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Milestone 10 TESLA Second Year summary report

Project Information	
Name of fellow	Yifang Wei (ESR1)
Host Research Department	Department of Electrical, Electronic and Communications Engineering. Heriot-Watt University (HWU)
Supervisor 1 name and host	Prof. Jiasheng Hong (HWU)
Supervisor 2 name and host	Dr. Christian Arnold (TESAT)
Supervisor 3 name and host	
Start Date	01/07/2019

Summary Report

During the second year of the TESLA project about the Beamforming Network Based on Active Phased Array, Yifang Wei (ESR1) continued his research on each component of the beamforming system. Although the situation due to the covid-19 affected the events and network of the project, the research and the work are continued from home by remote controlling the PCs in office and attended workshops and meetings online.

The first fabrications of the waveguide transitions have been completed and got the preliminary experimental results, which have been included in the submitted conference paper for EUMW2021. Compared the measured results with the simulated results, some analysis and optimizations have been completed for the next fabrications for the waveguide transitions to improve the performance. In next fabrication, the preparations of the 2 inputs and 2 outputs feeding network, optimized waveguide transitions and the waveguide transition with multi-layer patches have been completed and sent to the company. The feeding network based on power dividers with the load and the waveguide antenna are also simulating and will prepare to fabricate next.

Now, the waveguide antenna is simulating to improve the performance of the circular polarization. The 2 inputs and 4 outputs final beamforming system samples also start to design which will demonstrate and validate its performance with both the simulation results and the measured results in the final report.

The fabrications and measurements of the 2 inputs and 4 outputs final beamforming system will consist of the feeding network, phase and gain control sections, the waveguide transitions connected to the top of the PCB, PA/LNA, the waveguide antenna array, the control section and power supply. If it is possible, it is very helpful to test the beamforming samples at TESAT company in Germany during the secondment if the international situation is allowed in 2022.

Project Information	
Name of fellow	Abdul Sami (ESR 2)
Host Research Department	Department of Electrical, Electronics and Communication Engineering
Supervisor 1 name and host	Prof. Miguel Laso (Public University of Navarre)
Supervisor 2 name and host	Prof. Ivan Arregui (Public University of Navarre)
Supervisor 3 name and host	N/A
Start Date	7/30/2021

Summary Report

My second year of PhD started in September 2020 at Microwave Component Group (MCG) in Public University of Navarre (UPNA) under the supervision of **Prof. Miguel Laso** and **Dr. Ivan Arregui**. The title of PhD is "**Microwave and millimeter-wave components for easy fabrication**". As I reported last year that the first draft of the manuscript was written based on the design technique where a band-pass filter was designed using waveguide sections with varying widths and heights for Q-band application. Later on, the manuscript was improved following the suggestions and valuable inputs of all the supervisors. The paper was submitted to IEEE Microwave and Wireless Components Letters (MWCL) in January 2021. Later on, we received a very detailed review from the journal. We worked on the comments made by the reviewers and all the comments were very well addressed. The manuscript was also revised upon the suggestions of the reviewers. The paper was accepted by the journal and will be publish very soon (it is already available by Early Access) with the title "*Robust tolerance design of bandpass filter with improved frequency response for Q-band satellite applications*". Based on the work presented in the paper, a Deliverable (D2.2) titled *"Breadboard of waveguide filter aiming for high-yield fabrications"* under work package 2 (WP2) has been recently submitted to TESLA. I also worked on the Chained Functions to check whether it is a viable solution in stepped impedance structures based on commensurate lines. For that purpose, a design example was implemented using Chained Functions in CST Microwave Studio. The sensitivity analysis of the design example was performed in FEST3D. Furthermore, I have been working on filter structures with stub added design entities. In these structures, the stubs are added in the waveguide cavities to create transmission zeros near the passband to improve the selectivity of the filter. The basic idea is to propose a design technique which is easy to implement and also to obtain multiple transmission zeros around the passband with the help of multiple stubs. This work is still in progress, and we are exploring the best configuration and position of the stubs in waveguide cavities to obtain excellent out of band response and high selectivity. In order to implement this idea, a baseline filter of 7^{th} order is designed for Ku-band application. Stubs with different lengths are added in the baseline filter to create transmission zeros in the stopband at the desired frequencies. Several design examples have been implemented using multiple stubs to create multiple transmission zeros. This work will be concluded by the end of the August.

