

PEOPLE
MARIE CURIE ACTIONS

International Outgoing Fellowships (IOF)
Call: FP7-PEOPLE-IOF-2008

“Radar Imaging: Challenges And New Approaches (RICANA)”

Objectives:

The RICANA project is concerned with the improvement of Radar Imaging technology and its application to Ground Penetrating Radar (GPR), or Through Wall Radar (TWR) systems.

The general milestone of the RICANA project is to achieve novel advances in the Radar Imaging field so that a disruptive technology can emerge.

The desired progress cannot be undertaken without solving previously known technological challenges. It becomes essential, in the first place, to determine the electromagnetic behaviour for the usual materials disposed between the sounder and the objectives targets, based on its spectral signature, in order to correctly design a reliable detection system. Once determined this behaviour, a research field is opened for the optimization of these systems and their different components and subsystems.

The further step is the design of transmitting and receiving antennas adapted to the characteristics of the elements to detect. Also there is place for the research of other aspects of the sounding, like the optimization of the transmitted signal, alternative receiver schemes, and the processing algorithm of the received signal.

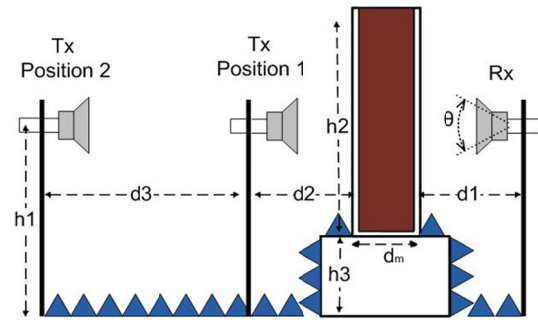
This project is funded by the 2008 IOF Marie Curie Actions (EU FP7 People Program) and this grant extends from June 2009 to December 2011. The participants are the Radio Systems Research Group of the University of Vigo (Vigo, SPAIN) (UVIGO) and the EMAG Research Group of the New Mexico State University (Las Cruces, NM, USA) (NMSU). The scientist in charge is Dr Manuel Garcia Sanchez in UVIGO and Dr Muhammad Dawood in NMSU. The fellow researcher is Dr Ana Alejos.

Outcomes

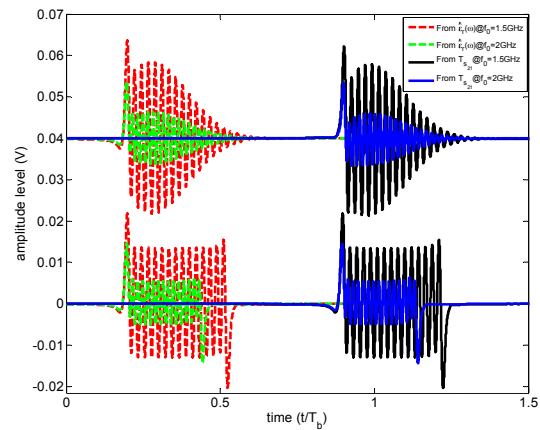
Up to present, the outcomes surpassed the initial objectives and the more noticeable result has been the achievement of the experimental demonstration of an electromagnetic phenomenon related to the dispersive nature of media such as soil, water, vegetation, tissues, metal and so on. The dispersive propagation occurring in these media produces the arise out of a waveform known as Brillouin precursor which has slept down on scientific textbooks since

its theoretical prediction in 1914 due to the mathematical and computational difficulties to board the study as well as the technical challenge to demonstrate their practical existence.

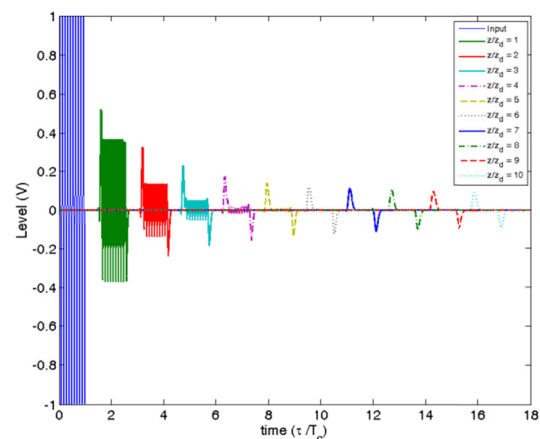
Theoretically, the Brillouin precursor can provide larger penetration depths into a dispersive medium compared to that achieved by the conventional single frequency or narrow-band signals, thereby providing: (i) enhanced signal-to-noise ratio (SNR) and thus better imaging through hard-to-image dispersive media; and/or (ii) larger propagation distance for the same transmitted power, or conversely less transmitted power to achieve the same distance for a given receiver sensitivity, hence contributing to “green technologies.



