THESIS SUMMARY

Signal Modality Characterization: from Phase Space Reconstruction to Real Applications

Alicia Carrión García
Supervisor: Ramón Miralles Ricós
Defended on June 27th, 2018

The characterization of the modality of a signal is a new concept, which has been the subject of recent research. Its main purpose is to identify any changes in the nature of a real signal. The term "nature of a signal" refers to the underlying model that generates the signal from the point of view of two main characteristics: determinism and linearity. In this thesis, the modality of a signal is used for the advanced processing of acoustic signals, and in particular, in non-destructive tests of non-homogeneous materials, such as concrete.

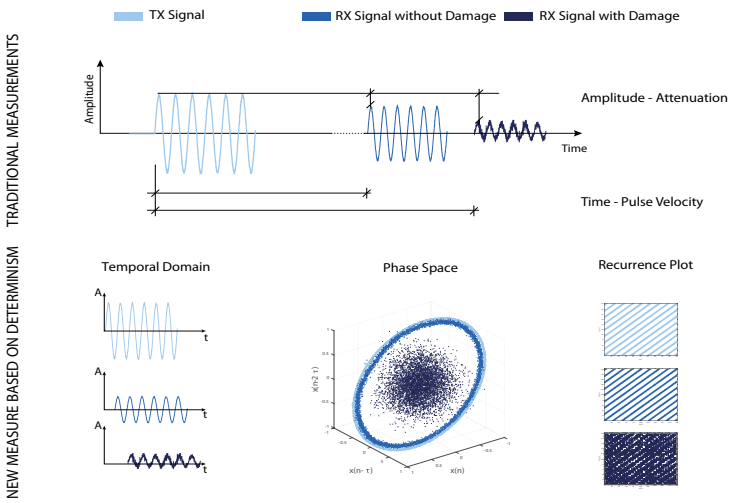
The problem of the characterization of the modality begins with the correct reconstruction of the phase space. This new domain allows identifying the different states of a signal, as to whether they are recurrent or not, depending on whether they are deterministic, respectively, random. In the field of non-destructive testing based on ultrasound, the material is excited with a purely deterministic signal. However, the nature of the received signal depends on the internal structure of the material. This working hypothesis allows us to propose measuring the degree of determinism as a complementary alternative to the usual ultrasound parameters such, as attenuation and speed. The level of determinism has been found to be proportional to the level of porosity in cementitious materials. It also allows characterizing the level of damage of mortar test pieces subjected to different kinds of damaging processes: external attack by sulphates, and loading processes.

The study of the non-linearity or complexity of a time series is initially presented blindly (without having information about the input signal) through hypothesis tests: generating surrogate data and applying a statistical test. Significant progress has been made in adapting this approach to nonstationary data, a common feature of real non-linear signals. The main results in this regard have been achieved in the characterization of the complexity of oscillatory signals of limited duration.

The concept of signal modality has also been used to perform a detailed study of the non-linear phenomenon of acoustic impact spectroscopy. This analysis has allowed understanding the variables involved, and thus, proposing a mathematical model that characterizes the phenomenon. The understanding of the phenomenon and the model have allowed proposing a new processing algorithm equivalent to the usual NIRAS technique, but optimal in its application. This processing alternative may mean significant advances, especially in industrial applications where time and effort are variables to be optimized.

This thesis demonstrates that the characterization of the modality of a signal presents an alternative to the characterization of complicated real phenomena. The measure of determinism and the FANSIRAS algorithm have shown that the modality of a signal is an interesting tool for future research into the characterization of cementitious materials.