Project Information	
Name of fellow	Jabir Hussain (ESR3)
Host Research Department	Department of Electrical, Electronic and Communications Engineering. Public University of Navarre (UPNA)
Supervisor 1 name and host	Miguel A. G. Laso (UPNA)
Supervisor 2 name and host	José M. Lopetegui Beregaña (UPNA)
Supervisor 3 name and host	Israel Arnedo Gil (UPNA)
Start Date	01/09/2020

Summary Report

A summary of the technical findings under the project geared towards a PhD thesis titled "New design techniques for telecommunication payloads of space systems suitable for additive manufacturing in the context of large platforms" is briefed below.

1. Continuing from the previous year, the performance of the compensation method to take into account the effect of the cut-off modes was analysed. The performance was studied based on increasing and decreasing the minimum mechanical gap of the rectangular waveguide filter. Following the results, the performance of the compensation method was also analysed at different compensation frequencies. The results obtained have been very good, revealing the very good performance of the compensation method developed.

2. The increase and decrease of the minimum mechanical gap were done by increasing and decreasing the height of the rectangular waveguide, respectively. In order to maintain the standardised input and output ports, tapers were introduced to match the difference in height. An in-depth analysis of the tapers based on their length and their location with respect to the waveguide filter was performed to get consistent results. A very good command of the tapering techniques was achieved.

3. The power handling capability of the designed smooth rectangular waveguide filters was also analysed. The analysis was simulated on SPARK3D based on the minimum mechanical gap as well as the SEY of the material used for fabrication. The results for varying the mechanical gap are in agreement with the theoretical understanding. Further power simulations on varying SEYs are to be performed to get more consistent results. In general, very high values for the power handing capability have been obtained.

4. An analysis of the insertion loss based on material conductivities and minimum mechanical gap was performed. The CST simulation results are in agreement with the theoretical predictions.

5. Based on the simulated results, six filter designs were selected for fabrication using direct metal additive manufacturing, at 3 different manufacturers. Some initial measurement results are consistent with the simulated results. However, there are some marked disparities based on the manufacturer and the filter design fabricated. The precise measurement of these prototypes in underway.

Project Information	
Name of fellow	Abhishek Sharma (ESR4)
Host Research Department	Universidad Politécnica de Valencia (UPV)
Supervisor 1 name and host	Dr. Vicente Boria (ITEAM-,UPV)
Supervisor 2 name and host	Dr. Santiago Cogollos (ITEAM-UPV)
Supervisor 3 name and host	Prof. Michael Höft (CAU)
Start Date	12/09/2019

Summary Report

This report summarizes my research from July 2020 to June 2021. As explained in my research plan, my work is concentrated on exploring the novel reconfigurable/tunable topologies in cavity waveguide filters.

In the present era, satellite transmissions have been crowded with multi-channel links having numerous frequency and bandwidth specifications. Deploying an identical filter for each channel will not only increase the complexity of the payload but also drastically increment the production cost. Henceforth, there is a need to replace the set of fixed filters with reconfigurable filter topologies. These filter topologies provide the flexibility to adapt the central frequencies at the user end. Continuing the research work that we had shown in previous reports, I have intended to explore the compact reconfigurable filter combline topology in the L and S-band frequency bands.

The basic idea was to achieve a compact topology, as the generic waveguide filters in L and S-band are bulky. Therefore, combline topologies have been adopted to achieve compactness and spurious-free response. The filter topology has been developed with a stepwise procedure while exploiting every part of the filter design. Numerous experiments have been carried out in order to observe and extract the best possible response from the studies performed. For instance, the filter design can be broadly segmented into three parts: The cavity configuration, the inter-resonator coupling and the input/output coupling topologies. The studies are concluded with the new contributions on every stage of the filter design. As a result, a novel topology has been coined using dielectric tuners. It is worth noting at this stage that we have already submitted the outcomes (reached up to now) to the 2021 European Microwave Week (EuMW) Conference and the paper is under review.

