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A Fully Embedded LTCC Stripline Parallel Coupled BPF for 40 GHz BMWS Application

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Abstract— **A low-loss fully embedded bandpass filter (BPF) is proposed using low-temperature co-fired ceramic (LTCC) technology with enhanced stopband characteristics for the broadband multimedia wireless system (BMWS) applications. The measured insertion loss was as small as 1.7 dB at a center frequency of 41.8 GHz, and the return loss was 10.2 dB including the loss associated with two stripline-to-CPW transitions. This six-layer BPF showed 3-dB bandwidth of 8.4 % at a center frequency of 41.8 GHz and suppressed the local oscillator (LO) signal to 20 dB at a local oscillator frequency of 38.8GHz.**

Index Terms **–BPF, BMWS, Coupled, Embedded, LTCC**

I. INTRODUCTION

The increasing demands for real time and high-speed wireless data transmissions have accelerated realization of broadband wireless systems like wireless local area networks (WLANs) [1] and wireless IEEE1394 [2]. One of the most important issues for millimeter-wave systems implementation is the miniaturization of the systems as well as an even greater functionality and lower manufacturing cost. The component, which covers significant space and is required to be integrated three dimensionally (3-D) with active circuitry, is the filter, especially, the band-pass filter (BPF), which cannot be integrated within the active circuit.

Recently, there have been several reports on millimeter-wave filters. However, they are developed as off-chip discrete components, which need to be packaged on a separate printed circuit board [3]-[6] or be placed on top of the substrate [7][8], and so, consume a large footprint in the RF systems. One of the most promising candidates offering the low loss substrate for mm-wave multi-layer circuits as well as the dielectric for filter is the low-temperature co-fired ceramics (LTCC) technology [9]. With LTCC, the three-dimensional integration technology, filters can be fully embedded within the multi-layer circuit, and then above them, other circuits such as amplifiers and mixers can be mounted space-efficiently. It has been reported recently that the embedded BPFs have been built just for Ku-Band transmitter module [10], for C-band RF front-end module [9], and for Bluetooth RF transceiver module [11].

In this paper, we propose a low-loss fully embedded stripline BPF for 40GHz BMWS applications using 3-D multilayered LTCC technology. Within the authors' knowledge this is the first report on the fully embedded millimeter-wave BPF suitable for system-in-package (SIP) applications.

II. BAND-PASS FILTER DESIGN

The stripline structure is especially well suited for the implementation of the millimeter-wave passive components because upper and lower ground planes make the even- and odd-mode phase velocities equal and also it has less radiation loss [12]. The low-loss parallel coupled stripline BPF was designed to realize third-order Tchebyscheff prototype response having a 3-dB bandwidth of 8.4 % at the center frequency of 41.8 GHz with 0.01 dB ripple. Fig. 1 shows the schematic diagram of a symmetric stripline parallel coupled BPF.

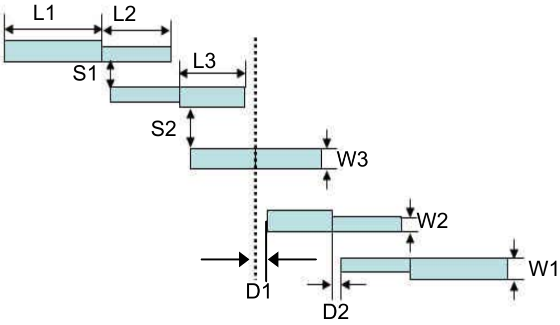
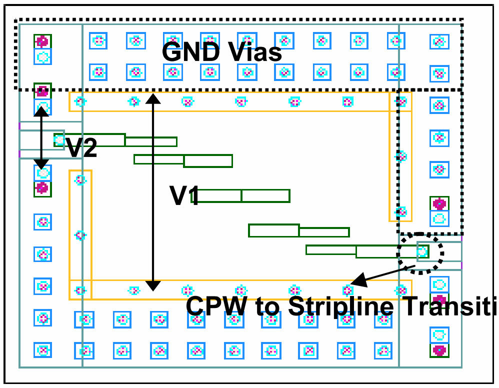


Fig.1. Schematic layout of symmetric stripline parallel coupled BPF (L: the conductor length, W: the conductor width, D: the gap of fringing capacitance)

