ACTIVITIES IN ACE WP 2.3-1 ON WIDEBAND AND MULTIBAND RADIATORS

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ABSTRACT

Developments in wireless communications and sensing require increasing wider frequency bands and that multiple functions can be provided by single antenna systems. This paper presents an overview of the activities of ACE work package 2.3-1, intended to gather and integrate expertise on a European level. We review here the progress of the partners and relate the work to other ACE activities.

1. INTRODUCTION

Wideband and multiband antennas are vital to many applications ranging from handheld terminals, basestations, sensors, aircraft, satellites etc. As the number of services and functions increase, stringent constraints with respect to available space, mass limitations and the need to reduce cost dictate that several systems or functions use a single antenna. Some applications like ultra wideband communications and radar use unprecedented wide frequency bands and have demanding requirements, e.g. on antenna dispersion.

The EU 6th Framework Network of Excellence ACE – Antenna Centre of Excellence [1] – includes wideband and multiband antennas as one of its five vertical joint research activities. The activity is divided into three work packages: WP 2.3-1 on wideband and multiband radiators dealt with in this paper, WP 2.3-2 on reflector surface models dealt with in a parallel paper [2], and WP 2.3-3 on antennas for ground or surface probing radars including medical imaging described previously [3]. The radiator work package focuses on comparatively large radiating elements including reflector antennas. Cooperation takes place with the activities A2.1 on mm and sub-mm wave antennas, A2.2 on small antennas and A2.4 on arrays. There is a wide variety of wideband, multiband and ultra wideband antennas needed for existing applications that continue to develop as well as for emerging applications, and there is a wide range of expertise in these fields across Europe. Our main objective is to gather and integrate this expertise. To increase the relevance of the work, ESA/ESTEC participates in an advisory role. Strengthening the cooperation with colleagues in the new EU member states and improving gender policies have also high priorities.

2. WIDEBAND RADIATOR DATABASE

A main activity at the start of ACE was to generate a wideband radiator database on the Virtual Centre of Excellence (VCE) accessible at [1]. The database includes now 29 antenna types divided into six groups and 22 antenna applications divided into five groups as indicated in Table 1 and 2, respectively. The antenna applications provide not only the context for the different antenna types, but also the link to the system requirements for the appropriate wideband or multiband antenna system. Companies working in these fields have been active in producing these system-based antenna requirements.

A responsible appointed for each antenna type or application has prepared the corresponding reference document. The antenna type documents contain a definition including pictures or drawings, explanation of the principle of operation, list of typical performance and technology, and sources for further information. The antenna application documents give the background for the application, define frequency bands and antenna specifications for various requirements, and indicate sources for further information and potential antenna types for the application. The catalogue will be updated throughout the lifetime of ACE as new information become available and the capabilities of the VCE expand. This information is available to the public via the ACE Community on the VCE. The documents are extremely useful for future work. The system-based

Proc. 'EuCAP 2006', Nice, France
6–10 November 2006 (ESA SP-626, October 2006)

antenna requirements are essential for making new antenna research relevant and as a reference. They link the researchers and future engineers and scientists at universities with the evolving needs of the society joining universities and industry.

Table 1. Wideband radiator database antenna types.

Antenna Type	
Planar:	
1	Patch antenna
2	Annular slot antenna
3	Printed dipole antenna
4	Aperture antenna
5	PIFA
6	Curl antenna
7	Bow tie
8	Inverted F
9	Elliptical monopole antenna
10	Semi circular disc antenna
11	PEC element
12	Biomorphic planar antenna
13	Connected array antenna
Waveguides and horns:	
1	Hard horn and waveguide
2	Horn
3	Corrugated horn
4	TEM horn
5	Ridged horn
6	Waveguide with and without dielectric filling
Wire:	
1	Helix antenna
2	Dipole
Traveling wave:	
1	Log periodic
2	Spiral
3	Leaky lens
4	Vivaldi
Fractal:	
1	Prefractal antenna
Related technologies:	
1	Tunable antenna
2	EBG for surface wave reduction
3	Baluns

3. JOINT RESEARCH ACTIVITIES

The restructuring of the research activities is based on selected programmes going on and planned among the participants. The projects are organized in groups with similar orientation. The project groups form “clubs” with similar research interests and objectives. The projects are conducted as separate programmes due to programmatic, reporting and funding reasons with a project responsible. However, mutual participation, staff exchanges sharing facilities and expertise, exchange of results and ideas etc. take place in the project groups. New projects and project groups are created as needed. The current research activities are divided in four different groups emphasising ultra wideband (UWB) applications:

1. WB/UWB Antenna Design Methods
2. WB/UWB Terminal Antennas
3. WB/UWB Antenna Verification
4. WB/UWB Radar Antennas

The largest group is area 2, WB/UWB Terminal Antennas. Seven research activities belong to this group, of which the majority relates to low power UWB and MIMO. UWB antenna design is furthermore supported by area 1, WB/UWB Antenna Design Methods, where methods for efficient design of wide bands are pursued. Several of the activities in area 3, WB/UWB Antenna Verification, are also directed towards UWB measurements, an important aspect in UWB antenna development. New European UWB regulation are expected to strongly limit the use the lower part of the 3.1-10.6 GHz band in addition to blocking the Wireless LAN band 5.1-6 GHz leaving mainly the 6-9 GHz band for use without additional mitigation techniques. This will greatly impact future UWB antenna work, and a new important activity is to develop a UWB antenna specification for the wideband radiator database. This work is greatly supported by partners that like Univ. Karlsruhe are in the forefront of the UWB discussions with strong expertise not only in antennas, but also in system-related aspects [4].

Table 2. Wideband radiator database applications.

Antenna Application	
Navigation:	
1	GNSS terminal
Mobile communication:	
1	Ultra WB communication
2	Multiband/UWB communication
3	Mobile satellite terminal antenna
4	Handheld terminal
5	Portable satellite terminal
6	Base station antennas
7	Indoor comm.
8	WLAN
9	Bluetooth
10	DVB-H
Satellite communication:	
1	TT&C satellite antenna
2	Satellite communication, space
3	Multibeam satellite communication, space
EMC and test:	
1	Electro-optical field sensors
2	Test range probe
Sensing (remote and near field):	
1	Surface Penetrating Radar
2	Medical imaging applications
3	Radar systems
4	Radiometry/radio astronomy
5	Wideband Synthetic Aperture Radar
6	Square kilometre array

4. EXAMPLES OF JOINT RESEARCH

4.1. Particle Swarm Optimisation of UWB Antennas

The main objective of this work is to demonstrate and deepen the cooperation between three partners, ICCS/NTUA, UP Catalunya and FOI, in an investigation of the applicability of stochastic multidimensional optimisation methods, as *Particle Swarm Optimization* (PSO) described in [5], for optimising UWB planar antenna designs. A second objective is to implement calculations on a parallel level to reduce long computation times. This will allow the use of time consuming full-wave EM analysis methods. A third and final objective is to build a strong scientific background that will allow the partners to share intellectual property rights and integrate their research orientation towards common goals.

A number of planar antenna concepts have been investigated. Figure 1 shows a rectangular patch antenna with a Π–shaped slot fed by a coaxial probe through a ground plane. However, this concept was abandoned due to problems with the analysis. One reason is that the selected EM analysis software neglects the currents on the inner coaxial conductor exciting the patch. The second candidate indicated by the meshing arrangement in Figure 2 is a microstrip-fed elliptical patch antenna located above a ground plane with an elliptical aperture. This radiator type can have an ultra wideband impedance bandwidth [6]. The simulations in Figure 3 were carried out by a commercial software. This antenna required some special attention. Firstly, the mesh cell sizes arising from the meshing software are very non-uniform - especially for ellipses with a high ratio between the major and minor axis. This was dealt with by adopting piecewise linear meshes. More importantly, it was not straightforward how to define the excitation for the microstrip structure to compute the S_{11} parameter. The method-of-moments software selected uses Green's functions for infinite layered media and has options for top or bottom infinite ground planes. Then, S_{11} may be calculated by a standard one-port approach using a delta gap excitation at the end of the microstrip feeding the patch. However, the bottom ground plane of the elliptical antenna is finite and must be meshed, and the method for calculating S_{11} had to be changed to a two-port approach and a difference mode impedance. The status of the work is that an initial study has been completed, and further work is planned. The UWB antennas investigated have defined interesting wish lists to the ACE software activity 1.1.

4.2. Other Telecom Multiband and UWB Antennas

Related work also comprising small multiband antennas is performed at Univ. Liverpool and UP Valencia in cooperation with ACE activity 2.2 on small antennas. The work at Univ, Liverpool includes an inverted F antenna with integrated with dual-band PIFA, square monopole with tuning slot, tri-band PIFA, planar elliptical monopole etc. Of particular interest may be the CPW-fed modified semi-circular disk ultra-wideband antenna in Figure 4 [7]. The antenna uses a novel tapered ground and can cover the band 3-12 GHz. The half-wavelength semi-circular slot rejects the Wireless LAN band 5.1-6 GHz. Detailed radiation patterns of mobile handheld terminal antennas have been measured at SATIMO as part of the ACE activity 1.2 antenna measurement facility sharing.