Brillouin precursors carry a significant portion of the energy of the propagating ultrawideband pulse in any dispersive attenuative media, thereby delivering either more power at the same distance, or larger distance, and/or both. Neglecting these field means to eliminate an important and significant part of the received signal energy. It is therefore reasonable to conclude that Brillouin precursors have a large potential to impact positively the ground penetrating radar, through-the-wall imaging, imaging through seawater and leafy foliage, communication through foliage and seawater, non-destructive testing, material characterization, etc.

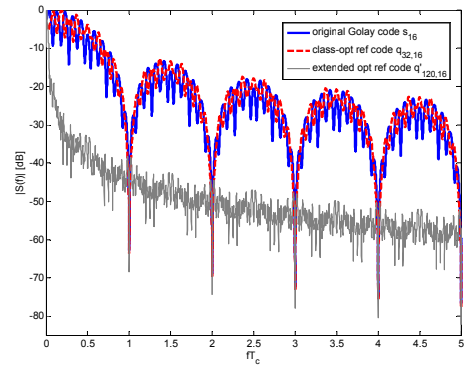


So, alongside the remaining WPs of the RICANA project we have considered the dispersive propagation phenomenon in order to achieve an optimal system design and signal data processing. The correct design of the radiating elements and also the suitable transmitted signal become key elements which must be analyzed under the light of the Brillouin precursor formation.



The analysis of the sidelobe level issue of the pseudorandom binary sequences used in the noise radar technique was also an initial goal. From this point of view, we have designed and patented an extended optimal filtering technique for adaptive-on-transmit radar based on the transmission of pseudorandom noise waveforms as a method to simultaneously achieve low sidelobe level and spectral purity without degrading the main peak of the cross-correlation function.

The understanding of electromagnetic field evolution of waveforms using digital sequences and the effects on the receiver structure is one of the vital aspects for improving the penetration through the dispersive media. The digital sequences have been demonstrated to obey a non-exponential peak amplitude attenuation law that is better than the single pulse case, and it seems to be a good trade-off with the broadening impairment.



Other analogue waveforms have been designed to achieve a near-optimal performance in terms of peak amplitude decay and pulse broadening through dispersive media.

These outcomes have reached a large impact on the international scientific community and it has been rewarded through the rapid publication of journal papers. Different conference papers have been also accepted and presented, and many other publications are under review process and elaboration.

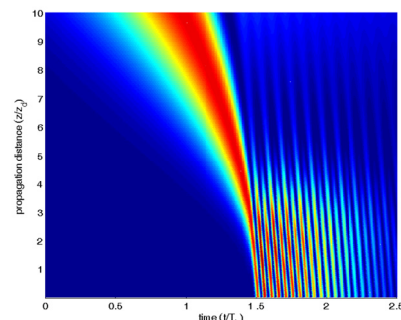
We can mention among other outcomes, a pending patent presented to protect the intellectual property on the measurement technique developed to detect and characterize the dispersive phenomenon of the Brillouin precursor waveforms. The optimal filtering technique aforementioned is the topic of a second pending patent.

The research team considers that with the work performed around the Brillouin precursor phenomenon, this break-up technology is stated to be practically possible and especially, the analysis performed can help to introduce important improvements in the imaging techniques under use at present.

Generally speaking, the investigated technology provides a valid tool and a versatile framework to theoretically analyze the phenomenon of the Brillouin and Sommerfield precursor formation and evolution through a given medium even in optic frequencies. This tool would also be useful to observe the influence of different variables such as the type of the input signal, the carrier frequency, the pulse width, the dielectric model, the bandwidth limiting, the multipath, the filtering, and so on. We also demonstrated that the antenna frequency response can be easily incorporated to achieve a complete simulation of all the elements present in a propagation scenario. Even multipath models have been considered due to the feasibility of the analysis approach herein described.

We demonstrated the importance of the precursor fields and the further research needed in this direction. Outcomes indicate that the propagation phenomena derived from the analysis of Brillouin and Sommerfield precursor waveforms cannot be neglected, neither at microwave nor at optical bands.

In order to take advantage of the potential benefits due to the precursor fields, some difficulties must be overcome, both in the experimental and theoretical field. No theoretical approach can emerge as the most



suitable if its results cannot be experimentally checked.