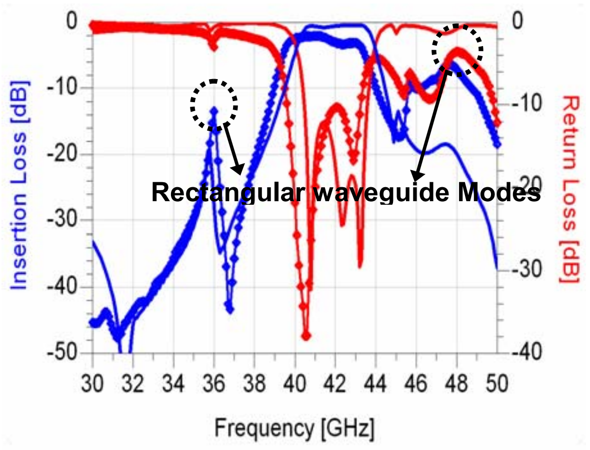
The even- and odd-mode impedance values for each segment were obtained by using the admittance inverter corresponding to the single section [13], and the physical dimensions of coupled stripline were obtained by using the nomodiagrams [13]. The width, gap, and length for each section are summarized in Table 1.

TABLE 1 PHYSICAL DIMENSIONS OF THE SYMMETRIC PARALLEL COUPLED BPF

	L (㎛)	W (㎛)	S (㎛)	D (㎛)
1	1250	130	115	99
2	585	100	310	99
3	568	145		



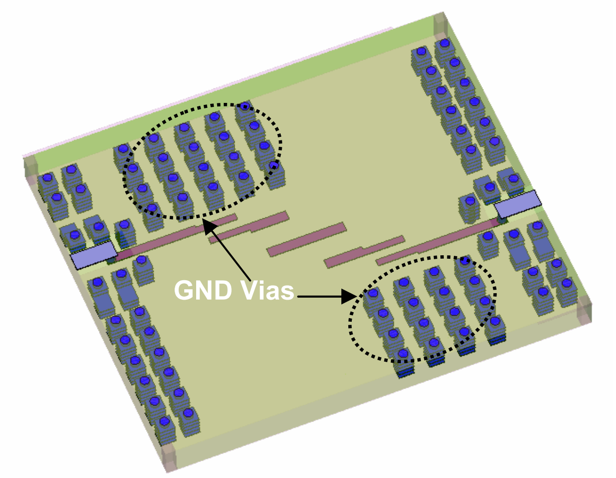
(a) Initial BPF (V1: 2.32mm, V2: 1.15mm)



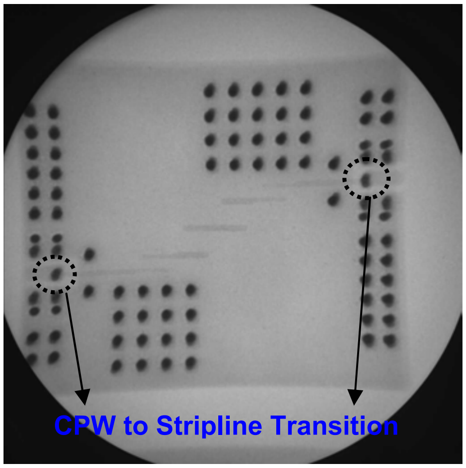
(b) Measured results

Fig.2 The layout view of Initial BPF(a) and the measured results(b)

In order to make electric potential equal between upper and lower ground planes of the stripline structure, ground vias are placed surrounding the filter. Fig. 2 shows the layout view of the initial BPF (a) and the measured insertion loss results (b). Fig. 2 (b) shows the measured insertion loss and return loss of the initial filter superimposed with the electromagnetic (EM) simulation results for the frequency range from 30 to 50 GHz. The spurious responses at 36 GHz in the measured results and at 35.6 GHz in the EM simulated results are due to the rectangular waveguide mode generated by the V1 distance between the ground vias which placed at the both side of the stripline. Another response at 47.6 GHz in the measured results and at 47.7 GHz in the EM simulated results is caused by the V2 distance of vertically located CPW ground vias [14]. These spurious responses affect heavily the performance of the filters such as the flatness and out-of-stop band.