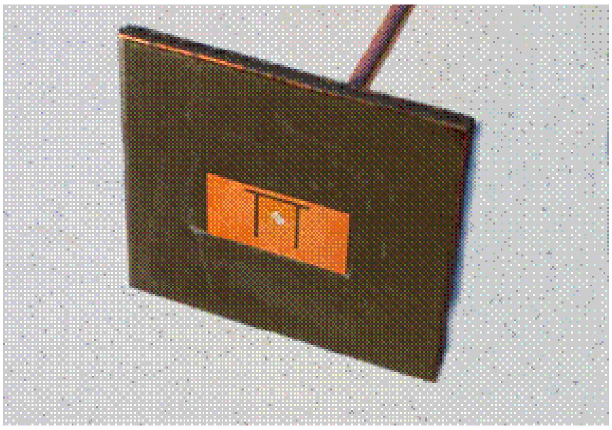

Figure 1. Microstrip antenna with Π-shaped slot.

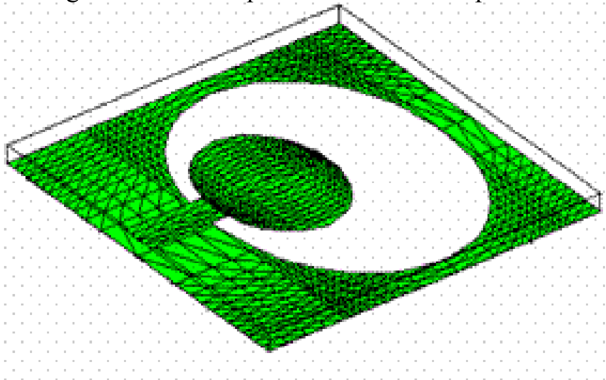

Figure 2. Elliptical microstrip-fed antenna meshing.

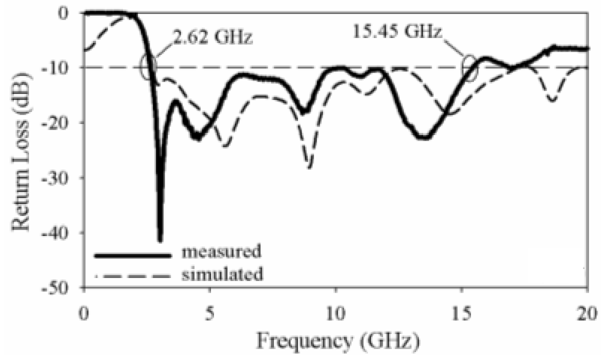

Figure 3. Elliptical antenna measured/simulated $|S_{11}|$.

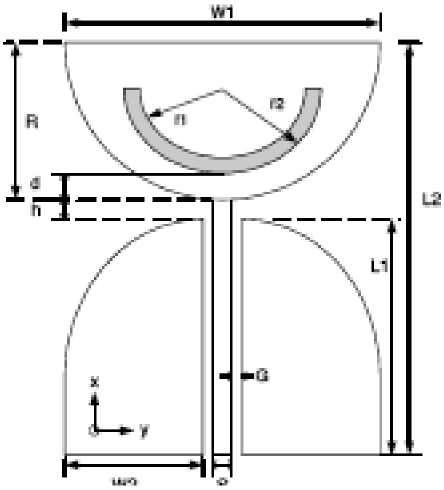

Figure 4. Modified semi-circular disk antenna.

UP Valencia works with design of compact wideband antennas for handheld devices and basestation antennas using the Theory of Characteristic Modes. By definition, characteristic modes have real currents on the surface of a conducting body that are independent of the excitation. They give valuable information about the resonances and radiating behaviour of the antenna, and can be used to improve the antenna design and identify the best feeding arrangement. A software tool computes efficiently the characteristic modes of arbitrarily shaped antennas over a wide frequency band. The research focuses on planar monopole antennas for basestations and mobile handset antennas that use the Printed Circuit Board (PCB) of the handset to radiate. Figure 5 shows a novel double-fed planar monopole antenna aimed at indoor basestation applications [8]. The antenna operates for several wireless standards and has a return loss better than about 10 dB for 1.3-6 GHz. Figure 6 compares the measured and predicted match for a folded PCB antenna excited by a square plate recently developed in cooperation with IMST. The design is based upon the characteristic mode theory, which indicates that modes with longitudinal currents on the PCB provide wider bandwidth than other modes [9].