Apart from the advantages in terms of performance, we have observed that the novel topology is highly adaptive in terms of scaling and adopting different material for tuning. This led us to stretch our research to design a fully reconfigurable bandpass filter that can be tuned with respect to both bandwidth and centre frequency. For this purpose, new dielectric materials were explored to fit into the desired specifications. As a result, a whole new filter has been designed incorporating dimensional scaling and a novel dielectric material. It means that the structure provides the freedom to choose several frequencies and bandwidth combinations as per the user requirement.

For validation and manufacturing purposes, the 3D modelling has been carried out using Solidworks while considering the required manufacturing tolerances and adjustments. This filter model is under bench testing in the current stage. Also, we are in the final stages of writing a journal article with the outcomes of the above-demonstrated studies.

Another activity has been conducted to explore the various aspects of dielectric screws in comparison with metallic screws. As our research team had already published a few works related to tuning with metallic and dielectric tuners, we have intended to explore the more rigid and practically acceptable tuning mechanism for the remote tuning of satellite payloads. Continuing with those previous results, I have designed inductively-coupled WR90 waveguide filters having the center frequency at 10 GHz. For the sake of the industrial approach, the tuning behavior has been studied with the use of industrial-grade tuners developed by the German company Tronser Gmbh. The basic idea of this study was to explore the feasibility to tune the filter with remotely-controlled motors. Moreover, it was necessary to establish the optimum balance between the dimension of the tuner and the cavity dimensions. In this

process, two filter prototypes have been designed (one with metallic tuners and another one with dielectric tuners). Both filters have been modelled with SolidWorks while considering the practical tolerances. Also, the results of the above-said studies have been compiled and properly discussed. Alongside, the paper related to the outcomes of the tuning of WR90-based waveguide filter has also been submitted to the IEEE TMTT journal and is presently under review.

Project Information	
Name of fellow	El Mehdi Messaoudi (ESR 5)
Host Research Department	ITEAM, Universitat Politecnica de Valencia (UPV)
Supervisor 1 name and host	Prof. Vicente E. Boria (UPV)
Supervisor 2 name and host	Prof. Jorge D. Martìnez (UPV)
Supervisor 3 name and host	
Start Date	16th September 2019

Summary Report

The main objective of this Ph.D. thesis is the design and development of miniaturised and reconfigurable hybrid/passive structures (such as substrate integrated waveguide technology, SIW) for the realization of passive devices such as filters and multiplexers. These filters should have advanced response for space communications applications with frequencies in the C-, X-, Ku- and K-band. To obtain filters with good selectivity, solutions with additional transmission zeros can be used. Multilayer technology allows to reduce the size and to offer alternative solutions for coupling and, in general, for the structure. Tunable elements can be used to design reconfigurable filters.

The results obtained are summarised as follows:

1. Firstly, a compact ultra-wideband bandpass filter employing substrate integrated quasi-lumped resonators has been designed, manufactured and measured. The structure is in multi-layer hybrid technology, combining quasi-lumped resonators and surface mount components. This allows a huge miniaturization degree due to the high capacitive loading. Moreover, mixed-coupling and consequently higher filter selectivity by introducing transmission zeros was implemented. The filter presents a 4^{th} Chebyshev filter centered at 5.35 GHz with a bandwidth of 2.9 GHz (FBW=54.2%) and minimum in-band return loss of 15 dB. It has been implemented in a 4-layer PCB stack-up. The filter must provide rejection higher than 30 dB in the lower band and 20 dB in the upper side. The paper containing the results has been accepted for the IEEE International Microwave Filter Workshop.
2. A modified version of the previous structure with additional transmission zero in the upper band of the filter has been designed, fabricated and tested. The results obtained differ from those simulated. The SMD capacitors were mounted manually. Due to the millimeter size of the SMD elements (0.3mm x 0.6mm) and the strong miniaturized structure, there may have been errors in the manual welding process of the capacitive elements. In addition, a study of manufacturing tolerances has been carried out. A further extended version of the IMFW paper will be sent, including the version with the additional zero, a study for reconfigurability of the filter by modification of the SMD capacitors mounted on the top layer, and a manufacture tolerances study.
3. A miniaturized reconfigurable coaxial substrate integrated waveguide filter has been investigated. Varactor diode elements were used as tuning elements, which allow coupling and resonance frequency control. To prove the concept a 2nd order filter has been designed and fabricated. The filter is centered at 5 GHz. The results of the simulation are promising. As soon as possible, the varactors will be mounted on the top layer and the filter will be tested. In case the experimental results match the simulation results, a 3rd order and a 4th order (already designed) filter will be fabricated and tested.
4. A novel miniaturized structure in a multilayer technology is being investigated. A 2nd order filter designed and simulated in HFSS has given good results, but the extension to a higher-order filter is challenging and is being studied.
5. Cross-curricular courses of Ph.D. program.

