Triple-mode ceramic: the key in ultra-compact filter research

To meet the space limitations of tomorrow’s cellular base stations, Radio Frequency Systems is researching an ultra-compact hybrid filter technology based on a low-loss dielectric ceramic.

With the deployment of ‘micro’ base stations and the co-location of multiple cellular services, the challenge is on to fit more and more equipment into a shrinking amount of space. One component that can occupy a significant fraction of base station volume is the RF bandpass filter, increasingly introduced to control interference and improve quality of service.

As a result, base station manufacturers are demanding RF filter technologies that are both less costly and more compact, while continuing to meet stringent base station performance specifications.

Perhaps the most logical means of minimizing the size of an RF bandpass filter is to minimize the volume allocated to the resonant chambers—or cavities—that determine the bandpass selectivity of the filter. The use of low-loss dielectric ceramics has proven useful in this regard, by allowing the development of multi-mode filters—essentially where a single cavity supports two or three resonant modes (or poles). A ‘dielectric-loaded’ multi-mode cavity offers a compact filter with a high-quality factor (Q). However, the resonator volume can be even further reduced by making the entire multi-mode cavity out of the low-loss ceramic dielectric. In this case, the metallic housing is replaced by metallic plating of the ceramic and—although the Q is sacrificed to some extent—it remains in the range of typical metallic coaxial resonators that are commonly used in base station filters.

Such use of low-loss dielectric ceramics for triple-mode cavities means that the size of the resonator can be scaled down by as much as the square root of the dielectric constant, relative to an air-filled cavity resonant at the same mode. In addition, power handling is relatively high because there are no air gaps, and because the majority of the power loss in the filter is resistive loss at the resonator surface and can easily be dissipated.

Seven-pole UMTS filter

Radio Frequency Systems has applied these principles to develop a proposed ultra-compact RF bandpass filter for universal mobile telecommunication system (UMTS) base station applications. The seven-pole hybrid filter comprises a metallic coaxial combline resonator sandwiched between two triple-mode plated ceramic resonators, each with three orthogonal modes (Figure 1). The two types of resonators form a hybrid structure, which is used to address the poor spurious performance—typical of multi-mode filters based on dielectric ceramic.

Using various computer simulation techniques, the proposed UMTS filter was designed to accommodate a pass band of 1920-1980 MHz, with greater than 70-dB rejection below 1880 MHz and better than 95-dB rejection above 2110 MHz. Insertion loss and return loss were designed to be less than 1 dB and less than -20 dB respectively. The ideal response of the triple-mode cavity and the central coaxial resonator is achieved using an aperture of specific dimensions.

Double optimization

Optimization of the overall triple-mode cavity dimensions was achieved using a combination of two techniques: a finite element method (FEM)-based three-dimensional electromagnetic simulator, and RF-developed filter synthesis software.

The assembled hybrid seven-pole filter is less than 33 millimetres (excluding tuning screws), compared with the desired pass band for universal mobile telecommunication system (UMTS) base station applications, with a third the size of a traditional metallic coaxial resonator cavity. In addition, it meets the stringent performance requirements demanded by UMTS base station manufacturers and cellular operators, ensuring that it has a good potential for base station application.