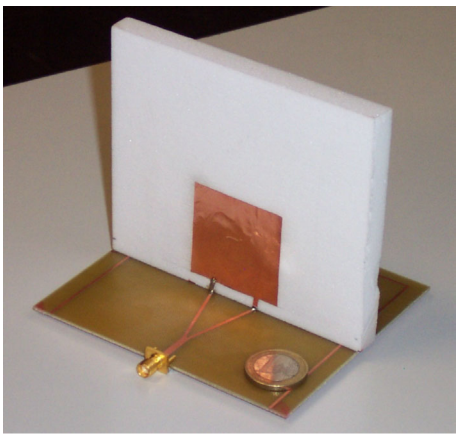

Figure 5. Square monopole with double feed.

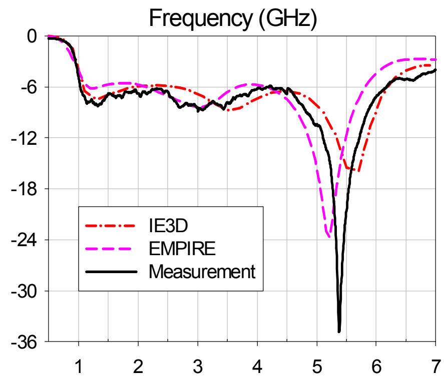

Figure 6. PCB wideband antenna $|S_{11}|$.

4.3. Large Wideband Radiators

Larger wideband, multiband and ultra wideband radiators are used by radars, to measure other antennas, EMC measurements, satellite communications etc. These applications typically require a higher performance than mass-market low power communications and cost is less important. The UWB pyramid antenna developed at TNO and also presented in this session is an ultra wideband version of the leaky lens antenna with interesting properties [10]. Other papers of this session deal with Vivaldi and spiral antenna. Univ. Karlsruhe studied the time-domain response of some of these antennas for their use in ultra wideband communication [11]. Chalmers Univ. designed and manufactured a decade bandwidth dual polarised log-periodic reflector antenna feed for the Square Kilometre Array [12] and developed dual-band multi-mode hard horns for 20/30 GHz satellite multibeam communications antennas [13]. These multibeam antennas usually require that the feeds and the associated beams be divided among three or four reflectors to achieve both a low spillover and a high crossover level. ASC demonstrated that the three or four reflectors can be replaced by a single large shaped reflector and that this approach can operate well over a wide band [14].

Tech. Univ. Delft has addressed the multifunctionality of antenna systems with the shared aperture approach where separate radiators operating in different frequency bands are interleaved in an array [15]. Thus, each function is associated with a specific thinned subarray. A number of wideband and ultra wideband far-field and near-field probes have been developed. Figure 7 shows a double ridged TEM horn developed by Geozondas in Vilnius, Lithuania and used by TU Delft as far-field probe in the band 1-26 GHz. The horn has been measured both in the frequency and the time domain [16]. Figure 8 compares patterns at 15 GHz measured in the time domain (blue colour) and in the frequency domain (green colour). The discrepancies may be the effect of parasitic reflections, e.g. from the absorbers in the anechoic chamber. The measurements in time domain remove some of the parasitic reflections by time gating while this does not occur in the frequency domain. Figure 9 shows the antennas of a new Surface Probing Radar System (SPR) in the TU Delft SPR antenna test facility being shared with ACE. The radar operates in the band 0.17-3.3 GHz and has a digital near-field steering and focusing on receive. The down-looking antenna system consists of a single transmit dielectric wedge antenna [17] and a linear digitally controlled 7-element receive antenna array.

Figure 7. Double ridged horn far-field probe.

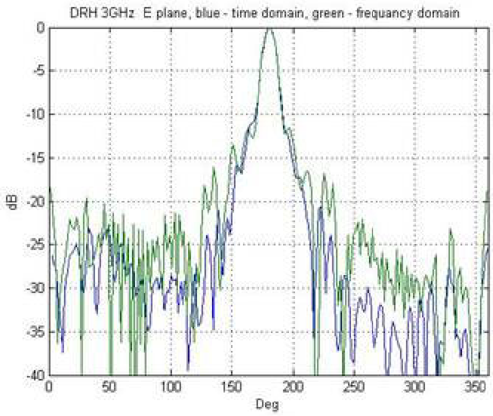

Figure 8. Frequency-/time-domain measured patterns.