Project Information	
Name of fellow	Chad Bartlett (ESR6)
Host Research Department	Chair of Microwave Engineering – Kiel university
Supervisor 1 name and host	Prof. Michael Höft (CAU)
Supervisor 2 name and host	Dr. Christian Arnold (TESAT)
Supervisor 3 name and host	Prof. Joachim Oberhammer (KTH)
Start Date	01/09/2019

Summary Report

The key objective of this research project is to introduce novel W-band cavity-based filter designs for satellite applications. Throughout the second year of the project, the student has utilized the filter background and manufacturing experience from the first year of study for the realization of novel filter components.

Over the last year, the student has completed two additional secondments (three total) in order to gain experience with high-end manufacturing and miniature filter design techniques. The two secondments were concluded with Spinner GmbH -Germany, and TESLA's Partnering University KTH - Sweden, in which high-precision milling and silicon wafer etching methods were explored. The student has developed various filter designs in order to explore different methods of overcoming challenges at mm-wave frequencies and demonstrate exceptional measured results with designs using high-precision milling and stereolithography 3D-printing. To date, 5 scientific articles have been submitted, 2 of which are currently published in journal print, while 3 others have been provisionally accepted for future journal and conference print.

In the first year of study, a patent document was agreed upon between CAU and Tesat-Spacecom & Co. KG that has been submitted for patent approval (Pending). Legal review continues at this time, meanwhile, the Airbus GmbH has agreed to purchase the patent (Tesat is an independent subsidiary of Airbus).

The student participated in various TESLA workshops and summer schools such as "RF High Power Effects" by Technical University of Valencia UPV, and "ESA Workshop on Advanced Manufacturing" organized by the European Space Agency – Paris, France. The student will be participating in the upcoming 'International Microwave Workshop' – Perugia, Italy, as well as contributing to a workshop on high-precision milling at the '2021/2022 European microwave Week' – London, United Kingdom.

The student continues to investigate novel filter designs for overcoming challenges in mm-wave designs and potential technologies for future satellite applications.

Project Information	
Name of fellow	Abdulrahaman Widaa(ESR7)
Host Research Department	Chair of Microwave Engineering – Kiel university
Supervisor 1 name and host	Prof. Michael Höft (CAU)
Supervisor 2 name and host	Prof. Cristiano Tomassoni (UNIPG)
Supervisor 3 name and host	Dr.-Ing. Holger Maune (TUD)
Start Date	01/09/2019

Summary Report

The aim of ESR 7 project is to investigate and present new efficient solutions for the design of tunable filters for the applications of future flexible satellite payloads. The first year of research mainly focused on the study and review of previous literature and the different available tunable filters' designs and configurations.

Following the progress of the 1st year, ESR 7 investigated various possible tuning techniques in the second year of the project based on TM-mode dielectric resonator (DR) filters. TM-mode dielectric resonator structures are chosen because of their highly desirable features to the next generation satellite payloads including the light weight, compact size, and the high unloaded quality factor (QU). Different tuning means were investigated on TM-mode DR configurations. Also, couple new tuning techniques were introduced and first prototypes were manufactured for proof-of-concept purposes. The first results of the presented mechanisms/filters showed many interesting advantages for future flexible satellites including the wide tuning capabilities, simple configurations, and the high quality factors. A brief introduction of two of the proposed tuning techniques will be presented in recently accepted papers at the International Microwave Filter Workshop 2021 (IMFW 2021) in Perugia-Italy next November. Also, another article of a highly miniaturized reconfigurable filter for future satellite communications was submitted to the next European Microwave Week in London (EuMW 2022). Another two/three articles are being prepared for future journal/conference submissions. ESR 7 also reported the first deliverable of TESLA work package 1 (D1.1, comparison of tuning means) which presents a review of the different tuning mechanisms available in the literature (December 2020).

