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SAW-BAW duplexers for WCDMA

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Best of both worlds

EPCOS has succeeded in combining the benefits of SAW and BAW technologies in a duplexer for the WCDMA band, thus achieving a greater degree of miniaturization together with improved electrical parameters.

One example for implementation of this technology is the antenna duplexer in CDMA phones. It acts as a passive crossover network that conducts the RF signals from the power amplifier to the antenna in the transmit direction along the TX path. At the same time, it conducts the incoming signals from

the antenna to the low-noise amplifier in the receive path (RX path). The RX and TX paths use different frequency bands that are very close together for the simultaneous transmission and reception of RF signals to and from the base station.

The large difference between the power levels of the receive and transmit signals of up to 120 dB places extremely tough demands on the signal separation, near selection, insertion loss and power stability of the duplexer. This means that the key components of this device are two high-performance band-pass filters for the corresponding frequency bands as well as the right matching network between these filters and the antenna.

Tough requirements with WCDMA

One of the most demanding frequency bands for duplexers is the US PCS band, also known as WCDMA band II. It has a very narrow frequency gap of only 20 MHz between the transmit band (1850 to 1910 MHz) and the receive band (1930 to 1990 MHz). Until recently, the high temperature coefficients of high-coupling SAW substrates such as lithium tantalate and lithium niobate meant that these applications could not be realized with SAW-based filter solutions.

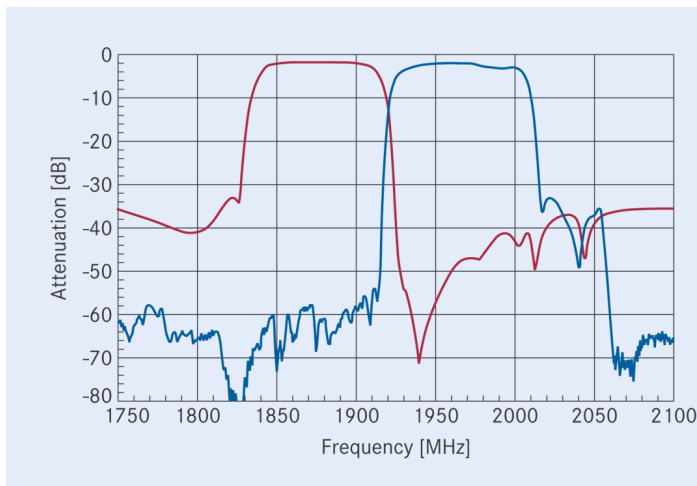
Up to the end of the 1990s, only ceramic resonators were able to satisfy the demanding PCS specifications with dimensions that were acceptable for mobile phones. These components make use of electromagnetic resonances and as a result are relatively large.

The first PCS duplexers based on BAW came onto the market in 2000: thanks to the excellent quality of the BAW resonators, their performance was similar to that of the relatively large ceramic components. Although their footprint was initially not much smaller than that of their ceramic counterparts, they soon gained market shares thanks to their considerably lower insertion height of less than two millimeters. These BAW components now have dimensions of only 3.8 x 2.8 x 1.3 mm³.



FIGURE 1: FILTER CHARACTERISTIC OF THE SAW-BAW DUPLEXER

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The new duplexer offers the required edge steepness in the transmit band (red) and receive band (blue) for WCDMA II

The integration of the low-noise amplifiers in the transceiver chipset as well as the trend toward less expensive front-end architectures based on CMOS technology have led to strong demand for filters with integrated symmetry converters and duplexer components. When the conversion of an asymmetrical signal referred to ground – also known as single-balanced conversion – is conventionally implemented with a balun in the form of a transformer, this impedance converter may be positioned at one of two places: either between the common TX/RX line leading to the antenna and the RX filter, or after the asymmetrical RX filter.

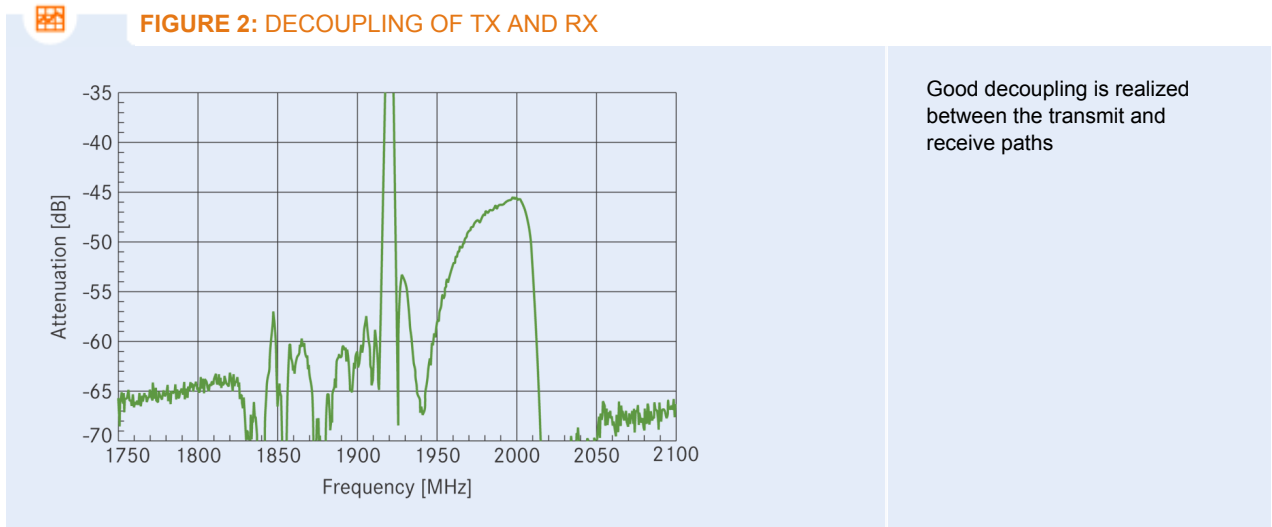
In the first case, the balun becomes an integral part of the duplexer and must therefore be carefully matched. In the second case, the impedance converter has a simpler design because it merely acts as a symmetry and impedance converter within a chain of matched RF components.

