FINAL PUBLISHABLE SUMMARY REPORT OF THE PROJECT "CONFORMAL"

Recent progress in the design of conformal antennas and in their practical implementation has stimulated the use of these types of antennas in different communication systems: on spaceships, aircrafts, for mobile communication base stations, etc.. An accurate modeling of these antennas requires fundamentally new theoretical developments. Being much more complicated, the **theory of cylindrical microstrip antennas** is not developed up to the same level as planar microstrip antenna theory. Advancing this theory is crucial in view of future design flexibility and widespread application.
The ***major goal*** of the project "Conformal" was to solve **the most problematic points** in the modern theory of cylindrically conformal antennas, namely, the need for efficient approaches to analyze a cylindrical microstrip antenna array, whose size considerably exceeds the wavelength of operation (i.e. **large arrays**) and whose patches are of a **complex shape**. Both points are clearly linked to the issue of design flexibility.
Within the project, new and effective theoretical developments, which include even **new physical ideas and concepts,** have been conceived and implemented to realize the analysis of novel cylindrically conformal antenna arrays of a large electrical size and with patches of a complex shape. Further, the **theory of excitation** of Cylindrical Microstrip Antennas with **complex shaped patches** has been developed for different excitation types, namely, excitation by **a plane wave**, by a **cylindrical microstrip line**, and excitation by a **probe.** All these techniques have been theoretically developed and have been implemented. With the new software, practical Cylindrical Microstrip array antennas which possess an **omnidirectional** radiation pattern and an **extended bandwidth** have been designed, optimized, fabricated and measured.

In more detail, the following three main tasks have been performed.

I) A **rigorous model** for a CMAA (Conformal Microstrip Antenna Array) with patches of complex shape has been built theoretically and realized numerically. The problem has been solved with the help of the method of moments in the spectral domain. Piecewise sinusoidal basis functions have been used. The model includes very innovating theoretical developments, like taking into account explicitly in the calculation of the Green's function the two singular contributions: the asymptote and the surface wave contribution. Several subtasks have been performed.

1) The problem of scattering of a plane wave by a CMS (Conformal Microstrip Scatterer) with patches of arbitrary shape has been considered. A numerical algorithm for the calculation of the RCS has been developed.
2) Several patch shapes have been designed: the cylindrical rectangular patch with a horizontal slot, the cylindrical rectangular patch with a slotted frame, and the cylindrical rectangular patch with two U-shaped slots.
3) A rigorous theoretical model to analyze the input impedance and far field pattern of a line-fed CMAA with patches of a different shape has been worked out in detail. The de-embedding procedure necessary to extract the input impedance from the current distribution on the line has been developed.
4) The ultimate "practical" result of this first effort was the design of a large cylindrical microstrip antenna array with 5 pairs of coupled slotted strip-frame patches proximity-fed by a microstrip line of about 5 wavelengths. A rigorous analysis of such large proximity-fed cylindrical array *that takes into account all electromagnetic couplings* has never been realised before. The computation time consumed has been reduced considerably by using the special techniques mentioned before. An extremely low level of cross polarization (<- 40 dB) was obtained. The advantage of the proximity fed antenna array consists of the fact that the effective patch-to-CML coupling is controlled by varying the space between the CML and the patches. The slot size and the patch shape do not need to be changed. Therefore the weak coupling regime allows to provide different classical array profiles of current distributions on the elements, like cosine, cosine-quadratic, etc., which is very useful in practical designs.

II) The theory of probe-fed CMAs with complex-shaped patches has been advanced, see in Fig. 1 the illustrating demonstrator that has been built.

1) The **two-dimensional asymptotical behaviour** of the probe related spectral GFs has been rigorously derived, subtracted, and the corresponding reaction integrals have been inverse Fourier transformed without the occurrence of any calculation time consuming cylindrical functions. *To our best knowledge, this extraction solution has never been presented in literature before*.
2) Numerical results for CMAs with probe-fed complex-shaped patches have been obtained. Various single patches with slots and notches have been discussed, with both smaller and **larger bandwidths**. Moreover, the concept of using parasitic patches with slots and notches has been used for the first time in a CMA topology, yielding a bandwidth improvement with a factor 2.8. Several structures have been fabricated and measurements are in good agreement with simulations**.**

III) Some CMAAs have been designed even with **textile substrates** and patches made from **conducting textiles**. Two new types of wide-band omnidirectional cylindrical microstrip antennas were designed, one with vertical and one with horizontal polarization, based on the topology of coupled E-shaped patches plus additional parasitic patches arranged on the cylindrical substrate. After optimization, a bandwidth of 20% was reached, thanks to the use of the low permittivity textile substrate. In fact a compromise between bandwidth and radiation pattern deviation (from the omnidirectional one) has been found for a given radius of the ground cylinder thickness. These structures also have been fabricated and measured.

In conclusion, the *expected outcome* of the project has been fully reached. **Not only new theoretical knowledge about this type of antennas, but also new, powerful and flexible software useful for the design of a wide variety of realistic cylindrically conformal antenna systems is now available**. In particular, the results of this project can be used in the design of wireless networking mobile base stations with beam forming capability and in the design of on-body antenna applications. On top, this project has started with the investigation of some technological aspects in the fabrication of cylindrically conformal antennas with textile materials.

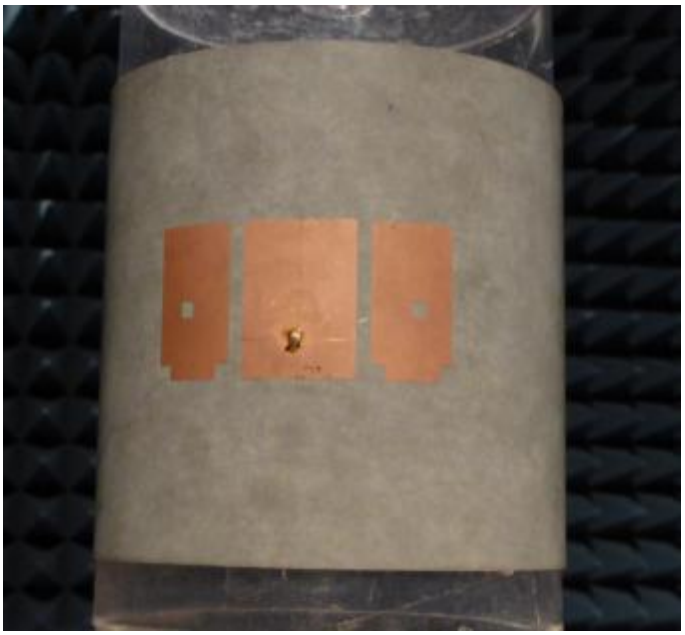

Fig. 1. Photo of a probe-fed arbitrary shaped patch cylindrically conformal antenna array designed, fabricated, and measured within the context of the CONFORMAL project.