing fast and accurate software simulators.

ESR13 involved **RF Microtech** in his Innovation Triangle and, as part of the activities in this TESLA triangle, he took part in the **European Space Agency projects COMFID and DOMUK.**

Abdulrahman Widaa – ESR7 CAU: Novel tuning techniques for frequency-agile RF filters



In **ESR7's Innovation Triangle**, two international patents of novel tuning techniques for frequency-agile RF filters were filed by **Kiel University**, and they are currently being promoted to industry with the aid of a technology transfer company (**TUTECH INNOVATION GmbH**):

- Abdulrahman Widaa, Chad Bartlett, Michael Höft, "Tunable Resonator Arrangement, Tunable Frequency Filter and Method of Tuning Thereof", (PCT Patent Pending, 2022).
- Abdulrahman Widaa, Michael Höft, "Tunable resonator, tunable frequency filter and method of tuning thereof", (PCT Patent, 2020) WO2022117212A1.

Some meetings have been already held with companies that have shown interest in ERS7's inventions. Besides, these tuning solutions were introduced and promoted to broad range of prospective industry and research collaborators at the first International Workshop of Microwave Filters in Italy (2021), and the 2022 International Microwave Symposium, which is the largest and the most prestigious conference in the field with more than 440 companies attending every year. Furthermore, an article is also published at the top microwave journal, i.e. the IEEE Transactions on Microwave Theory and Techniques.

ESR7 also worked in his Innovation Triangle with **RF Microtech,** along with his TESLA advisors Prof. Cristiano Tomassoni and Prof. Michael Höft, within a **European Space Agency project** for the development and space assessment of miniaturized C and Ku RF filters based on dielectric materials (**ESA Artes Advanced Technology, Contract 4000129893/20/NL/NR**). The results of this collaboration have been also published at the largest European microwave conference: 2022 52nd European Microwave Conference, in Italy.

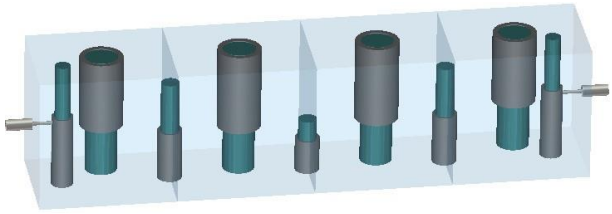
Abhishek Sharma – ESR4 UPV: Inductive filter and combline filter

The WR90-based inductive and combline filters created in **ESR4's Innovation Triangle** can be easily tuned using affordable and controlled actuator motors (due to a decreased sensitivity of the tuning element). Within ESR4's Innovation Triangle, two filter prototypes have been implemented using dielectric tuners developed in collaboration with the German company **Tronser Gmbh**. The filters provide a wide tuning range in terms of the center frequency with a high Q factor and a constant bandwidth and return losses. A filter prototype has been designed at Ku-band. The tuning experiment shows repeatable results in terms of frequency vs. GUI-controlled actuators. A similar tunable test bench can be implemented in the combline filter design published in EUMW-2022. The significant merit of this segment of the reconfigurable filters are:

1. Throughout the tuning process, the filter displayed close to -25dB equiripple return loss, which results in a higher quality factor. In reconfigurable filters, these two elements are rare.

2. Most suppliers have not mentioned how tuners affect the PIM phenomenon, which is covered in one of our articles.

3. The reconfigurable filter with ceramic tuners can be an add-on to the present on-shelf components.



El Mehdi Messaoudi – ESR5 UPV: Miniaturized and self-packaged C-band filters

ESR5 Innovation Triangle's main goal is to develop miniaturized and self-packaged C-band filters with advanced responses for space applications using substrate integrated (SIW) coaxial resonators. To prove the concept, a 4th-order ultra-wideband bandpass filter has been designed and manufactured in a standard low-cost PCB manufacturing process. In order to increase the pass-band and obtain the high coupling values required, as well as reduce the resonator's size, SMD capacitors have been included in the structure in a hybrid way. This approach drastically reduces the device size, while providing additional degrees of freedom for designing and post-manufacturing tuning, which is also critical for high-end filter implementations. This filter prototype avoids additional fabrication processes to correct response degradation due to fabrication tolerances.

The proposed work combines extremely compact dimensions with great flexibility in design and post-fabrication tuning process.

As part of his work in his Innovation Triangle, ESR5 took part in a **European Space Agency project**, where **TAS (Spain and France)** was involved.