Miniaturization of mobile communications equipment and multimedia applications such as mobile phones, MP3 players, games consoles, laptops, digital cameras and photo printers requires the use of components with ever more compact dimensions. However, there are limits to the miniaturization of discrete passive components. Further space savings can be achieved only with passive integration into modules on the basis of ceramic multilayer technology. Additional benefits of such modules for WLAN applications are lower costs and extremely high reliability.

**Integration in layers**

LTCC (low temperature co-fired ceramics) is the keyword describing one of the most important technologies for the integration of passive and active components. It involves embedding the technical characteristics of passive components such as capacitors, inductors, varistors as well as resistors in a multi-layer ceramic substrate. The remaining components, especially those with active functions, are assembled on the upper side of the LTCC substrate such as semiconductor chips (e.g., amplifiers or antenna switches) and subsequently encapsulated. Passive and active components can be combined in this way into a single module. Fig. 1 describes the steps in the fabrication of a multilayer module. Depending on the version, a front-end module can then save up to 90 percent of its area. LTCC modules are among the most innovative ceramic products made by EPCOS: they are the result of decades of research in ceramic multilayer technology in combination with the company’s in-depth know-how in RF technology and its wide experience in assembly and packaging technologies.
LTCC modules not only save space on the circuit board, but also considerably shrink the bill of material—with all the resulting positive effects such as lower logistics outlay and lower handling, assembly and testing costs. Reliability also rises, as the LTCC module behaves like a single component. In view of the considerable decrease in development effort required, EPCOS customers can bring new equipment more quickly onto the market. The demand for LTCC modules is growing enormously. RF modules are currently used mainly in mobile phone applications for which EPCOS also offers complete front-end modules with integrated amplifiers. These space-saving LTCC modules are continuously opening up new applications—for example, in automotive electronics, as shown by current developments at EPCOS for gearbox control and automatic distance detection systems.

**Growth market WLANs**

Wireless local area networks (WLANs) for computers represent another promising future application for LTCC modules. With some 100 million to 200 million systems sold annually, WLANs have now developed into a genuine volume market, according to a survey by Merrill Lynch (Fig. 2). EPCOS has already been offering complete front-end LTCC modules for this high-growth segment since 2004.
The complexity of WLAN systems is growing steadily as WLANs become ever more powerful. Dual-band applications are expected to reach a market share of around 50 percent in the near future. Data rates are also continuously rising, from an original 1 Mbit/s to a current figure of 54 Mbit/s. In the future they are even expected to climb to around 500 Mbit/s. “Multiple Input, Multiple Output” (MIMO) technology permits significantly higher data rates by sending and receiving parallel data streams via several antennas each equipped with separate front-end electronics.

Dimensional factors are simultaneously becoming ever smaller. Fig. 3 shows this development clearly. In the PCMCIA card for dual-band WLANs shown at left, above, the RF section was still of discrete design with two transceiver ICs and front-end electronics and took up as much as 40 x 40 mm$^2$ of space on the board. LTCC front-end modules from EPCOS have permitted significant miniaturization, so that shortly thereafter WLAN solutions soon became available with a footprint of less than 50 mm$^2$ (d). The space requirement for a WLAN function is thus expected to be reduced by up to 90 percent in a few years.

FIGURE 2: USE OF WLAN MODULES (WORLDWIDE)

WLANs are also used increasingly in mobile phones and multimedia applications. LTCC is the key technology for the high level of miniaturization required in WLAN applications. (Source: Merrill Lynch 2006)

FIGURE 3: INCREASING INTEGRATION DENSITY OF LTCC MODULES

The front-end of a WLAN card for a notebook (a) can today be integrated in a module (b) that is used in highly miniaturized variants (c). A complete system will soon be available with a footprint of less than 50 mm$^2$ (d).

The space requirement for a WLAN function is thus expected to be reduced by up to 90 percent in a few years.
the form of USB adapters—and in the meantime also as a minicards or SD cards.

**Miniaturized WLAN modules**

The latest WLAN front-end modules from EPCOS (Fig. 4) have boosted their performance even more. Thus, the single-band D2006 module integrates transmit and receive filters, antenna switches and even the power amplifier for the transmitter on an area of only 4.5 x 3.2 x 1.4 mm\(^3\) (Fig. 5). The D2005 dual-band FEM is designed for the most widespread WLAN standards 802.11 a/b/g and integrates two diplexers, the transmit and receive filters, a low-noise receive amplifier for 5 GHz as well as an antenna switch in a space measuring 5.4 x 4.0 x 1.4 mm\(^3\).

A further increase in the level of integration will make it possible, says Dr. Patric Heide, development head for WLAN products to integrate a complete WLAN system solution as a system in a package (SIP) on an area of only about 50 mm\(^2\) in about a year: this saves two to three times more space than the most compact solutions available today.

Thanks to its competence in RF and ceramic technology, EPCOS is currently world leader in this field and is also well placed for future applications. EPCOS is an expert in assembly and packaging technologies such as wire-bonding, flip-chip and SMT and has the necessary fast component testers. All modules undergo 100 percent electrical testing. Thus, many new options are available for SIP modules—complete plug-and-play system solutions integrated in a single module.

These ultra-compact WLAN SIP modules are really predestined for highly space-critical applications requiring the integration of WLAN functions in equipment such as digital cameras, MP3 players and mobile phones.

**Author:**

Thomas Kuther, freelance technical journalist

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