DEVELOPMENT OF NEW TECHNIQUES FOR ULTRA WIDEBAND (UWB) FILTER AND ANTENNA DESIGN FOR WIRELESS COMMUNICATION SYSTEMS

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Motivation of the work

- In the last years, there has been a significantly increasing interest in investigating antennas, filters and antennas-filters and various for ultra wideband systems. Challenges of these UWB systems include the enhancement of UWB performances of antennas, filters and antennas-filtering using filters indeed or notched UWB antennas.
- These performances consist of impedance matching, high gain, radiation stability, compact size and low manufacturing for UWB antennas, low insertion loss, good selectivity, simple structure with compact size and out-of-band rejection performance for UWB filters and enhancement of the response of UWB antenna with eliminate the whole narrowband services that already occupy frequencies in the UWB band.
- In this project, we will deepen in the design and implementation constraints for the actual implementation of ultrawideband antennas and filters according to the proposed novel approaches.

Thesis Objectives

The main objectives along the Project are:

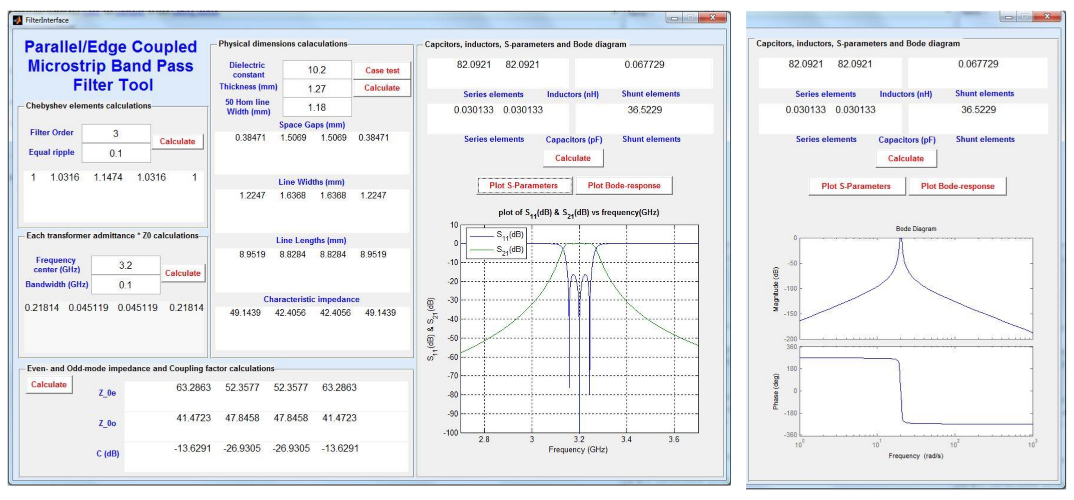
- Practical analysis of the implementation techniques available to build prototypes of Ultra-Wideband Antennas-filters for specific applications. Design requirements definition for specific applications: wireless communications, radar, frequency dispersive media, biomedical applications.
- Practical study of measurement techniques developed for the analysis of the implemented prototypes of Ultra-Wideband Antennas-filters.
- Development of specific measurement techniques for analysis of implemented prototypes of Ultra-Wideband Antennas-filters.
- Analysis of experimental results and comparison with the theoretical predictions.

Research plan

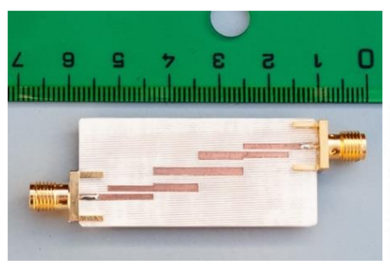
- Review of background theory of Ultra-Wideband Antennas-filters for Wireless Communication Systems.
- Mastering in CAD program for design of Ultra Wideband Antennas-filters.
- Development of an ad-hoc simulation tool.
- Mastering in implementation techniques to build prototypes of Ultra-Wideband Antennas-filters.
- Design requirements definition for specific applications: wireless communications, radar, frequency dispersive media.
- Development of specific measurement techniques for analysis of implemented prototypes of Ultra-Wideband Antennas-filters.
- Comparison of experimental and theoretical results.
- Writing scientific publications for journals and conferences.

