

# Antenna Design

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**Abstract—** In this chapter, the activities of the *Grupo de Ingeniería de Comunicaciones* of the *Universidad de Málaga* in the field of Antennas and Electromagnetic Radiation, are presented. The chapter is organized in six sections: Activities, Antenna Developments and Achievements, Technology, Contracts and Projects, Members, and Publications.

## I. ACTIVITIES

ACTIVITIES in the field of antenna analysis, design, consulting, and prototyping started in 1996 in the *Grupo de Ingeniería de Comunicaciones* (GIC) of the *Universidad de Málaga*. Most of the antennas developed were designed to be built with conventional photo-lithographic techniques, but wire antennas have been designed and built, as well.

Different antenna morphologies have been considered, the most significant being: the wide-band *bow-tie*; patch arrays, line- or slot coupled (Aperture Coupled Microstrip Patch Antenna, ACMPA); slot arrays; single and double slot loops with Coplanar Waveguide (CPW) ports; loop arrays; printed quasi-yagi, also with CPW port; and printed wire and slot fractal antennas.

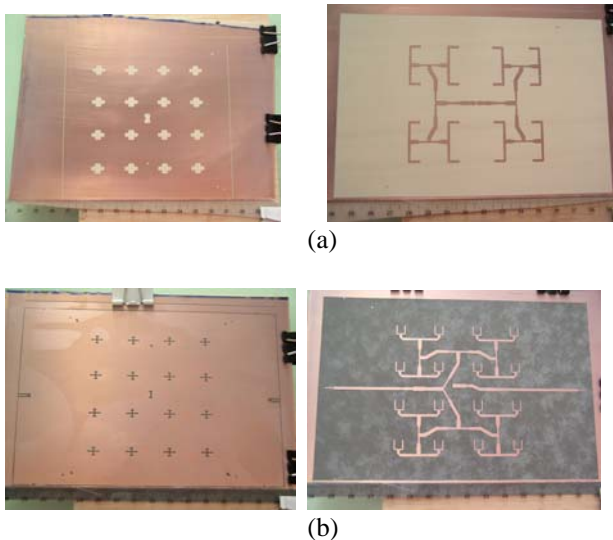


Fig. 1. Patch Array, two beams, two polarizations. Prototype manufacturing. (a) Coupling slots and feeding network of one of the beams. (b) Same, of the other beam.

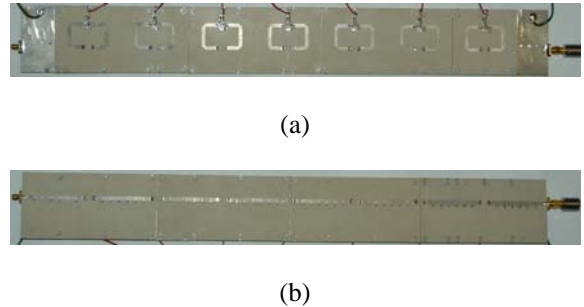


Fig. 2. Active leaky-wave antenna. (a) DC supply. (b) Composite Right/Left-Handed Transmission Line. Reference [8].

## II. ACHIEVEMENTS

The following list shows some of the achievements of the team members in the field of antennas, related devices, and close topics:

- Dielectric lens antennas for the mm- and submm-wave bands (under the direction of Prof. J.R. Mosig, LEMA-EPFL, 1996-1998).
- Planar slot antenna with single CPW port for GSM and DCS1800/DECT bands (1999-2000).
- Planar slot coupled patch (ACMPA) array for the 24 GHz band (2000-2002).
- Fractal morphology applied to miniature antenna design (2001-2002).
- Characterization and design of antenna elements for light arrays to operate in HF, VHF, and UHF frequencies (2001-2002).
- Slot arrays on Surface Integrated Waveguide (SIW) technology cavities (2002-2003).
- Traveling wave array antenna for the 26 GHz band (2003-2004).
- Azimuthal positioner for a mm-wave band antenna test bench (2003-04).
- Design procedure of transmission line transformers for baluns and impedance matching (2004-2005).
- Seeker UHF antenna for naval line-of-sight communications (2004-2005).
- Printed patch array, two beams, two polarizations, for Earth reception of satellite broadcasting (2005-2006).
- Slot antennas for WIMAX and MIMO antennas (2005-2006).
- Active leaky-wave antenna with composite right-left handed transmission line (CRLH/TL) (in collaboration with Prof. C.Caloz, *École Polytechnique de Montreal*, 2005).

- Printed and efficient zero-order antenna (current work).
- Passive leaky-wave antenna with CRLH/TL (current work).
- Printe MIMO antenna for the 5 GHz band (current work).