Keywords: Signal Modality, Determinism, Non-linearity, Recurrence Plots, surrogates, Non-Destructive Testing, concrete, FANSIRAS



Graphical description of the ultrasonic measurements: traditional ones, velocity and attenuation, and the alternative approach based on the concept of the level determinism

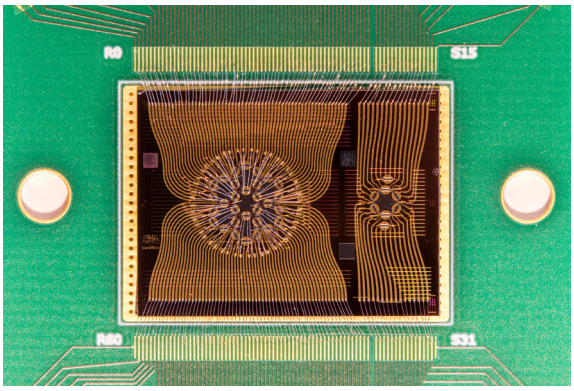
THESIS SUMMARY

Integrated Microwave Photonic Processors using Waveguide Mesh Cores

Daniel Pérez López
Supervisor: José Capmany Francoy, Ivana Gasulla Mestre
Defended on October 17th, 2017

Integrated microwave photonics changes the scaling laws of information and communication systems offering architectural choices that combine photonics with electronics to optimize performance, power, footprint and cost. Application Specific Photonic Integrated Circuits, where particular circuits/chips are designed to optimally perform particular functionalities, require a considerable number of design and fabrication iterations leading to long-development times and costly implementations.

A different approach inspired by electronic Field Programmable Gate Arrays is the programmable Microwave Photonic processor, where a common hardware implemented by the combination of microwave, photonic and electronic subsystems, realizes different functionalities through programming. Here, we propose the first-ever generic-purpose Microwave Photonic processor concept and architecture. This versatile processor requires a powerful end-to-end field-based analytical model to optimally configure all their subsystems as well as to evaluate their performance in terms of the radiofrequency gain, noise and dynamic range. Therefore, we develop a generic model for integrated Microwave Photonics systems. The key element of the processor is the reconfigurable optical core. It requires high flexibility and versatility to enable reconfigurable interconnections between subsystems as well as the synthesis of photonic integrated circuits. For this element, we focus on a 2-dimensional photonic waveguide mesh based on the interconnection of tunable couplers. Within the framework of this Thesis, we have proposed two novel interconnection schemes, aiming for a mesh design with a high level of versatility. Focusing on the hexagonal waveguide mesh, we explore the synthesis of a high variety of photonic integrated circuits and particular Microwave Photonics applications that can potentially be performed on a single hardware. In addition, we report the first-ever demonstration of such reconfigurable waveguide mesh in silicon. We demonstrate a world-record number of functionalities on a single photonic integrated circuit enabling over 30 different functionalities from the 100 that could be potentially obtained with a simple seven hexagonal cell structure. The resulting device can be applied to different fields including communications, chemical and biomedical sensing, signal processing, multiprocessor networks as well as quantum information systems. Our work is an important step towards this paradigm and sets the base for a new era of generic-purpose photonic integrated systems.



THESIS SUMMARY

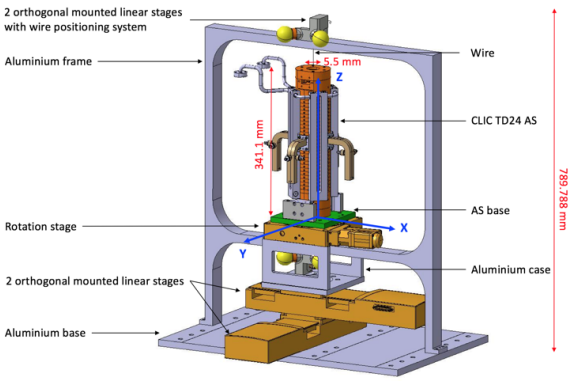
Development of direct measurement techniques for the in-situ internal alignment of accelerating structures

Natalia Galindo Munoz
Supervisors:Vicente E. Boria Esbert; Ángeles Faus Golfe
Defended on March 13th, 2018

In the next generation of linear particle accelerators, challenging alignment tolerances are required in the positioning of the components focusing, accelerating and detecting the beam over the accelerator length in order to achieve the maximum machine performance. In the case of the Compact Linear Collider (CLIC), accelerating structures (AS), beam position monitors and quadrupole magnets need to be aligned in their support with respect to their reference axes with an accuracy of 10 um. To reach such objective, the PACMAN (Particle Accelerator Components Metrology and Alignment to the Nanometer Scale) project strives for the improvement of the current alignment accuracy by developing new methods and tools, whose feasibility should be validated using the major CLIC components.