Results & Discussions

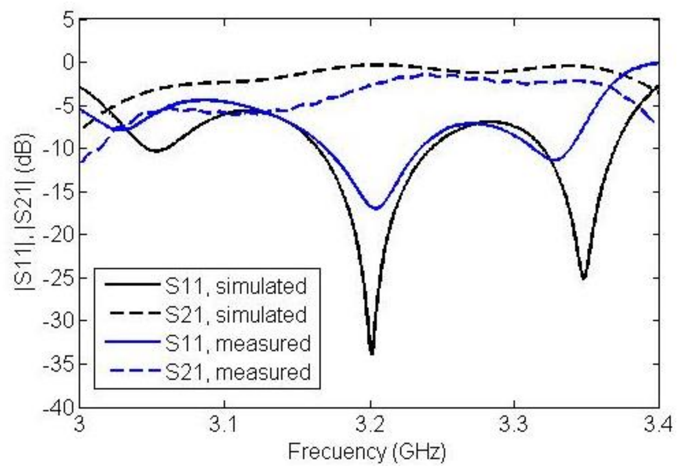
Work I: Development of a Calculator for Edge and Parallel Coupled Microstrip Band Pass Filters



Parallel coupled microstrip band pass filter at 3.2 GHz results using tool interface



Photograph of the tested filter



Measurement and simulation results of bandpass filter designed for3.2 GHz.

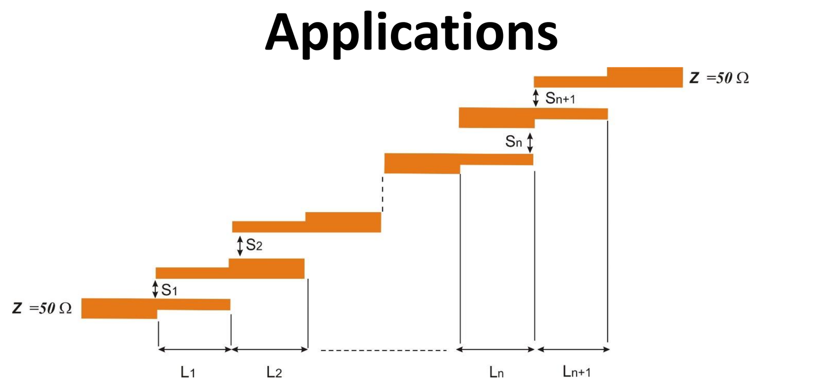
(I) $$L = \frac{\lambda_g}{4} = \frac{c}{4f\sqrt{\varepsilon_{re}}}$$

(II) $$\frac{s}{h} = \frac{2}{\pi}\cosh-1\left[\frac{\left(\cosh((\frac{\pi}{2})(\frac{w}{h})_{se})+\cosh((\frac{\pi}{2})(\frac{w}{h})_{so})-2\right)}{\left(\cosh((\frac{\pi}{2})(\frac{w}{h})_{so})-\cosh((\frac{\pi}{2})(\frac{w}{h})_{se})\right)}\right]$$

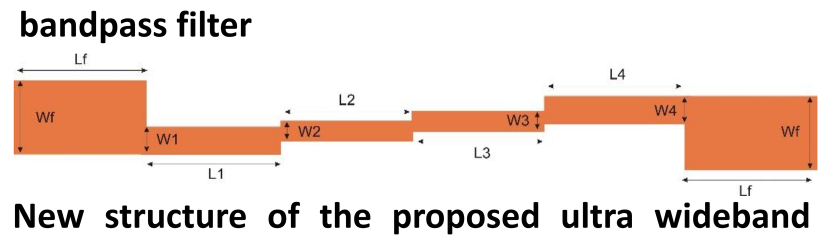
(III) $$\frac{w}{h} = \frac{1}{\pi}\left[\cosh-1\left(\frac{1}{2}[(\cosh(\frac{\pi s}{2h})-1)+(\cosh(\frac{\pi s}{2h})+1)\cosh((\frac{\pi}{2})(\frac{w}{h})_{se})]\right) -(\frac{\pi}{2})(\frac{s}{h})\right]$$

- In this work we introduced a calculator as a tool for design parallel coupled microstrip filters. Despite of using close form formulation (I, II, III), the performance accomplishes a reasonable accuracy[3]
- The proposed tool facilitates the understanding of the theory of parallel coupled microstrip filters and simultaneously it calculates the filter parameters design for research and also for educational purposes