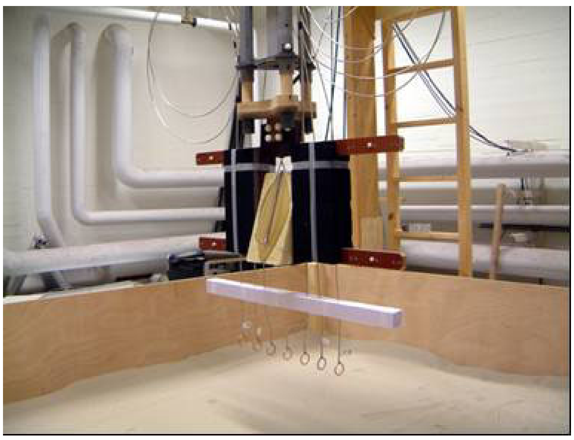

Figure 9. SPR antennas in SPR antenna test facility.

In the second two-year period of ACE that started Jan. 2006, several new partners in the new EU member states joined ACE. Among them, the Czech Tech. Univ. in Prague is together with the wideband antenna spin-off company RFspin [18] developing a new concept of double ridged antennas based on a new coaxial-waveguide transition and a waveguide mode study. The main focus is given to nonstandard ridged waveguides as discussed in another paper of the session [19]. Antennas have been developed and measured for the bands 0.2–2.2, 0.4–6 and 4–40 GHz – see Figure 10. The new theoretical results provide the means to improve the "well-known" ridged antennas and optimise them with respect to broadband gain, reflection and radiation pattern. The antennas are designed for special measurement purposes including EMC. Figure 11 compares the measured return loss for two antennas with simulated results. Figure 12 shows typical radiation patterns for the antenna optimised for the on-axis field. Future work will be oriented towards dual polarised ridged antennas.

Figure 10. Double ridged antenna (4-40 GHz).

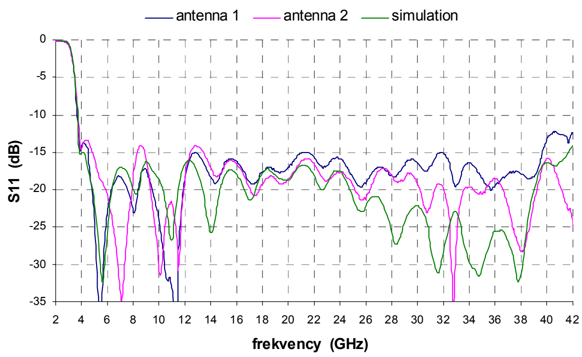

Figure 11. Ridged horn measured and predicted $|S_{11}|$

5. CONCLUSIONS

We have presented a range of wideband, multiband and ultra wideband antenna activities in ACE activity 2.3-1 and briefly described some future plans. Deliverables of the activity including a wideband antenna database are available from the ACE Community [1].

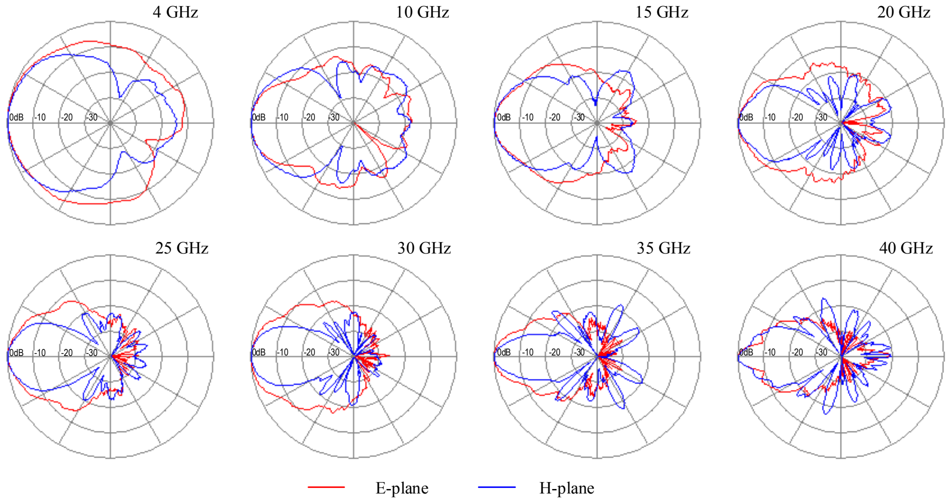

Figure 12. Typical patterns for double ridged horn.

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