This Ph.D. thesis concerns the investigation, development and implementation of a new non-destructive intracavity technique, referenced here as the perturbative method, to determine the electromagnetic axes of ASs by means of a stretched wire, acting as a reference of alignment. Of particular importance is the experimental validation of the method through the 5.5 mm iris-mean aperture CLIC prototype known as TD24, with complex mechanical features and difficult accessibility, in a dedicated test bench.

In the first chapter of this thesis, the alignment techniques in particle accelerators and the novel proposals to be implemented in the future linear colliders are introduced, and a detailed description of the PACMAN project is provided. The feasibility study of the method, carried out with extensive electromagnetic fields simulations, is described in chapter 2, giving as a result, the knowledge of the theoretical accuracy expected in the measurement of the electromagnetic axes and facilitating the development of a measurement algorithm. The conceptual design, manufacturing and calibration of the automated experimental set-up, integrating the solution developed to measure the electromagnetic axes of the TD24, are covered in chapter 3. The future lines of research and developments of the perturbative method are also explored. In chapter 4, the most significant results obtained from an extensive experimental work are presented, analysed and compared with simulations. The proof-of-principle is completed, the measurement algorithm is optimised and the electromagnetic centre is measured in the TD24 with a precision less than 1 um and an estimated error less than ±8.5 um. Finally, in chapter 5, the developments undertaken along this research work are summarised, the innovative achievements accomplished within the PACMAN project are listed and its impact is analysed.

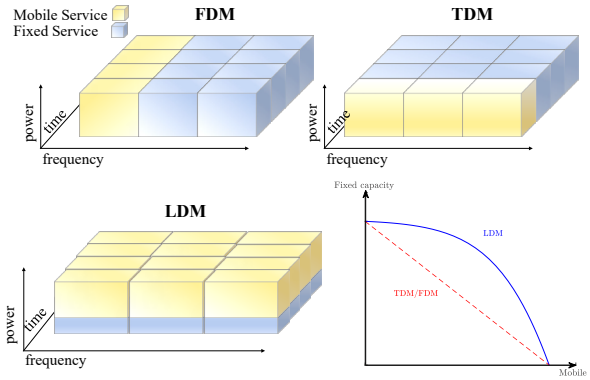


THESIS SUMMARY

Advanced Layered Division Multiplexing Technologies for Next-Gen Broadcast

Eduardo Garro Crevillén
Supervisors: David Gómez Barquero, Narcís Cardona Marcet
Defended on June 4th, 2018