Journal papers:

- Habib Mohammed, Muhammad Dawood, Ana Vázquez Alejos, "Experimental Detection of Brillouin Precursors Through Tap Water at Microwave Frequencies", *IET Electronics Letters* vol. 42, nº 25, pp. 1645 – 1647, December 9th 2010.
- Ana Vázquez Alejos, Muhammad Dawood, Luis Medina, "Experimental dynamical evolution of the Brillouin precursor for broadband wireless communication through vegetation", *Progress In Electromagnetics Research* vol. 111, pp. 291-309, 2011.
- Ana Vázquez Alejos, Muhammad Dawood, Habib U.R. Mohammed, "Analysis of Brillouin precursor propagation through foliage for digital sequences of pulses", *IEEE Geoscience and Remote Sensing Letters*, vol. 8, issue 1, pp. 59-63, January 2011.
- Ana Vázquez Alejos, Muhammad Dawood, "Estimation of power extinction factor in presence of Brillouin precursors through dispersive media", *Journal of Electromagnetic Waves and Applications*, vol. 25, no. 4, pp. 455-465, 2011.
- Habib Mohammed, Muhammad Dawood, Ana Vázquez Alejos, "Experimental detection of Brillouin precursor formation through loamy soil at microwave frequencies", *IEEE Transactions on Geoscience and Remote Sensing*, vol. 50, nº 2, pp. 436-445, January 2012.
- Ana Vázquez Alejos, Muhammad Dawood, Habib Mohammed, "Pseudo-optimal waveform design for dispersive propagation through loamy soil", *IEEE Geoscience and Remote Sensing Letters* forthcoming 2012.

Conference papers:

- Habib Ur Rahman Mohammed, Ana Vazquez Alejos, Muhammad Dawood, "A Novel Approach to Observe Precursor Waveforms", *White Sands Chapter of International Test and Evaluation Association Live-Virtual-Constructive Conference*, El Paso (NM, USA), January 2010.
- Jose Carlos Garcia Valladares, Ana Vazquez Alejos, Ana Varela Cotelo, Manuel Garcia Sanchez, "Implementation of a FPGA-based system for Human Presence Detection by Using micro-Doppler radar at 24GHz", *White Sands Chapter of International Test and Evaluation Association Live-Virtual-Constructive Conference*, El Paso (NM, USA), January 2010.
- Ana Vazquez Alejos, Muhammad Dawood, Habib Ur Rahman Mohammed, Manuel Garcia Sanchez, "Educational system to approach teaching of bi static noise radar", *2010 European Association for Education in Electrical and Information Engineering Annual Conference (EAEEIE)*, Palanga (Lithuania), June 2010.

- Habeeb Ur Rahman Mohammed, Dawood Muhammad, Ana Vázquez Alejos, "Software Tool for Simulation of Brillouin Precursors in Dispersive Dielectrics", *2010 IEEE International Symposium on Antennas and Propagation - URSI*, Toronto (Canada), 2010.
- Habeeb Ur Rahman Mohammed, Ana Vázquez Alejos, Dawood Muhammad, "Brillouin Precursor Observation in a Loamy Soil Using Novel Simulation Technique", *2010 IEEE International Symposium on Antennas and Propagation – URSI Radio Science Meeting*, Toronto (Canada), 2010.
- Ana Vázquez Alejos, D. Muhammad, H. U. R. Mohammed, "Analysis of the Brillouin precursor effect on receiver end schemes for UWB noise radar in dispersive media", *2010 IEEE International Symposium on Antennas and Propagation – URSI Radio Science Meeting*, Toronto (Canada), 2010.
- Ana Vázquez Alejos, D. Muhammad, H. U. R. Mohammed, M. Garcia Sanchez, "Analysis and mitigation of distortion effects on autocorrelation function of pseudorandom binary codes due to non-ideal receiving conditions", *2010 IEEE International Symposium on Antennas and Propagation – URSI Radio Science Meeting*, Toronto (Canada), 2010.
- Muhammad Dawood, H. U. R. Mohammed, Ana Vazquez Alejos, "Experimental characterization of Brillouin precursors through loamy soil at microwave frequencies", *University Research Council Research and Creativity Activities Fair*, New Mexico State University, Las Cruces (NM, USA), October 2nd 2010.
- Luis Medina, Ana Vazquez Alejos, Muhammad Dawood, "Experimental dynamical evolution of Brillouin precursors through leafy vegetation", *University Research Council Research and Creativity Activities Fair*, New Mexico State University, Las Cruces (NM, USA), October 2nd 2010.
- Ana Vazquez Alejos, Luis Medina, Muhammad Dawood, Luis Rodríguez, "Analysis of dispersive propagation through foliage in remote sensing frequency bands", *2011 Progress in Electromagnetics Research Symposium (PIERS)*, Marrakesh (Morocco), March 20th – 23rd, 2011.
- Jianxiong Sun, Ana Vazquez Alejos, Muhammad Dawood, "Under-Sea Remote Sensing Using Brillouin Precursors", *7th IEEE International Workshop on Antenna Technology*, Hong Kong, April 5th – 7th, 2011.
- Ana Vazquez Alejos, Muhammad Dawood, Jianxiong Sun, "Dynamical evolution of Brillouin precursors in multilayered sea water-based media", *2011 European Conference on Antennas and Propagation*, Rome (Italy), April 11th-15th, 2011.
- Ana Vazquez Alejos, F. Falcone Lanas, M. Dawood, M. Navarro Moreno, "Analysis of time and spatial evolution of Brillouin precursors through metallic metamaterial media in TGHz band", *2011 European Conference on Antennas and Propagation*, Rome (Italy), April 11th-15th, 2011.