ESR 7 has also participated in many webinars, conferences, workshops, and summer schools in his second year of research including the activities organized by TESLA network. ESR 7 participated as an author in the 50th European Microwave Week in Utrecht, the Netherlands (January 2021) with a student grant, and also in the 21st IEEE Wireless and Microwave Technology Conference (WAMICON21) in the USA (April 2021), and the IEEEE International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE) in Sudan (March 2021). ESR 7 also attended couple online activities including the 2020 Asia-Pacific Microwave Conference (December 2020), 2021 China Microwave Week (May 2021), TESLA online workshop on "Entrepreneurship, Exploitation of Results, and IP Issues" (September 2020), and TESLA summer school on RF high Power Effects (July 2021).

ESR 7 also successfully did a 3 month combined research secondment with TESLA partners in Italy: university of Perugia and RF Microtech company where he was involved in the design phase of some European Space Agency (ESA) projects in dielectric filters (May 2021 – July 2021). First design results were satisfactory and a prototype is under manufacturing for testing.

Project Information	
Name of fellow	Mohammad Mehrabi (ESR8)
Host Research Department	KTH Royal Institute of Technology
Supervisor 1 name and host	Prof. Joachim Oberhammer (KTH)
Supervisor 2 name and host	Dr. Oleksandr Glubokov (KTH)
Supervisor 3 name and host	Prof. Michael Höft (CAU)
Start Date	19/08/2019

Summary Report

In his second year at KTH, Mohammad has been working on several concepts on micromachined filters with high-quality factors. He has completed three PhD courses on applied antennas, microwave filters and basic communication and teaching. Through the applied antenna course, Mohammad has learned how to design and fabricate various kinds of antennas and their space application. He gained information about numerous ESA satellites and their tasks and operations. Advanced methods of teaching were discussed in the basic communication and teaching course. Practical methods of microwave filter design theory have been learnt from the microwave filter course. He also took part in teaching the Radar and the Hands-on MEMS courses at KTH.

Mohammad has been working on two concepts for designing novel filters with high-quality factors at sub-THz frequencies. He has investigated various techniques to implement high-Q resonators through silicon micromachining manufacturing technology. Each of the concepts included analyzing achievable internal and external coupling coefficients. Several fundamental limitations have been confronted in the designs and an approach to overcome them have been found successfully. Mohammad has designed several narrowband band-pass filters using the developed resonators, including a higher-mode filter and a dielectric-resonator filter. He has proposed a novel assembly approach for the micromachined filters, prepared their experimental verification, including a transition for a simplified excitation of the filters, and a calibration kit for the measurements. He has designed photomasks, successfully fabricated the chips in the cleanroom, assembled them and characterized. Unfortunately, the obtained experimental results cannot be considered as acceptable for publication. Currently, the reasons for the failure are under examination, and a new fabrication run will be prepared when the investigation has been finished.

Mohammad has attended several conferences and workshops. He took part in the TESLA virtual summer school on RF High-Power effects, including the TESLA meeting, where he attended a workshop on high power filters. Workshop on satellite applications, business, and the New Space has been taken online.

Mohammad has done a two-months research secondment (May-June 2021, partially virtual due to Covid-19 travel restrictions) with CAU in Kiel, Germany. There he has learnt high precision milling techniques and successfully designed and fabricated an interposer required for time-efficient characterization of micromachined chips fabricated at KTH.

Project Information	
Name of fellow	Armin Karimi (ESR 9)
Host Research Department	KTH Royale institute of Technology
Supervisor 1 name and host	Prof. Joachim Oberhammer
Supervisor 2 name and host	Dr. Syed Umer Abbas Shah
Supervisor 3 name and host	Dr. Oleksandr Glubokov
Start Date	25/11/2019

Summary Report

During the last year, Armin has been working on MEMS reconfigurable frontend for future space applications and has taken during two courses related to his research programme: Hands-on MEMS and Radar Technology.

In the first course, he has learnt silicon micromachining and working in clean room environment. He has designed and fabricated an actuator, which is directly related to the switching network that Armin will be using in his project. In the radar course, he gained a great experience in deep radar concepts and learned about practical SAR imaging.