Since the beginning of the 21st century, terrestrial broadcasting systems have been blamed of an inefficient use of the allocated spectrum. To increase the spectral efficiency, Digital Terrestrial Television (DTT) Standards Developing Organizations settled to develop the technical evolution of the first-generation DTT systems. Among others, a primary goal of next-generation DTT systems (DVB-T2 and ATSC 3.0) is to simultaneously provide TV services to mobile and fixed devices. The major drawback of this simultaneous delivery is the different requirement of each reception condition. To address these constraints, different multiplexing techniques have been considered. While DVB-T2 fulfilled the simultaneous delivery of the two services by TDM, ATSC 3.0 adopted the Layered Division Multiplexing (LDM) technology. LDM can outperform Time Division Multiplexing (TDM) and FDM by taking advantage of the unequal error protection ratio, as both services, namely layers, utilize all the frequency and time resources with different power levels. At receiver side, two implementations are distinguished, according to the intended layer. Mobile receivers are only intended to obtain the upper layer, known as CL. In order not to increase their complexity compared to single layer receivers, the lower layer, known as EL is treated as an additional noise on the CL decoding. Fixed receivers, increase their complexity, as they should performed a successive interference cancellation process on the CL for getting the EL. To limit the additional complexity of fixed receivers, the LDM layers in ATSC 3.0 are configured with different error correction capabilities, but share the rest of waveform parameters, including the interleaving, the pilot pattern, the FFT size and the guard interval. This dissertation investigates advanced technologies to optimize the LDM performance. A demapping optimization for the two LDM layers is first proposed. A capacity increase is achieved by the proposed algorithm, which takes into account the underlying layer shape in the demapping process. Nevertheless, the number of Euclidean distances to be computed can be significantly increased, contributing to not only more complex fixed receivers, but also more complex mobile receivers. Next, the most suitable ATSC 3.0 pilot configuration for LDM is determined. Considering the two layers share the same PP a trade-off between pilot density (CL) and data overhead (EL) arises. From the performance results, it is recommended the use of a not very dense PP, as they have been already designed to cope with long echoes and high speeds. The optimum pilot amplitude depends on the channel estimator at receivers (e.g. the minimum amplitude is recommended for a Wiener implementation, while the maximum for a FFT implementation). The potential combination of LDM with three advanced technologies that have been adopted in ATSC 3.0 is also investigated: MultiRF technologies, distributed MISO schemes, and co-located MIMO schemes. The potential use cases, the transmitter and receiver implementations, and the performance gains of the joint configurations are studied for the two LDM layers. The additional constraints of combining LDM with the advanced technologies is considered admissible, as the greatest demands (e.g. a second receiving chain) are already contemplated in ATSC 3.0. Significant gains are found for the mobile layer at pedestrian reception conditions thanks to the frequency diversity provided by MultiRF technologies. The conjunction of LDM with distributed MISO schemes provides significant performance gains on SFNs for the fixed layer with Alamouti scheme. Last, considering the complexity in the mobile receivers and the CL performance, the recommended joint configuration is MISO in the CL and MIMO in the EL.

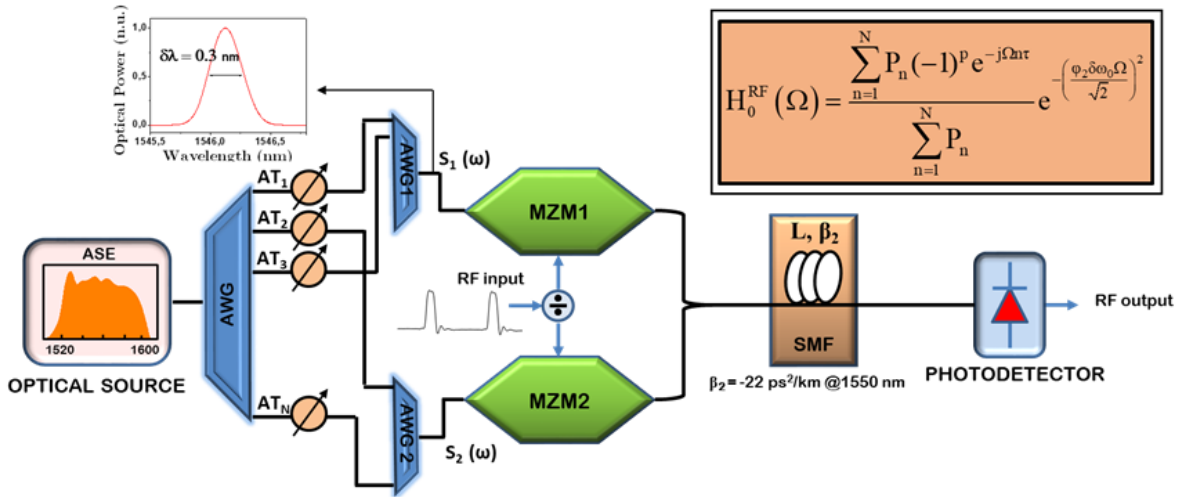


Radiofrequency signal generation systems based on Microwave Photonics

Manuel Rius Mercado
Supervisors: José Mora Almerich, Mario Bolea Boluda
Defended on 17th July 2018

The use of Photonics technology for the generation of arbitrary microwave signals permits to overcome the limitations of electrical systems and its direct integration in radio over fibre systems. The photonic technique based on microwave photonic filters presents ease of reconfiguration and frequency tuning of the generated waveform, as well as robustness and simplicity of the different structures.