- Ana Vazquez Alejos, Muhammad Dawood, "Improvement of UWB, impulse and noise radar performance by enforcing Brillouin precursor fields", *2011 SPIE Defense Security and Sensing Symposium*, Orlando (FL), 25-29 April 2011.
- Ana Vazquez Alejos, Muhammad Dawood, "Dynamical evolution of Brillouin precursor waveforms in dispersive media for sensor radar applications", *2011 SPIE Defense Security and Sensing Symposium*, Orlando (FL), 25-29 April 2011.
- Ana Vazquez Alejos, M. Dawood, Jianxiang Sun, "Experimental analysis of Brillouin precursor formation in salted water", *2011 IEEE International Symposium on Antennas and Propagation - URSI/USNC/CNC Meeting*, Spokane (WA, USA), 3-8 de July 2011.
- Ana Vazquez Alejos, M. Dawood, Luis Medina, "Improvement of vegetation masses remote sensing by introducing analysis of Brillouin precursor", *2011 IEEE International Symposium on Antennas and Propagation - URSI/USNC/CNC Meeting*, Spokane (WA, USA), 3-8 de July 2011.
- Michael Abravanel, Ana Vazquez Alejos, Muhammad Dawood, "Experimental detection of Brillouin precursor through planar metallic slab in microwave frequencies", *2011 IEEE International Symposium on Antennas and Propagation - URSI/USNC/CNC Meeting*, Spokane (WA, USA), 3-8 de July 2011.
- Ana Vazquez Alejos, Muhammad Dawood, "Information retrieval and cross-correlation function analysis of random noise radar signal through dispersive media", accepted for 2012 Radar Sensor Technology in X SPIE Defense Security and Sensing Symposium, Baltimore (MA), 23-27 April 2012.
- Ana Vazquez Alejos, F. Falcone Lanas, M. Dawood, "Dispersive propagation of ultra wideband pulses through triply distilled water at PHz frequencies", accepted for 2012 European Conference on Antennas and Propagation, Prague (Czech Republic), March 26th-30th, 2012.
- Ana Vázquez Alejos, M. Dawood, F. Falcone, M. Beruete, M. Sorolla, "A less opaque ionosphere: Brillouin precursors evolution in natural and artificial plasmas", in review for 2012 IEEE International Symposium on Antennas and Propagation – URSI Radio Science Meeting, Chicago (USA), 2012.
- M. Dawood, M. Zeeshan, Ana Vázquez Alejos, "Brillouin Precursors Through Concrete Walls for Through-the-wall imaging at Microwave frequencies", in review for 2012 IEEE International Symposium on Antennas and Propagation – URSI Radio Science Meeting, Chicago (USA), 2012.
- M. Dawood, H. U. R. Mohammed, Ana Vázquez Alejos, "Breast Cancer Detection Utilizing Brillouin Precursors at Microwave Frequencies", in review for 2012 IEEE International Symposium on Antennas and Propagation – URSI Radio Science Meeting, Chicago (USA), 2012.

Book chapter:

- Ana Vazquez Alejos, Manuel Garcia Sanchez, Mohammad Dawood, Iñigo Cuiñas Gomez, Chapter “Wideband Noise Radar based in Phase Coded Sequences”, in book “Radar Technology”, ISBN 978-953-307-029-2, edited by Guy Kouemou, published by IN-TECH (www.intech.org), in Vienna (Austria), 2010.

Patent #1 (pending)

Title: *An experimental method to detect and process precursors at RF and microwave frequencies for greater penetration depths and enhanced imaging through dispersive media*

Patent #2 (pending)

Title: *Extended optimal filters for adaptive radar systems using binary codes*