A Low Loss Multi-Layer Dielectric Waveguide Filter for 60-GHz System-on-Package Applications

Dong Yun JUNG†, Student Member, Won Il CHANG†, Nonmember, Ji Hoon KIM†, Student Member, and Chul Soon PARK†, Nonmember

SUMMARY For V-band applications, this paper presents a fully embedded multi-layer dielectric waveguide filter (DWGF) with very low insertion loss and small size, which does not need any more assemblies such as flip-chip bonding and bond wires. The top and bottom plane are grounded, and therefore, although we make a metal housing, there will be no resonance occurrences. Especially, the proposed structure is very suitable for MMICs interconnection because the input/output pads consist of conductor backed co-planar waveguide (CBCPW). The filter is formed incorporating metallized through holes in low temperature co-fired ceramic (LTCC) substrates with relative dielectric constant of 7.05. The total volume of the filter including transitions is 4.5 mm × 2.65 mm × 0.4 mm. A fabricated DWGF with four transitions shows an insertion loss and a return loss of 2.95 dB and less than 15 dB at the center frequency of 62.17 GHz, respectively. According to the authors’ knowledge, the proposed filter shows the lowest insertion loss among the embedded multi-layer millimeter-wave filters ever reported for 60 GHz applications.

key words: low temperature co-fired ceramic (LTCC), dielectric waveguide filter, system-on-package (SoP)

1. Introduction

For wireless communications applications, there have been tremendous interests in utilizing the 60 GHz band of frequency spectrum due to the unlicensed wide bandwidth available, maximization of frequency reuse, and the short wavelength that allows very compact passive devices [1], [2]. Recently, many research groups have proposed and developed planar dielectric waveguide filters (DWGF) for low-cost, small size, and good performance [3]–[6]. However, most of the previous off-chip DWGFs require additional flip-chip or wire bonding on to a system module, and thus their performances are prominently deteriorated [4]–[6].

We have studied a DWGF using multi-layer low temperature co-fired ceramic (LTCC) suitable for integrating a 60 GHz system on LTCC substrates. We propose a fully embedded multi-layer dielectric waveguide filter structure without additional assemblies as shown in Fig. 1(a). It enables connections to neighbor MMICs on a multi-layer substrate, while the conventional structure of Fig. 1(b) requires additional flip-chip or wire bonding [6].

Fig. 1 The package structures using the proposed fully embedded multi-layer DWGF (a) and the conventional off-chip bonded WGF (b).

2. Super Low-Loss DWGF Design and Fabrication

Figure 2 shows the schematic of the proposed multi-layer DWGF with the conductor backed co-planar waveguide–to-embedded microstrip-to-waveguide (CBCPW-to-eMSL-to-WG) transitions. This is a Chebyshev DWGF with two resonators using just one LTCC layer (100 µm). The side wall ground of the waveguide consists of two series zigzagged via fences with 450 µm space based on design rules for secure ground. The diameter of all vias is 160 µm and the space of upper and lower WG GND related on cutoff frequency of the waveguide is 1487 µm.

Fig. 2 A schematic of the fully embedded DWGF.
Fig. 3  The measured transmission and reflection characteristics of a test pattern including both of CBCPW-to-eMSL-to-WG transitions and waveguide of a 2750 µm length.

To optimize dominant modal electric field profiles in the dielectric waveguide and the embedded microstrip line, the width (TW) of the eMSL-to-WG transition is 1090 µm and its length (TL) is 860 µm. In order to obtain the filter’s characteristics for 60 GHz applications, \( L = 1120 \mu m \), \( a_1 = 786 \mu m \), and \( a_2 = 484 \mu m \) are required by the filter design technique using a K-inverter network [7].

3. Performance

The measured results of a test pattern including both of the transitions and the waveguide of a 2750 µm length show insertion loss as small as 0.7 dB at the center frequency of 62.17 GHz and a return loss better than 11 dB for overall V-band as shown in Fig. 3. A two-pole chebyshev filter with 1.69 GHz bandwidth centered at 62.17 GHz has been designed, fabricated, and measured.

Figure 4 shows the designed and the fabricated transmission and reflection characteristics and the fabricated photograph of the filter. The filter was formed in the LTCC substrate with a relative dielectric constant of 7.05 and its thickness is 200 µm, however the fabricated total filter was used 4 LTCC layers (400 µm) for removing bending of green sheets. The total volume of the filter including two transitions connected to the in/output transmission line is \( 4.5 \times 2.65 \times 0.4 \) mm\(^3\). The insertion loss is 2.95 dB at the center frequency and the return loss is better than 15 dB within the pass-band. Table 1 shows the results of this work and the previous work.

### Acknowledgments

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### Table 1  Comparison between this work and the previous work.

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### References