In this thesis, the study and implementation of arbitrary microwave signal generators with optical processors based on microwave photonic filters is introduced. Firstly, a theoretical development of the general transfer function is found for the photonic systems based on microwave photonic filters with optical processors composed by delay lines or dispersive devices. This theoretical development has permitted to evaluate the harmonic distortion generated in these systems, which has revealed its relevance when a design of these systems is carried out. Secondly, arbitrary microwave signal generators based on microwave photonic filters have been proposed and specific waveforms have been generated for Ultra-Wideband technology as well as chirped signals, specifically, electrical chirped pulses. Moreover, capabilities of reconfiguration and tuning of the generated signal have been demonstrated for the proposed systems. Regarding theoretical response in relation to experimental measurements, a good concordance has been found and, consequently, the theoretical development has been validated. In this way, this theoretical development has been proved as a suitable tool to design photonic generators of arbitrary microwave signals.



$$H_0^{RF}(\Omega) = \frac{\sum_{n=1}^{N} P_n (-1)^p e^{-j\Omega n\tau}}{\sum_{n=1}^{N} P_n} e^{-\left(\frac{\varphi_2 \delta\omega_0 \Omega}{\sqrt{2}}\right)^2}$$

THESIS SUMMARY

New broadband, low cost and compact MIMO radar frontends

Enric Miralles Navarro
Supervisors: Héctor Esteban, Ángel Belenguer, Volker Ziegler
Defended on July 2nd, 2018

This doctoral thesis deals with the design of new radiofrequency circuits for MIMO-type radars. The MIMO algorithms applied to radars are capable of increasing the virtual size of an antenna array in each dimension, provided that the radiant elements are properly placed. This artificial elongation of the effective area of the cluster provides improved radar resolution. MIMO radars do not only improve the performance of conventional radars, but they also reduce their cost. By reducing the number of antennas, all the radio frequency circuitry associated with the antenna (filters, amplifiers, switches...) is also reduced.

The first chapter makes a brief introduction to the history of radar until the present day and presents the objectives, methodology and structure of this work.

The second chapter introduces the basic radar concepts necessary for the development of this thesis.

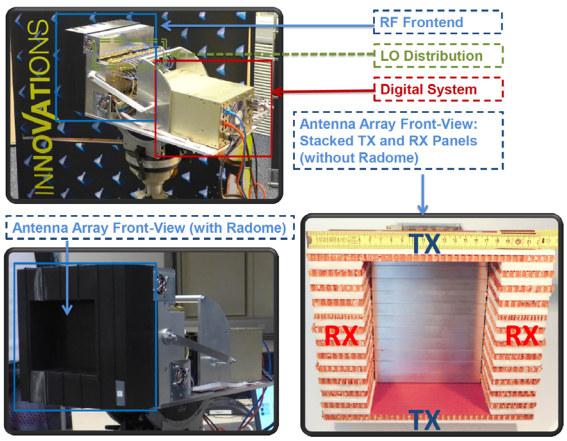
The third chapter presents the first prototype of MIMO radar developed at Airbus. This radar uses a stacked printed circuit board structure to achieve a two-dimensional antenna array. The design and performance of each one of the radiofrequency circuit devices are presented and discussed in detail, and the final performance of the whole system are also briefly described.

The fourth chapter describes a second prototype of MIMO radar. To make the radar more compact, the antennas have been replaced by printed antennas. In this way it is possible to create a two-dimensional cluster with only one printed circuit. The MIMO antenna configurations used have an unoccupied space in the centre. This space has been used to place spiral antennas for communication, and a camera with a servomotor.

The fifth chapter emphasizes the design of passive components with a large bandwidth (from 4 to 40 GHz). A Wilkinson splitter integrated in a printed circuit board in microstrip technology and a 3D printed antenna, achieve the proposed bandwidth. These devices integrated in a MIMO radar type would increase its performance. For example, they would enable algorithms of "frequency hopping". Thus, a single hardware could be used in different areas, with different frequency regulations, or modulations, with a higher bandwidth and in turn with higher resolution.