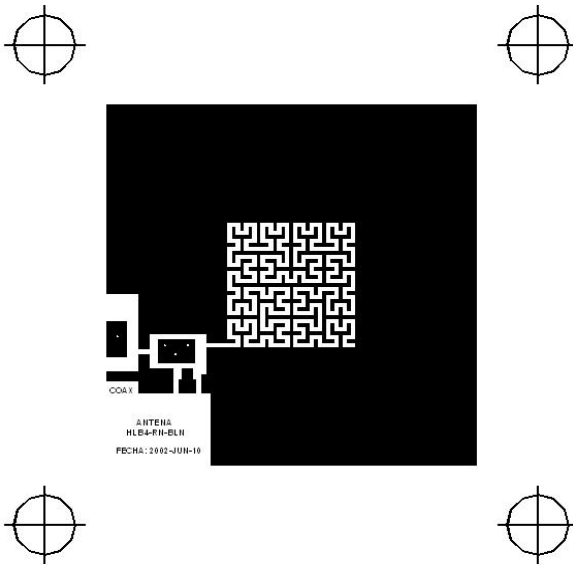


Fig. 3. Upper side mask of a fractal antenna that has been designed, fabricated and characterized by members of GIC.

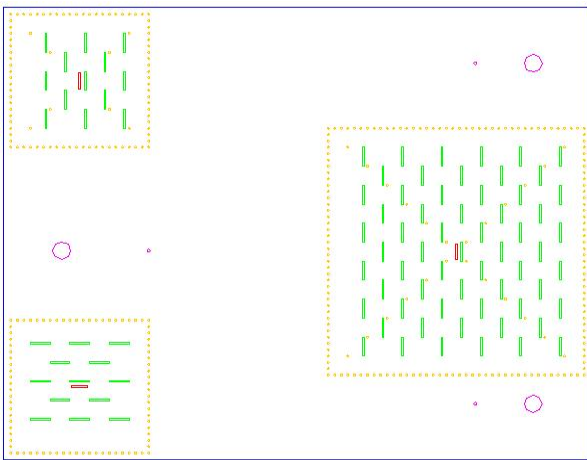


Fig. 4. Upper side mask of three slot arrays (green lines), slot coupled (in red) from a not shown microstrip line. SIW Technology. Designed and characterized in GIC, external fabrication. In yellow, the via-holes.

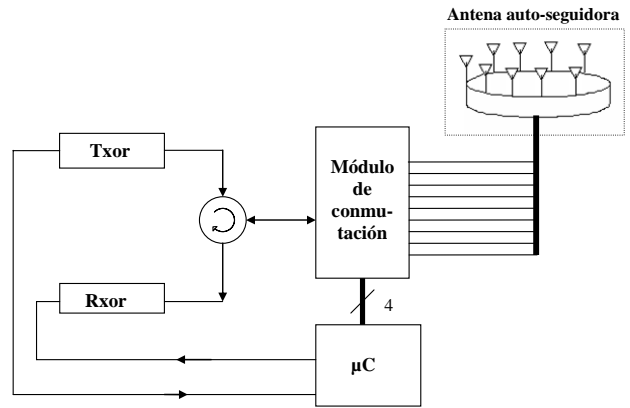


Fig. 5. Block diagram of the seeker UHF antenna for naval line-of-sight communications, developed by members of GIC.

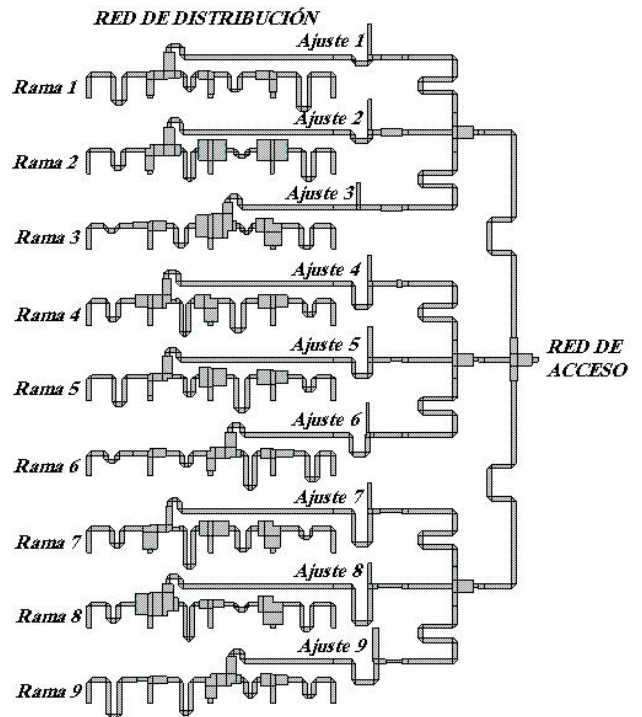


Fig. 6. Feeding network of a 8x8 ACMPA array, with Woodward-Lawson synthesis. Designed, fabricated and characterized by members of GIC.

### III. TECHNOLOGY

The most significant technological resources available at GIC are listed below:

- Vector Network Analyzer Hewlett-Packard HP-8510B with measurement capacity up to 40 GHz.
- Vector Network Analyzer Agilent PNA E8364A with measurement capacity up to 50 GHz.
- Spectrum Analyzer Agilent PSA E4448A with measurement capacity up to 50 GHz.
- CPW probe station *on-wafer* CASCADE MICROTECH Summit 10000.

- Electromagnetic analysis Software: Agilent ADS, Ansoft Ensemble y HFSS.
- Wire-bonding machine Kulicke and Soffa, K&S-4523.
- Printed circuit shop, with capacity of photoresist coating of microwave substrate boards and milling machine T-TECH Quick Circuit 7000.