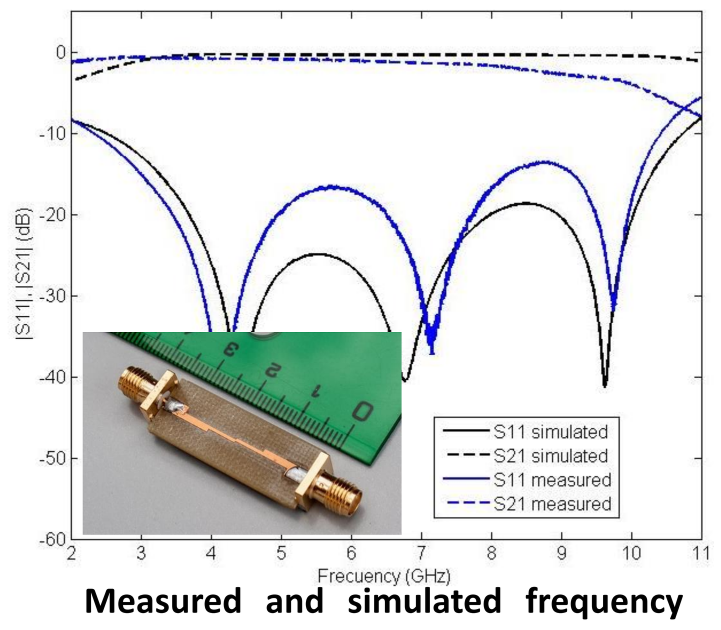
Work II: A Compact Microstrip Bandpass Filter for UWB Applications



Conventional structure of Edge microstrip bandpass filter



New structure of the proposed ultra wideband bandpass filter



Measured and simulated frequency response of UWB bandpass filter with photograph of the fabricated filter,

- A novel UWB band pass filter is presented. To create the UWB response, a structure of UWB edge-coupled band pass filter is modified in order to avoid the problem of very small coupling between resonators. The main advantages of the proposed simple structure are its small profile, low cost, wide impedance, low insertion loss, sharp rejection and good pass-band selectivity indicate that make the presented filter a good candidate for UWB applications [4].

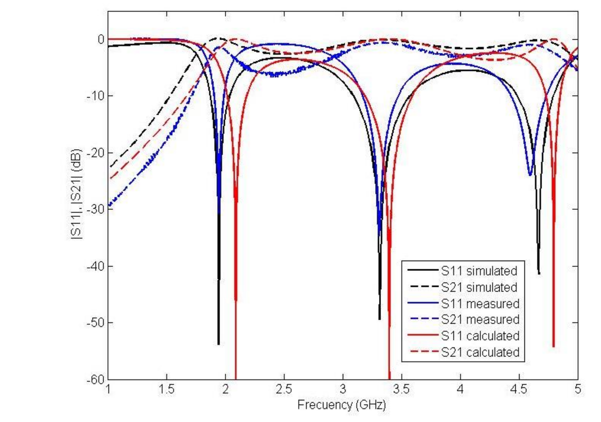
Work III: A Compact Tri-band Bandpass filter with suppression of Second Harmonic Response

(I) $$V_{p,i} = \frac{c}{\sqrt{\varepsilon_{eff,i}}} \quad \text{where } i = even, odd$$

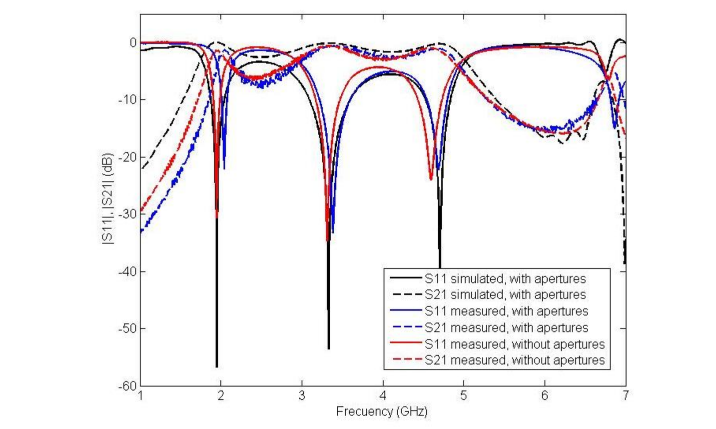
(II) $$Z_{L,e}(u,g) = \sqrt{\frac{\varepsilon_{reff}(u,\varepsilon_r)}{\varepsilon_{reff,e}(u,g,\varepsilon_r)}}\,\frac{Z_L(u,\varepsilon_r)}{1-\frac{Z_L(u,\varepsilon_r)}{377}\sqrt{\varepsilon_{r_{eff}}(u,g,\varepsilon_r)}Q_4}$$