The sixth chapter presents an antenna and a coupler manufactured in a novel technology (ESIW). ESIW is a waveguide integrated in a substrate in which the inner dielectric has been emptied. This guide is compact, low cost and very low loss. These qualities make ESIW an ideal technology for radars.

The seventh and final chapter sets out the conclusions and future lines of research.



Advanced Optical Techniques of Transmission for OOFDM-WDM Networks

Francisco Israel Chicharro López
Supervisors: Beatriz Ortega Tamarit and José Mora Almerich
Defended on July 23rd, 2018

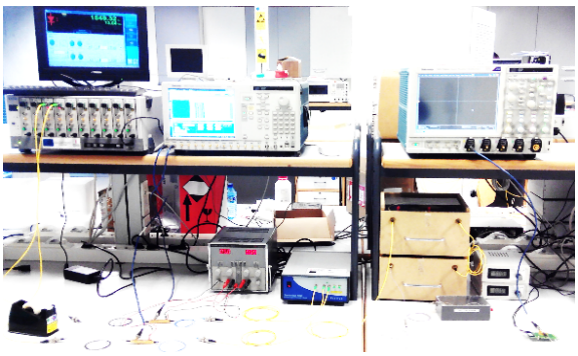
The increasing demand of bandwidth per end-user required by current Internet services, high-definition video, multimedia applications or on-line gaming drives the advanced modulations to play a significant role in optical networks. OOFDM (Optical Orthogonal Frequency Division Multiplexing) has been widely employed as a solution for network communications due to its advantages, such as overcoming chromatic and polarization dispersion impairments, its adaptability to channel variations and its high spectral efficiency.

The generation of OFDM signals, intensity modulated and directly detected, from double sideband modulations results in an inefficient use of the spectrum, adding the power fading related to the chromatic dispersion. Alternatively, the single band modulations avoid this drawback. In this work, we are introducing an original scheme of transmission of optical OFDM signals based on the single band modulation that makes a better use of the spectrum. It consists of the definition of paired channels. Each one includes two optical carriers with a narrow spectral separation, and the external single sideband.

Furthermore, this Thesis provides a low-cost solution for the implementation of WDM-OFDM transmitters based on the use of broadband sources. Despite the chromatic dispersion avoids the use of this kind of optical sources, the inclusion of some structures before the detection enable the transmission of OFDM signals in optical links. The use of a Mach-Zehnder interferometer, properly designed, enables the use of broadband sources in a dispersion tolerant scheme, as will be experimentally demonstrated. Moreover, every parameter that concerns the transmission of the signals is studied, with the goal of defining the optimal operation of these systems.

As an example of the flexibility of the introduced systems, the transmission of multiband OFDM signals is also demonstrated. Different OFDM bands form these signals, increasing the electric spectrum efficiency. Once again, the proper design of the Mach-Zehnder interferometer will result in an adaptive solution regarding the end-user requirements in each moment, as the experimental results will confirm.

Therefore, this Doctoral Thesis proposes and demonstrates advanced, novel and efficient solutions for the transmission of OFDM signals in optical networks. They are also validated along the Thesis in the context of the DWDM technology, for exploring their potential as a candidate for implementation in future networks.



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OTHER THESES

Other PhD dissertations held in iTEAM between August 2017 and October 2018:

Title: Técnicas de transmisión sobre fibra óptica con dispersión modal (in Spanish)

Author: Medina Sevila, Pau

Supervisors: Juan Luis Corral González, Vicenç Almenar Terré

Defended on September 14th, 2017.

http://hdl.handle.net/10251/90414

Title: UWB radio channel and diversity characterization for wireless implanted devices

Author: Andreu Estellés, Carlos

Supervisors: Concepción García Pardo, José Francisco Monserrat Del Río, Narciso Cardona Marcet

Defended on September 26th, 2018.

http://hdl.handle.net/10251/111836

Title: Encoding optical FBG sensors to enhance the capacity of optical sensing systems

Author: Triana Infante, Cristian Andrés

Supervisors: Daniel Pastor Abellán, Gloria Margarita Varón Durán

Defended on October 11th, 2018.