Armin has finalized the design of the MEMS reconfigurable mm-wave frontend. Every component of the frontend including antenna, switch network, beam former, and phase shifter has been designed, attached together and optimized. The simulation data shows promising performance of the system. The preparation of the experiment and design of the photomasks have been completed. Due to many limitations, including machine failure in the cleanroom and Covid-19 restrictions, this fabrication run encountered some shut down periods and then restarted. The fabrication process is currently in progress: the first run on dummy wafers has been completed to verify the process flow and learn the machines needed for the main fabrication run. The main fabrication run is ongoing: hard masks have been completed for the frontside and backside etching, the other steps, such as main etching and metallization are expected to get completed by the end of August 2021. If the experimental verification is successful, two papers are expected to be published by the end of 2021.

Armin has attended several conferences and workshops. He took part in events organized by TESLA, such as virtual summer schools and other trainings. He has also taken part in “microsystem technology” and “hands-on-MEMS” courses taught by KTH as a teaching assistant.

Project Information	
Name of fellow	Luke Robins (ESR10)
Host Research Department	(TU GRAZ)
Supervisor 1 name and host	Dr. Reinhard Teschl (TU GRAZ), Prof. Wolfang Bösch (TU GRAZ)
Supervisor 2 name and host	Dominik Brouczek, MSc. (Lithoz), Dr. Martin Schwentenwein (Lithoz)
Supervisor 3 name and host	
Start Date	01/09/2019

Summary Report

Within the TESLA framework, Luke Robins (ESR10) investigates ceramic additive manufacturing technologies with the focus on non-planar passive RF-components. This summary highlights some of the work completed during the Second year.

A Secondment took place at Lithoz to gain practical experience with the ceramic additive manufacturing process. This knowledge was used to print various samples to access the fabrication limitations and possibilities enabled. A prototype stepped impedance filter was proposed and designed, which allowed the identification of several critical areas of test required to fabricate the final component. The ability to print various dielectric lattices in order to create designer porosities which would allow the creation of desired dielectric constants was tested. The influence of lattice type or shape relative to the wavelength was investigated to assess how arbitrary the choice could be, allowing the optimisation of the structure to be based on cleaning or strength requirements. Lattices were tested in combination with bulky parts to access what effect the mass accumulation would have on the sintering process. Finally, a simple method to increase the maximum wall thickness for the material was tested to enable the sintering of larger parts.

The samples were then characterised in terms of RF performance and the prototype filter adapted using the experience gained. The protype filter was successfully printed and sintered, however non uniform sinkage was identified a large factor in the size of the final filter and therefore the RF performance. An additional run of filters was designed and printed to investigate lattice shape and orientation on this shrinkage effect. The best of these samples was chosen and inserted into a milled waveguide cavity with Coaxial probe feeding. The RF performance of the filter was measured and found to have issues with the holes for the probe feeding and the penetration depth thereof which seriously degraded the response of the filter. An X-ray was conducted on the prototype which confirmed the probe was not inserted at the correct depth.

The D2.1 deliverable report as completed and submitted ahead of schedule in March 2021. Additionally, a proposal was submitted for a workshop contribution for “Advanced manufacturing and packaging” at EuMW 2022 on additive manufacturing.

The work completed was compiled and submitted to the IMFW 2021 conference with the intention of expansion into a Journal Article. A second paper was Co-authored with ESR 11 and submitted to the same conference. Both submissions were accepted.

Project Information	
Name of fellow	Arash Arsanjani (ESR11)
Host Research Department	(TU GRAZ)
Supervisor 1 name and host	Dr. Reinhard Teschl (TU GRAZ), Prof. Wolfang Bösch (TU GRAZ)
Supervisor 2 name and host	Dr. Wolfgang Waldhauser (Joanneum Research)
Supervisor 3 name and host	Dr. Vojislav Petrovic Filipovic (Joanneum Research)
Start Date	03/09/2019

Summary Report

ESR 11 is focused on the "Design of mm-wave passive components in semi-planar technology", by investigating the implementation of semi-planar metamaterial structures with additive manufacturing. A summary of the work done in the second year is presented below:

During this period, ESR 11 collaborated with Joanneum research to optimise metal additive manufacturing for the implementation of metamaterial microwave and mm-wave components. A parametric study was performed on the proposed designs to identify trade-offs between manufacturing feasibility and the performance of the components. The research resulted in two papers, one presented at the EuMC 2020 and the other is accepted at the upcoming IMFW 2021 conference with the possibility of expansion to a journal paper. Further investigations comparing the alternative additive manufacturing technologies, SLA and FDM are being conducted to enable more detailed evaluations of these technologies for the proposed structure types. Additionally, further investigation has been made on the metallization process to make the components conductive and improve the losses.

