A study on a multilayer diplexer using LTCC technology for ultra-wideband wireless modules

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Abstract: A multilayer diplexer in a low temperature co-fired ceramic substrate for compact ultra-wideband (UWB) wireless modules is presented. This diplexer can separate the band group 1 (3.168–4.752 GHz) of multiband orthogonal frequency-division multiplexing UWB systems from the band groups 3 and 4 (6.336–9.504 GHz) of the same systems. The basic characteristics of the diplexer are simulated with a circuit simulator and an electromagnetic simulator. The fabrication and measurement of the presented diplexer are also carried out. The measured results of the fabricated diplexer agree well with the simulated results. The insertion losses are less than 2.0 dB and the isolation characteristics are higher than 30 dB. The diplexer achieves a compact size (7.2 x 3.6 x 0.384 mm3).

Keywords: diplexer, low temperature co-fired ceramic (LTCC) substrate, matching circuits, ultra-wideband (UWB)

Classification: Microwave and millimeter wave devices, circuits, and systems

References

1 Introduction

Low temperature co-fired ceramic (LTCC) technology is very useful for compact wireless modules which consist of chip components, integrated circuits, an LTCC substrate and passive components embedded in the LTCC substrate. Therefore, this technology has been applied to some wireless systems [1, 2]. Ultra-wideband (UWB) systems are actively researched worldwide. For the compact UWB wireless modules using the LTCC technology, we have studied on the wideband bandpass filter [3], the dual band filter [4], and the diplexer with one wide passband [5]. The planar diplexer with two wide passbands has been proposed [6] because it can separate the UWB systems which are lower or higher than 5 GHz wireless local-area networks. However, there have been few studies about the diplexer which has two wide passbands and is suitable for the LTCC technology.

In this letter, we present that the technology of the dual band filter [4] can be expanded for the diplexer with two wide passbands. It is suitable for the LTCC technology. UWB systems are chosen for the band groups 1, 3, and 4 of the multiband orthogonal frequency-division multiplexing systems [7].

2 Schematic of diplexer with two wide passbands

The dual band filter [4] consists of two UWB bandpass filters and matching circuits at input and output ports. For the diplexer with two wide passbands, the matching circuits at the output port are eliminated. Figure 1 shows the schematic of the diplexer. The UWB bandpass filter for the low-frequency band has the matching circuits which are a series inductor near the common port and a grounding capacitor near the filter. The matching circuits of


the UWB bandpass filter for the high-frequency band are a series capacitor near the common port and the capacitor $C_{H4}$ which is set at the input of the UWB bandpass filter for the high-frequency band. Here, $C_{sm}$ is the stray capacitance of the multilayer inductor due to its three-dimensional structure. The stray capacitance is about $0.1\sim0.2\ \text{pF}$. It is very difficult that the input admittance of one filter in the other band is designed to meet the open condition, because each band is very wide. In this study, the conjugate matching method [8] adapts to the UWB bandpass filters in order to achieve
the UWB diplexer. The matching circuits for the each filter are decided by the following conditions. The input admittance of the filter for the low-frequency band is the inductive region from 0.02 S at the passband and acts as the inductor at the other band. On the other hand, the input admittance of the filter for the high-frequency band sets the capacitive region from 0.02 S at the passband and behaves as the capacitor at the low-frequency band.

3 LTCC structure

Figure 2 shows the LTCC structure of the diplexer. The relative permittivity of the LTCC substrate is 8.0. The material of the conductor in the substrate is silver. The thickness of the conductor is 8 μm. This LTCC structure is obtained by means of modifying the structure based on the basic circuit shown in Fig. 1, taking into consideration the parasitic effects caused by the three-dimensional LTCC structure. The diplexer consists of the three conductor layers inserted into the middle portion of the LTCC substrate with the ground planes on the top and bottom layers. The dimensions are 7.2 x 3.6 x 0.384 mm³.

4 Experiments

Figure 3 (a) shows the prototype of the LTCC substrate. The LTCC substrate has electrodes for evaluation using ground-signal-ground (GSG) probes. The LTCC substrate is 7.6 x 4.0 x 0.384 mm³ and the compact diplexer (7.2 x 3.6 x 0.384 mm³) is embedded in this substrate. Figure 3 (b) shows the measured results and simulated results using a commercial circuit simulator (ADS, Agilent Technologies, Inc.) and a commercial electromagnetic simulator (HFSS, ANSYS, Inc.). Figure 3 (c) summarizes the measured results in the specified frequency bands. The prototype is measured with a vector network analyzer (N5230A PNA-L, Agilent Technologies, Inc.) using GSG probes (ACP40, Cascade Microtech, Inc.). The measured results are similar to the simulated results. The each fractional bandwidth achieves 40 percent. The insertion losses are less than 2.0 dB in the wide passbands. The isolation characteristics are higher than 30 dB. This diplexer also satisfies the target characteristics. As a result, we can confirm the effectiveness of the presented approach by the experiments.

5 Conclusion

A multilayer diplexer with two wide passbands for compact UWB wireless modules is presented. The diplexer consists of the two UWB bandpass filters and the matching circuits to connect them. We also verify the presented approach by experiments. In the future, we plan to develop the compact UWB wireless modules using this technology.
Fig. 2. UWB diplexer in the LTCC substrate; (a) Three-dimensional structure, (b) Top view of the structure, (c) Cross-sectional view of the structure.
Fig. 3. Experimental results; (a) A photograph of the prototype, (b) Frequency characteristics and simulated results, (c) Measured results.