Fig. 7. CPW probe station *on-wafer* CASCADE MICROTECH Summit 10000.



Fig. 9. Vector Network Analyzer Hewlett-Packard HP-8510B used to characterize devices.



Fig. 8. Wire-bonding machine Kulicke and Soffa, model K&S-4523.



Fig. 10. System for photoresist coating of microwave substrate boards, designed by members of GIC. Reference [7].



Fig. 11. Azimuthal positioner for a mm-wave band antenna test bench. Developed by GIC members.

#### IV. CONTRACTS AND PROJECTS

The Contracts and Projects developed by the Antenna Team of the GIC in the last few years and related to the antenna field are listed below:

- “Planar antennas for line-of-sight radio links in the 24 GHz band.” Supported by the *Universidad de Málaga*, external selection and evaluation of the “Agencia Nacional de Evaluación y Prospectiva” (ANEP). Principal Researcher: Pablo Otero Roth. April 2000 to March 2002.
- “Electromagnetic characterization and design of antenna elements for light arrays to operate in HF, VHF, and UHF frequencies. Phase one”. Supported by the “Instituto de Física Aplicada del Consejo Superior de Investigaciones Científicas” (Spanish National Research Agency). Principal Researcher: Pablo Otero Roth. May 2001 to September 2001.
- “Electromagnetic characterization and design of antenna elements for light arrays to operate in HF, VHF, and UHF frequencies. Phase two”. Supported by the “Instituto de Física Aplicada del Consejo Superior de Investigaciones Científicas” (Spanish National Research Agency). Principal Researcher: Pablo Otero Roth November 2001 to July 2002.
- “Aplicaciones en ingeniería de microondas de los materiales con permitividad y permeabilidad negativas”. Supported by “Ministerio de Ciencia y Tecnología, Plan Nacional de I+D”, 2003. Principal Researcher: Carlos Camacho Peñalosa. December 2003 to November 2006.

#### V. TEAM MEMBERS

The members of GIC that participate in the activities of antenna analysis and design are the following:

- Carlos Camacho-Peñalosa, Professor.
- Teresa M. Martín-Guerrero, Associate Professor.
- Enrique Márquez-Segura, Associate Professor.
- Pablo Otero, Associate Professor.

- F. Javier Mata-Contreras, Assistant Professor.
- Francisco P. Casares-Miranda, Telecommunications Engineer, Research Assistant.
- María Navarro-Tapia, Telecommunications Engineer, Project Assistant.

#### VI. PUBLICATIONS

Publications in international journals, related to antenna design and analysis are listed below (Symposia Communications and Contract Reports have been omitted):

- [1] P. Otero, G.V. Eleftheriades, and J.R. Mosig. “Modelling the coplanar transmission line excitation of planar antennas in the method of moments”. *Microwave and Optical Technology Letters* (John Wiley), Vol. 16, No. 4, pp. 219-225, November 1997.
- [2] P. Otero, A. Álvarez-Melcón, J.-F. Zürcher, and J.R. Mosig. “A microstrip-coupled slot-loop antenna for integrated receivers in the millimeter-wave band”. *Microwave and Optical Technology Letters* (John Wiley), Vol. 18, No. 2, pp. 91-95, 5 June 1998.
- [3] P. Otero, G.V. Eleftheriades, and J.R. Mosig. “Integrated modified rectangular loop slot antenna on substrate lenses for mm- and submm-wave frequencies mixer applications”. *IEEE Transactions on Antennas and Propagation*, Vol. 46, No. 10, pp. 1489-1497, October 1998.
- [4] D. Llorens, P. Otero, and C. Camacho-Peñalosa. “Dual band, single CPW port, planar slot antenna”. *IEEE Transactions on Antennas and Propagation*, Vol. 51, No. 1, pp. 137-139, January 2003.
- [5] F.P. Casares-Miranda, E. Márquez-Segura, P. Otero, and C. Camacho-Peñalosa. “Broadband Six-Port Circuit for Direction Finding Applications”. *Microwave and Optical Technology Letters* (John Wiley), Vol. 43, No. 6, pp. 457-458, 20 December 2004.
- [6] F.P. Casares-Miranda, P. Otero, E. Márquez-Segura, and C. Camacho-Peñalosa. “Assessment of a New Six-Port Circuit for Complex Voltage Ratio Measurements”. *Microwave and Optical Technology Letters* (John Wiley), Vol. 46, No. 1, pp. 24-27, July 2005.
- [7] E. Márquez-Segura, P. Otero, C. Camacho-Peñalosa, and J.-F. Zürcher. “A very low-cost system for photoresist coating of microwave substrate boards with educational purposes”. *International Journal of Electrical Engineering Education* (Manchester University Press), Vol. 43, No. 2, April 2006.
- [8] F. P. Casares-Miranda, C. Camacho-Peñalosa, and C. Caloz, “High-gain active composite right/left-handed leaky-wave antenna,” *IEEE Transactions on Antennas and Propagation*, accepted for publication (15 March, 2006).