(a) Improved BPF



(b) X-ray photograph of the BPF

Fig. 3 The 3-D schematic view of the improved BPF (a) and X-ray photograph of the fabricated stripline BPF (b)

To eliminate the rectangular waveguide mode resonances, the distribution of the ground vias has been modified. Fig. 3 shows the 3-D schematic view of the improved BPF suppressing the rectangular waveguide modes (a) and the X-ray photograph of the fabricated BPF (b). The overall size is 6.1 mm x 5.3 mm x 0.6 mm including the ground vias and CPW pads. Among the six stacked layers, stripline filter was placed on the third layer, and the CPW pads on the top layer allow on-wafer characterization using GSG probes. Both top and bottom ground planes were connected to each other through ground vias to equalize the electric potential. A measured dielectric constant of each sheet is 7.4, and the value of the loss tangent is 0.002 at 40 GHz. The postfire thickness of each layer is 100 ㎛.

III. MEASUREMENT RESULTS

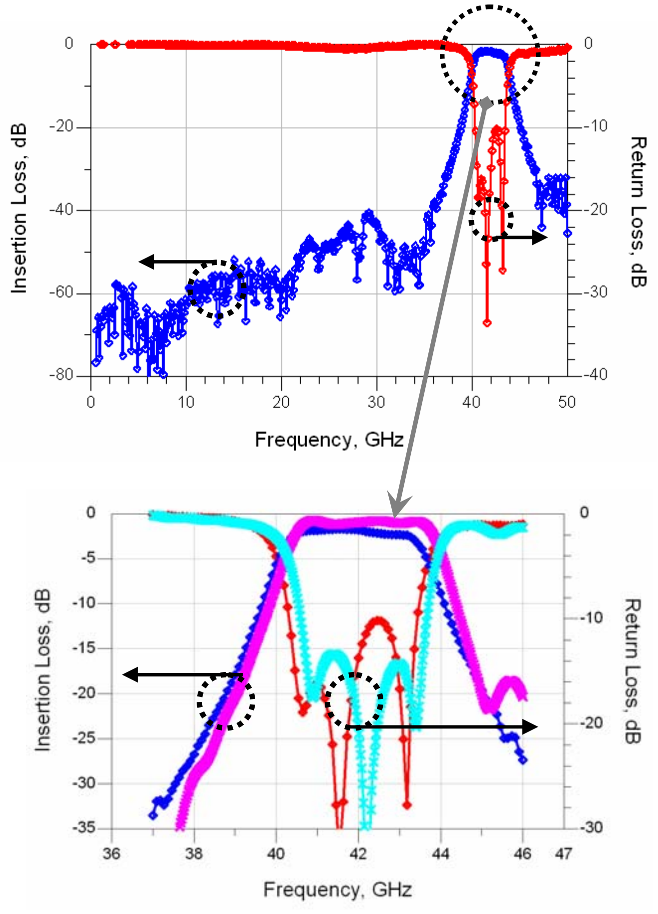


Fig. 4 The measured insertion (✕✕) and return loss (◇◇) of the improved BPF

TABLE 2 SUMMARY OF THE MEASURED RESULT COMPARED TO THE SIMULATED

Parameters	Simulated Data	Measured Data
Center Frequency (GHz)	42	41.8
3 dB Bandwidth (%)	9	8.4
Insertion Loss (dB)	0.7	1.7
Return Loss (dB)	13.4	10.2
LO rejection (dB) at 38.8 GHz	18.9	20

Fig. 4 shows the measured insertion loss and return loss of the filter superimposed with the electromagnetic (EM) simulation results for the frequency range from 37 to 46 GHz. The insertion loss of the filter including the transition losses is as small as 1.7 dB at the center frequency of 41.8 GHz, and the 3-dB bandwidth ratio is controlled to 8.4 %. The LO rejection at the local oscillator frequency of 38.8 GHz is as much as 20 dB. Table 2 outlines the measured performance compared to the simulated performance. The measured insertion loss at the center frequency is 1 dB larger than that of the simulated result. A center frequency shift of 0.2 GHz to the down side was observed. The main cause of this frequency shift is the tolerance of the LTCC fabricating process, which includes the dimension variation of 1.1 % caused by screen printing process.

IV. CONCLUSION

We have presented a low-loss fully embedded LTCC band pass filter with enhanced stopband characteristics for BMWS applications. This proposed filter allows the 3-D integration of the millimeter-wave systems that can result in the size reduction of the systems with low-loss and high stopband rejection. The measured insertion loss is as small as 1.7 dB, and the return loss is 10.2 dB. The 3-dB bandwidth is 8.4 % and center frequency of 41.8 GHz and LO rejection at 38.8 GHz is about 20 dB.

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