(III) $$Z_{L,o}(u,g) = \sqrt{\frac{\varepsilon_{r_{eff}}(u,\varepsilon_r)}{\varepsilon_{r_{eff,o}}(u,g,\varepsilon_r)}}\,\frac{Z_L(u,\varepsilon_r)}{1-\frac{Z_L(u,\varepsilon_r)}{377}\sqrt{\varepsilon_{r_{eff}}(u,g,\varepsilon_r)}Q_{10}}$$

(IV) $$\begin{bmatrix} A_i & B_i \\ C_i & D_i \end{bmatrix} = \frac{\sin(\theta_{eff})}{T_i}\begin{bmatrix} qS_i & \left\{\frac{j}{2}\left[T_i^2+q^2(T_i^2-S_i^2)\right]\right\}Z_0 \\ \frac{2j}{Z_0} & qS_i \end{bmatrix}$$

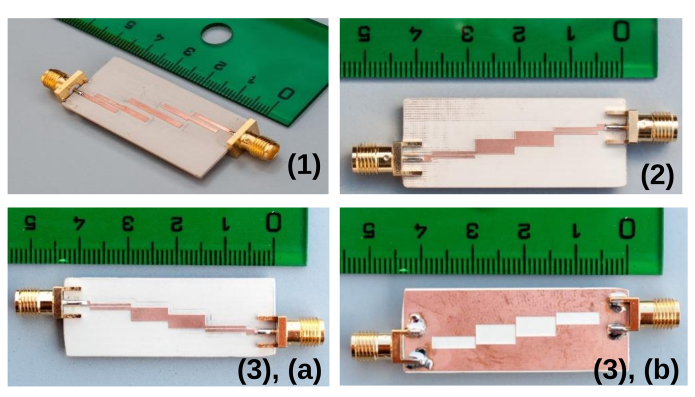


Measured, simulated and calculated frequency response of the proposed tri-band bandpass filter

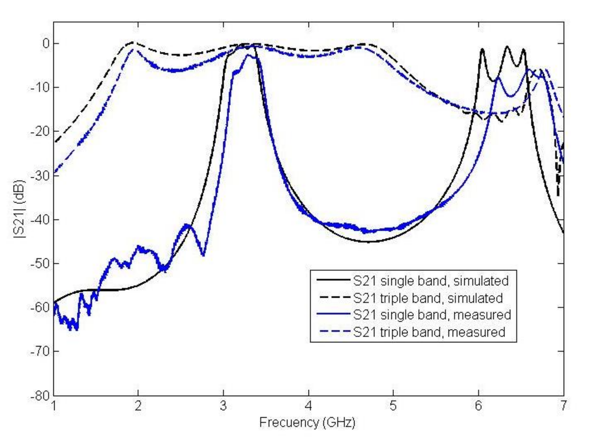


Measured and simulated frequency response of the proposed tri-band bandpass filter for conventional and modified versions

- A compact tri-band parallel coupled-line bandpass filter with suppression of second harmonic frequency is presented in this paper. This new filter is based on small coupling gap between resonators to achieve the desired multi-band frequency response and the spurious suppression [5].
- The proposed analysis of modeling the frequency-depend even- and odd-mode characteristics (II, III,IV) and difference in phase velocities (I) demonstrate the results obtained for this work.

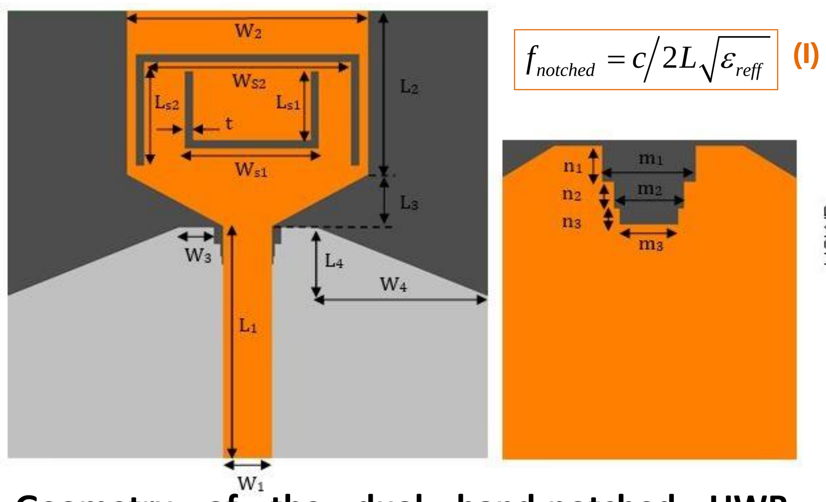


Photographs of the fabricated bandpass filters: (1) single band, (2) Tri-band, (3) Tri-band with apertures in ground plane, (a) top view, (b) bottom view.