In both cases, however, the conversion – namely signal symmetrization – incurs a signal loss caused by the mismatch as well as the internal losses of the balun.

A very elegant way of avoiding such balancing losses is to use bandpass filters with integrated symmetry converters. Both BAW and SAW components offer this option – but with significantly different effects on the design and production complexity. Whereas in SAW components the signal is balanced simply by connecting numerous resonator and double-mode SAW lines, the symmetry-converting stacked crystal filters or coupled resonator filters require two BAW resonators coupled directly above each other with corresponding process complexity.

Because EPCOS possesses design and manufacturing expertise for both SAW and BAW filter technologies, hybrid integration of a symmetry-converting SAW-RX as well as an asymmetrical BAW-TX filter could be implemented in a single component for the first time. LTCC technology is the integration platform used for this purpose, with CSSP as the package technology. The advantage is that the numerous components can be integrated with high performance and good reproducibility in LTCC technology.

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The challenge in developing the SAW-RX filters for WDCMA II lies in the need for particularly steep low-frequency edges. The higher temperature coefficient of the frequency from -35 ppm/K in uncompensated SAW resonators based on lithium tantalate (LT) requires a greater safety reserve to the edge of the passband. The design implemented by EPCOS succeeded in using a standard LT SAW production process with no additional need to reduce the temperature coefficient of the frequency. At the same time, the RX filter converts the asymmetrical input signal referred to ground into a symmetrical signal at the output.

The BAW filters in the TX path offer the following benefits:

- **Good power stability:** As the filters heat up, the maximum power of 500 mW emitted from the antenna as well as a typical signal attenuation of 3 dB lead to the worst-case situation. In this case, the power converted in the BAW filter can reach several 100 mW. Powers of this magnitude are easily handled by BAW resonators when the resonator areas are of appropriate design and the filter chip is correctly connected to the circuit board via a heat sink. This is due to the large and rugged design of the electrodes in the BAW resonators.
- **Steep filter edges:** Thanks to special designs, the temperature drift of the BAW filters was minimized even further, which has led to steeper and more stable edges.
- **Low insertion loss:** The higher performance of the BAW resonators translates into somewhat lower insertion losses at the TX filter, thus increasing the operating time of the mobile phones.

The BAW filter is designed as a line type with four series branches and three shunt resonator branches. To improve its power stability, all series resonators were duplicated.

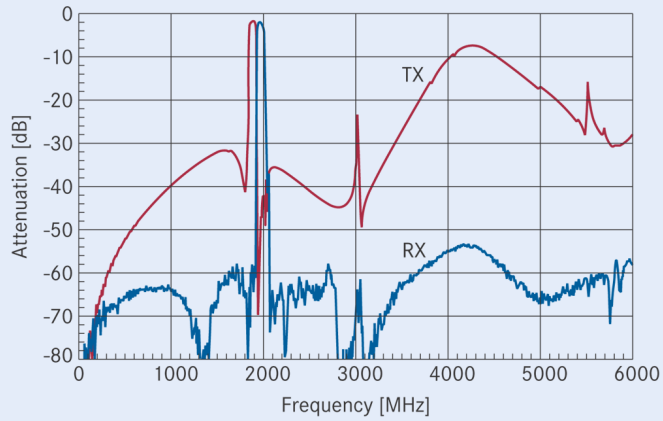
The footprint of the new SAW-BAW duplexer is 3.0×2.5 mm² with an insertion height of 1.3 mm. Fig. 1 shows the TX and RX filter functions with the required steep edges as well as low insertion losses.

Fig. 2 shows the excellent decoupling between TX and RX, especially across the TX band. The same applies to the broadband behavior, as shown in Fig. 3.

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FIGURE 3: BROADBAND BEHAVIOR



The broadband filtering in both the TX (red) and the RX path (blue) also shows good values

The integration of the hybrid SAW-BAW combination presented here is not limited to simple duplexers. In the future, it will also be used in more complex components such as quintplexers, PAiDs and complete RF front-end modules.

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