Design consideration for System-In-a-Package with embedded passive circuits

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Introduction: Recent advances in integration technology and device performance paved the way for higher level of System integration On Chip (SOC) or In Package (SIP). Complete front end radio for cellular systems includes several blocks, RFIC transceiver, Power Amplifier (PA), and Front End Module (FEM) blocks in addition to control circuitry and matching components. Passive components are essential in microwave integrated circuits design. Integrated embedded passive components can save the circuit real estate and are critical for the circuit performance of RF/microwave circuit. Integrated passive components improve package and Multichip Module (MCM) efficiency, enhance electrical and high frequency performance by reducing the parasitics, and eliminate surface mount assembly procedure which in turn improves the yield and reliability due to the reduced solder joint failures. Moreover, it is a cheaper and better quality alternative for on-chip passives. Low temperature co-fired ceramic (LTCC) MCM’s for RF and wireless systems have provided a solution to the above problem. However, LTCC is an extremely expensive process to implement for consumer applications. The low cost multilayer laminate MCM technology has been proved to be an alternate process to LTCC as an extremely cost effective, high density RF/microwave packaging solution with embedded passives.

In this paper, a new multilayer embedded lowpass filter and diplexer for GSM/DCS dualband application are presented. The compactness of newly developed embedded lowpass filter and diplexer makes the design and integration of front-end module attractive for further development and applications in Single Package Radio system (SPR).

Embedded passive circuits: All elements of diplexer and low-pass filter function can be realized using embedded inductors in the multilayer laminate substrate and SMT capacitors. The diplexer...
was realized using low-pass and high-pass filters, each with 50-Ohm characteristic impedance at the input and output terminals. The GSM portion of the diplexer was designed to produce a parallel resonance at 1.8 GHz by selection of $L_{\text{GSM}}$ and $C_{\text{GSM}}$. Said resonance provided greater than 30 dB of attenuation for the second harmonic. The DCS portion of the diplexer was realized using series resonance elements ($L_{\text{DCS1}}$ and $C_{\text{DCS1}}$) which were designed to produce a series resonance in the center of the passband at 1747 MHz. Additional resonance elements ($L_{\text{DCS2}}$ and $C_{\text{DCS2}}$) were designed to produce a series resonance at GSM frequencies and yielded greater than 30 dB signal rejection at 900 MHz. Newly developed diplexer using embedded inductors and SMT capacitors which consist of two embedded inductors and five SMT capacitors was measured and compared to simulation results using 3-D electromagnetic simulator, HFSS. The insertion losses are about 0.243 dB for GSM band and 0.382 dB for DCS band. The rejection signals of the other channel’s signal are greater than 17 dB for both bands.

*Single Package Radio with embedded passive circuits*: The main purpose of this work is the design of embedded passives that are optimized to work within the Single Package Radio (SPR) system environment. System-In-a-Package is of great interest to microelectronics, and the design of embedded passive circuits for real system remains a challenge due to the strong constraints of parasitic effects and unexpected coupling, leaving very little design margins. Although good results can be obtained for the embedded passive circuit itself, parasitic effects from packaging cause unwanted harmonics and poor isolation when trying to keep the stability of the Power Amplifier (PA) control loop and PA efficiency in the GSM SPR environment. Electromagnetic and circuit co-design study and implementation are required to improve the performance Single Package Radio system with embedded passive circuits. Two factors are critical for the implementation of the SIP module, coupling between different components and 50 ohm on long interconnects and between matching sensitive components, especially ion the FEM. EM/Circuit co-design is expected to produce better understanding of the system design trade-offs. SPR system modeling based on EM/Circuit co-design is in progress. We used GSM dualband Single Package Radio on MCM to design and optimize embedded passive circuits in a system environment with package effects. System level measurements will be made to optimize performance, including scattering parameter measurements of each passive circuit.
Summary: Embedded lowpass filter and diplexer on multilayer substrate are designed. The design is based on the embedded inductors and SMT capacitors. The filter design is flexible and can be implemented in SPR. The new embedded lowpass filter and diplexer exhibit a significant size reduction compared to the conventional discrete filters and diplexers. The compactness of the newly developed filter and diplexer make the design and integration of embedded passive circuits attractive for further development and applications in System-In-a-Package.