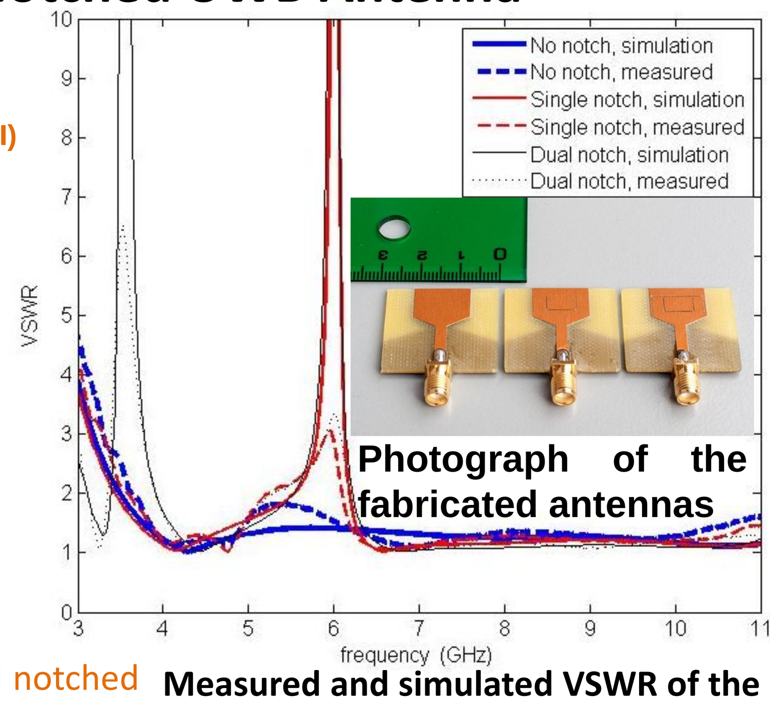
S21 curve performances for single band and tri-band bandpass filters without apertures

Work IV: A Compact Dual Band-Notched UWB Antenna based on Nested U-Shaped Slots



Geometry of the dual band-notched UWB antenna With its part of the ground plane

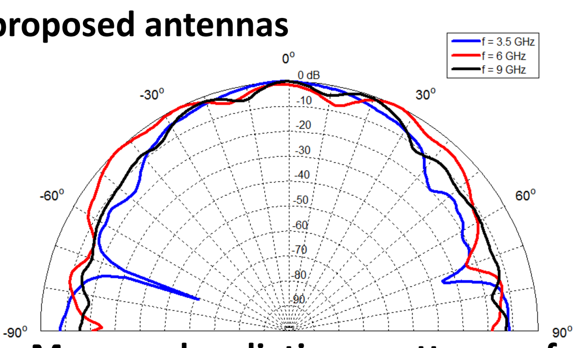
(I) $$f_{notched} = c/2L\sqrt{\varepsilon_{reff}}$$



Photograph of the fabricated antennas

Measured and simulated VSWR of the proposed antennas

- A compact printed UWB antenna with dual-band notched characteristic has been proposed in this work. Two nested U-shaped slots are embedded in the radiating patch antenna to create two stop-band filters with center frequencies of 3.4 GHz and 5.5 GHz [6]
- The notch frequency can be found by (I) where L is the total length of the slot, ε_{reff} is the effective dielectric constant and c is the speed of light. According to the resulting performances, the proposed antenna is a good candidate for UWB systems. It also might be easily integrated due to its small size.



Measured radiations patterns of dual band-notched UWB antenna at specific frequencies: H plane

Publications

[1] **A. Naghar**, O. Aghzout, F. Medina, M. Alaydrus and M. Essaaidi "Study and Design of a Compact Parallel Coupled Microstrip Band-Pass Filter for a 5 GHz Unlicensed Mobile WiMAX Networks", *International Journal of Science and Technology*, Volume 2, Page 492-497, N. 6, June 2013.