A paper was submitted to the Asia Pacific Microwave Conference (APMC) 2021 conference on addition of negative coupling of the filter components in the proposed semi-planar structure (IMFW) for transmission zeros. The results enable the implementation of various filter topologies with high selectivity characteristics and good miniaturization.

As part of side research, the possibility of creating a similar metamaterial component in the PCB platform has been investigated, where a mushroom-shaped unit-cell was employed to fabricate a metamaterial slot antenna. The optimized shape of the unit-cell provides a higher degree of miniaturization.

The first-year report and the D3.1 deliverable report were submitted before the deadline. Additionally, a propos al for contribution to the "Advanced manufacturing and packaging" workshop was submitted for the EuMW 2022 on additive manufacturing. An additional conference paper in collaboration with ESR 10 was submitted to the IMFW 2021 which was also accepted.

Additionally, as a part of PhD studies, the ESR 11 have completed two more courses during the second year:

- PhD Student Seminar Information and Communications Engineering --- 1 Semester Hour
- Inventions, Patents and Technology Exploitation --- 1 Semester Hour

Project Information	
Name of fellow	Abdul Rehman (ESR-12)
Host Research Department	University of Perugia
Supervisor 1 name and host	Prof. Cristiano Tomassoni (UNIPG)
Supervisor 2 name and host	Dr. Eng. Antonio Alvino (SERMS)
Supervisor 3 name and host	Dr. Luca Pelliccia (RF Microtech)
Start Date	04-03-2020

Summary Report

This short report summarizes Abdul Rehman research progress for the second year of PhD period covered from Sep 2020 – Aug 2021. During this period, Abdul focused on the designing of waveguide filters with wide spurious free band.

To reduce the cost and volume of overall satellite payload communication system, filter miniaturization is required. Another way of achieving this objective is to design filters with wide spurious free band, so that, a smaller number of filtering components are used in satellites, resulting in smaller system. In this research activity, filter size is not reduced itself, however, it avoids the use of low pass filters (or at least it allows reducing its volume) for improving stopband performance, thus reducing cost and volume of overall system.

Generally, in waveguide filters spurious resonance occurs due to higher order modes present in the cavity. For this purpose, a new technique based on coupling matrix is studied in this research activity and applied to waveguide TM cavity filters. Initially, the proposed technique was applied to second order TM cavity filters. Based on the promising results achieved, a paper has been accepted at International Microwave Symposium (IMS-2021). After that, the proposed technique has been applied to higher (even) order TM cavity filters. Stopband performance in higher order TM filters is degraded further due to coupling iris resonances as well as higher order modes spurious. However, very good results have been achieved by applying the proposed spurious suppression technique to both higher order mode spurious frequencies and iris spurious frequencies. Fourth order and sixth-order TM cavity filters with wide stopband performance have been designed. The sixth-order filter has been manufactured and measured. Based on the results obtained, an expanded version of the accepted IMS paper has been submitted to the Transaction on MTT. This paper is currently under review.

Furthermore, study has been carried out for Substrate Integrated Waveguide (SIW) filters with wide stopband performance. The proposed method for spurious suppression has been also applied to improve stopband performance in SIW filters. A 4^{th} order SIW filter with wide spurious free band has been designed and manufactured. Based on the results, very recently a paper has been accepted at international microwave filter workshop (IMFW) 2021. This proves the feasibility of the proposed spurious suppression method to different filter topologies.

Apart from this research activity, Abdul also took part in other different workshops under the umbrella of TESLA project and studied PhD courses offered by the Engineering Department of the University of Perugia, Italy. These workshops and courses contribute improving his skills in this field of study. Abdul also spent two months in RF Microtech as part of his secondment plan.

