Active Antenna Arrays

Small-Footprint, Scalable RF Solutions for Base Stations

BELL LABS Research Project

Context:

In traditional macro-cellular base stations, the RF (radio frequency) hardware contributes:

- half or more of the total equipment costs
- three quarters of the total cabinet volume
- the most power-hungry devices in base stations: the power amplifiers.

Space and costs issues increase in more advanced MIMO, beam steering and other intelligent antenna schemes. These require multiples of the RF transmit and receive paths of standard base stations with each path having its own set of RF hardware.

In active antenna arrays complete RF transceivers are integrated into each antenna element. Stacking these elements forms the array (Figure 1): the number and geometry depend on desired size, power output and capabilities. Each element is fed with a digital RF stream, allowing for independent signal transmission from each element.

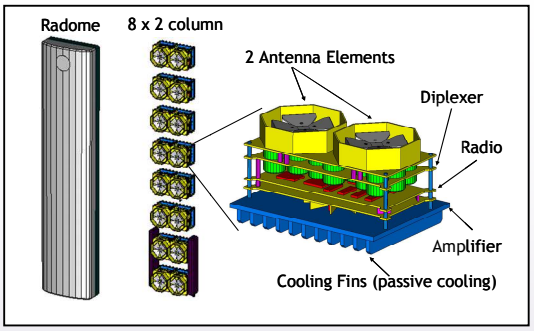

Figure 1: Active antenna array concept with a column array (left) and single antenna module (right)

Alcatel-Lucent is prototyping new technologies and novel RF hardware architectures to enable production of macro and microcell base stations with small footprints, reduced power requirements, and cost-effective RF hardware solutions that are scalable for advanced beam steering and MIMO schemes.

Challenge:

In realizing this vision, many technical challenges have been addressed:

- Miniaturizing RF hardware to fit weight and size parameters of typical antenna radomes.
- Increasing overall solution realiability.
- Minimizing component and systems costs.
- Maximizing overall power efficiency.

Innovation:

Scalable, Distributed Power Amplification

Power amplification is distributed in two ways:

(a) *Between antenna elements:* Each power amplifier sits behind an antenna element. Traditional passive antenna solutions' high-powered RF feeder cables and passive distribution networks are eliminated, saving power.

(b) *Within antenna elements:* Power amplification is split into parallel devices within the antenna element. This results in further power savings via switching off devices for low cell traffic loads.

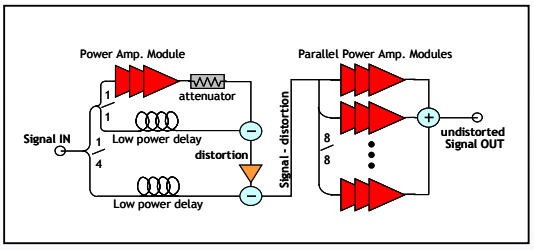

Figure 2: Power amplifier concept

Distributed solutions also help with reliability. Even if a device or module fails, there is only graceful degradation. The system still operates. Replacement of failing modules can be done on a scheduled basis.

Metalized Plastics to Reduce Weight

Novel antenna and filter solutions have been created that enable use of plastic injection-moulded parts with surface metalization (Figure 3). This enables a dramatic reduction in overall weight.

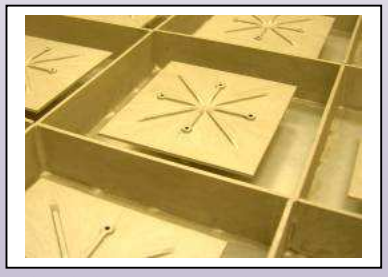

Figure 3: Metalized plastic antenna element

The antenna element design also provides some isolation between transmit and receive (over 20 dB in array configurations). This reduces the requirements on the front-end filters. It enables introduction of an innovative low-cost cavity resonator structure in the filters, with printed-circuit-board-based coupling between resonators (Figure 4).

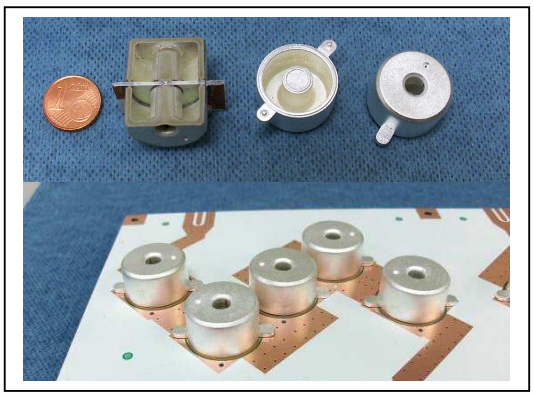

Figure 4: Metalized filter concept: Resonator structure (top) and filter using PCB-coupled resonators (bottom)

Low-Cost Manufacturing

The concept uses low-power power amplifier devices, metalized plastic parts and is assembled on printed circuit boards. This means manufacturing can employ standard pick'n'place machines and surface-mount technology thereby minimizing manufacturing costs.

Single Solution, Multiple Deployment Scenarios:

Current prototype active antenna elements transmit ~5W average power. By varying the number of active antenna elements and their geometry, the solution can address a number of different market segments:

- One or two elements can be used for low-footprint microcells.
- A vertical column of 8 or 10 elements would be used for a macrocell sector with the added benefit of adaptive vertical beamsteering.
- Square or rectangular arrays could be used for advanced forms of MIMO or beam-steering.

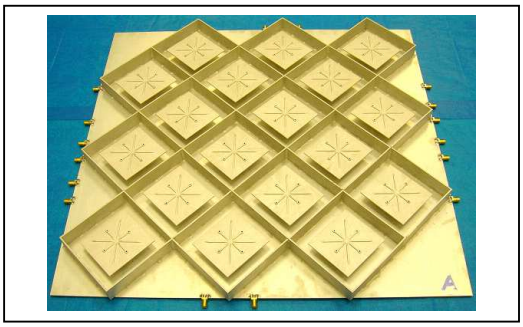

Figure 5: Prototype of a square antenna array configuration

BENEFIT: Power-scalable, small-footprint RF solutions for beam-steering and MIMO applications reduce unit cost, are more efficient and increase reliability.

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Résumé:

Alcatel-Lucent a mis au point et développé des prototypes de technologies destinés à la production de filtres en plastique métallisé et d'amplificateurs de puissance à répartition. Ces produits, faciles à fabriquer, permettront la mise en œuvre de solutions de réseaux d'antennes actives de nouvelle génération. Dans cette nouvelle architecture de réseaux d'antennes actives, les chaînes RF volumineuses et coûteuses sont miniaturisées, leurs coûts sont réduits. Elles sont intégrées à l'arrière de chaque élément d'antenne, pour composer le réseau d'antennes d'une station de base cellulaire. Des composants en plastique métallisé sont utilisés dans des dispositifs compacts et ultralégers innovants, qui peuvent être assemblés sur des cartes de circuits imprimés à l'aide de la technologie standard de montage en surface. L'ensemble de cette architecture satisfait aux normes de radiocommunication cellulaire et offre la fiabilité requise pour fonctionner en haut d'une tour. Au final, cette architecture de station de base présente un encombrement réduit et dispose de la souplesse et de l'évolutivité nécessaires pour les algorithmes de pointage de faisceau et les algorithmes MIMO avancés.