[2] O. Aghzout, **A. Naghar**, F. Medina, M. Alaydrus and M. Essaaidi "Novel U-Shaped Tri-Band Antenna on High Permittivity Multilayer Substrate for Wireless Communications", *JOURNAL OF TELECOMMUNICATIONS*, Volume 19, Issue 2, April 2013.

[3] **A. Naghar**, O. Aghzout, A. Alejos, M. Sanchez and M. Essaaidi, "Development of a Calculator for Edge and Parallel Coupled Microstrip Band Pass Filters", *IEEE International Symposium on Antennas and Propagation APS-URSI 2014*, July 6-12 Memphis, Tennessee, USA.

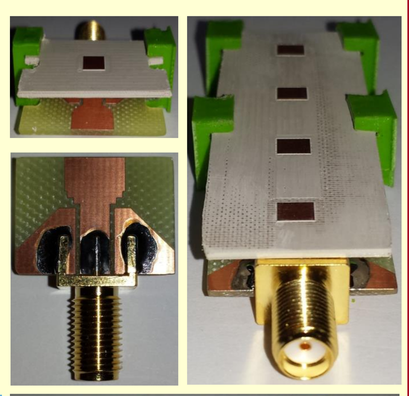
[4] **A. Naghar**, O. Aghzout, A. Alejos, M. Sanchez and M. Essaaidi, "A Compact Microstrip Bandpass filter for UWB applications", Electronics Letters. (submitted)

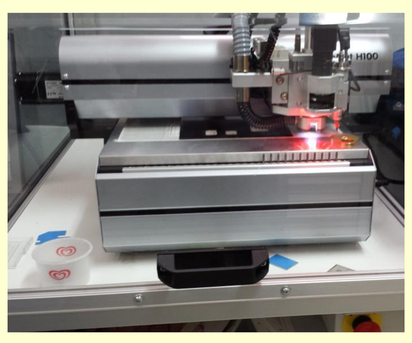
[5] **A. Naghar**, O. Aghzout, A. Alejos, M. Sanchez and M. Essaaidi, "A Compact Tri-band Bandpass filter with suppression of Second Harmonic Response", Journal of Electromagnetic Waves and Applications. (submitted)

[6] **A. Naghar**, O. Aghzout, A. Alejos, M. Sanchez and M. Essaaidi, "A Compact Dual Band-Notched UWB Antenna based on Nested U-Shaped Slots", Electronics Letters. (submitted)

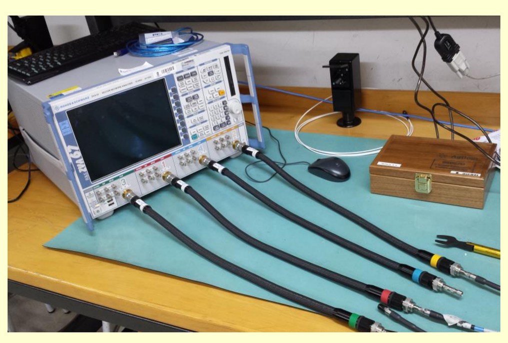
Next year planning

- Design of UWB Array antenna with notched Characteristics.
- Design of UWB Metamaterial antennas with filtering property.
- Design of UWB antennas-filters for Radar applications.
- Design of UWB Substrate Integrated Waveguide (SIW) filters.
- Design of UWB antennas-filters for Biomedical applications.

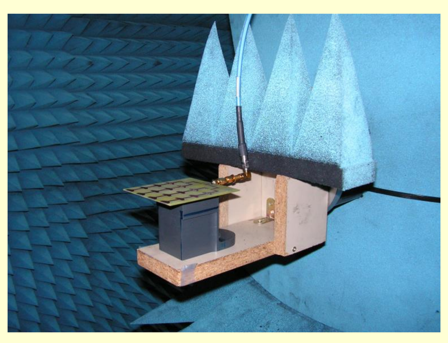




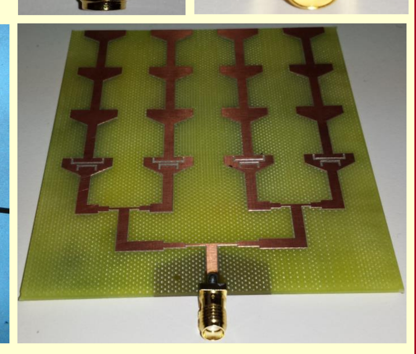
LPKF ProtoMat H100 for RF and MW applications



Vector Network Analyzer ZVA67, 10 MHz-67 GHz



Measurement proses in Anechoic Chamber



Antennas in Progress of study