So far, filters have been designed with small fractional bandwidth. In the next phase of this research activity, Abdul will study the design of filters with wide spurious free band using the proposed spurious suppression method for wider fractional bandwidth applications.

Project Information	
Name of fellow	Enrique López Oliver (ESR 13)
Host Research Department	Department of Engineering. UNIPG
Supervisor 1 name and host	Cristiano Tomassoni
Supervisor 2 name and host	
Supervisor 3 name and host	
Start Date	01/07/2019

Summary Report

The second year of the PhD student started 01/07/2020.

Enrique has taken two PhD module courses at the University of Perugia in order to pass his second year of the PhD program.

Enrique started his secondments at Rfmicrotech the second week of October. Nevetheless, due to increment of COVID cases in Italy back then, Enrique started working from home the following weeks. The project involved the use of additive manufacturing, which goes accordingly well with the research of the Ph.D. During the PhD a study of coupling and Q-factors were performed for different modes inside a ceramic puck.

Enrique has worked on a new family of filter based on ellipsoidal cavitites to design dual-mode filters that provide asymmetric responses, either in the upper or lower stopband of filter. As a proof-of-concept, a filter was manufactured with a SLA 3-Printer. This work was succesfully published in a Microwave and Wireless Components Letter.

In regards to previous work from the first year of the PhD program. A 2-pole and 4-pole spherical filter were manufactured by a Selective Laser Melting (SLM) machinery by the end of 2020. The results for the 2-pole filter are quite acceptable with a competitive Q-factor and a good agreement between simulation and measurement. For the 4-pole filter, the results in terms of Q-factor are good, but the return loss is not ideal. As a result, another prototype is expected to be manufactured later this year. These results are expected to be shown at IMFW2021 in Perugia.

Project Information	
Name of fellow	Elvira Saab Llatas (ESR 14)
Host Research Department	University of Limoges (UNILIM)
Supervisor 1 name and host	Prof. Alexandre Maître
Supervisor 2 name and host	Dr. Nicolas Pradeilles
Supervisor 3 name and host	Dr. Olivier Rapaud
Start Date	November 15, 2019

Summary Report

The current summary report presents the activities carried out between June 15, 2020 and August 21, 2021. This past year's effort was focused on establishing some correlations between the effect of manufacturing variables and the physical properties of aluminium nitride based ceramics. Therefore, these investigations allowed to determine the experimental conditions making the optimisation of ceramic performances possible whatever the raw powder origin. For this, the following research activities were continuously carried out in an iterative manner:

- bibliographic review,
- powder characterisation
- sample's manufacturing and characterisation,
- report writings and presentations.

Complementary research activities have been performed to improve the shaping step of green ceramic compacts and to master the microstructural evolution of aluminium nitride based ceramics during sintering, through finding suitable binding formulation and semi-wet-granulation parameters for alumina and aluminium nitride powders, which were the secondment's objectives at CTTC.

Two abstracts on thermal conductivity and dielectric properties of aluminium nitride based ceramics obtained by spark plasma sintering were prepared for submission. One abstract was intended for EUROMAT 2021 (Graz, Austria, September 13-17, 2021) and the other for the XVII ECerS Conference (Dresden, Germany, September 2021). Since the former event became a virtual conference and the later was postponed to 2022, both abstracts are currently available for other international congresses such as the ICC9-ECerS XVII-ELECTROCERAMICS XVIII (Krakow, Poland, July 10-14, 2022) and the 2022 Annual Conference of the French Ceramic Group (Alby, France, March 22-24, 2022).

Moreover, the following courses and joint training network events were attended:

- Summer School 1: Additive Manufacturing (UNILIM) – July, 2020.
- Workshop 3: Micromachining and MEMS (KTH) as a listener – September, 2020.
- Innovation training event. "Entrepreneurship, Exploitation of Results, and IP Issues" (TU GRAZ) – September, 2020.
- Team Management (UNILIM) – April, 2021.
- Summer School 2: High Power Effects (UPV) – July, 2021.

Other trainings:

- Characterisation techniques:
    - Scanning Electron Microscopy (UNILIM, 3h retraining)– April, 2021.
    - Dry Granulometry (UNILIM, 1h) – June, 2021.
- Processing technique for mixing and granulation purposes (CTTC, 2 days) – May, 2021.