40 GHz Vertical Transition with a Dual-Mode Cavity for a Low-Temperature Co-fired Ceramic Transceiver Module

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A new vertical transition between a substrate integrated waveguide in a low-temperature co-fired ceramic substrate and an air-filled standard waveguide is proposed in this paper. A rectangular cavity resonator with closely spaced metallic vias is designed to connect the substrate integrated waveguide to the standard air-filled waveguide. Physical characteristics of an air-filled WR-22 to WR-22 transition are compared with those of the proposed transition. Simulation and experiment demonstrate that the proposed transition shows a −1.3 dB insertion loss and 6.2 GHz bandwidth with a 10 dB return loss for the back-to-back module. A 40 GHz low-temperature co-fired ceramic module with the proposed vertical transition is also implemented. The implemented module is very compact, measuring 57 mm × 28 mm × 3.3 mm.

Keywords: SIW (substrate integrated waveguide), LTCC (low-temperature co-fired ceramic), millimeter wave, waveguide transition, transceiver module.

I. Introduction

Millimeter (mm) wave technology is recognized as having potential for emerging markets, such as broadband radio links for cellular base station backhaul networking, IEEE 802.16 fixed wireless access (FWA), and 60 GHz wireless personal area network (WPAN) applications. There has been a widespread trend toward higher levels of integration in mm-wave system designs which is motivated by a desire to reduce costs, size, and complexity.

Multilayer ceramic-based systems in a packaging solution are capable of overcoming these limitations by integrating components as part of a module package. As a result, low-temperature co-fired ceramic (LTCC) multilayer technology is becoming more and more popular for the production of highly integrated, complex, multilayer modules and circuits. This technology is appreciated for its flexibility in realizing an arbitrary number of layers with easy-to-integrate circuit components such as via holes and cavity-buried components. Many researchers have shown the feasibility of implementing LTCC-based components and transceiver modules [1]-[5].

Previously, an LTCC-based mm-wave transceiver module integrated with an antenna, which is mounted on a fire resistant-4 (FR-4) printed circuit board (PCB), was reported for low-power wireless applications [6]. However, in the case of long-distance mm-wave communication systems, high-gain antennas such as horn antennas, reflector antennas, or waveguide-fed microstrip patch antennas [7]-[9] are mainly used to compensate for free space path loss. For these purposes,

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an air-filled metallic waveguide is used to deliver a mm-wave signal to these types of antennas. Therefore, a waveguide transition is an essential part for practically connecting a transceiver module to an antenna.

Some kinds of substrate-integrated waveguide (SIW) to standard waveguide transitions have been reported [10]-[12]. However, new structures operating at a higher frequency band are still needed for more compact mm-wave packaging.

Recently, we proposed another vertical transition through an opening in an FR-4 PCB between an SIW and a standard WR-22 waveguide for a more compact transceiver module [13]. However, a detailed discussion on the numerical and measured results was not given.

In this paper, the design principle and physical mechanism of the proposed structure are further investigated with simulation results obtained from the commercial full wave software, CST Microwave Studio. In addition, to explicitly understand the concept for designing the proposed vertical (SIW-to-WR-22 waveguide) transition, the physical phenomena of an air-filled WR-22 to WR-22 transition are compared with those of the proposed SIW to WR-22 waveguide transition. Furthermore, a fully-implemented LTCC transceiver module using the proposed transition is also provided. The experimental results of the fabricated transition show a −1.3 dB insertion loss and 6.2 GHz (39.5 GHz to 45.7 GHz) bandwidth with a 10 dB return loss for the back-to-back module.

II. Configuration of a 40 GHz Transceiver Module

A transceiver in the 40 GHz band consists of a front-end part, receiver, transmitter, and local oscillator (LO) as shown in Fig. 1. The front-end part comprises an RF switch using a commercial monolithic microwave integrated circuit (MMIC), an SIW filter, and the proposed waveguide transition. Embedded stripline bandpass filters (BPFs), sub-harmonic mixers, and MMIC amplifiers are included in the transmitter and receiver. An IF frequency of 2.4 GHz is selected to transfer WLAN IEEE 802.11b and 11g signals via a mm-wave link. Therefore, an LO signal of 19.2 GHz is selected because sub-harmonic mixers are used for both the transmitter and receiver.

A three-dimensional (3D) integrated transceiver module using an LTCC and FR-4 PCB is shown in Fig. 2. This module is designed using a Dupont 943 LTCC. Typical properties of the LTCC are a permittivity of 7.1, loss tangent of 0.002 at 40 GHz, and a thickness of 100 μm for each layer. The thickness of the FR-4 PCB is 1 mm. A multi-stepped cavity technology in the LTCC process provides space for the embedded RF block, and active devices are connected to the LTCC by wire-bonding. The LTCC transceiver module is mounted onto the FR-4 PCB using a soldering process. A vertical transition is used to deliver a mm-wave signal from the in-depth transceiver module through the openings in the FR-4 PCB and the metal block to a high-gain antenna with a WR-22 waveguide port, such as in a waveguide-fed microstrip patch antenna [7], [9] and horn feeder for the reflector antenna.

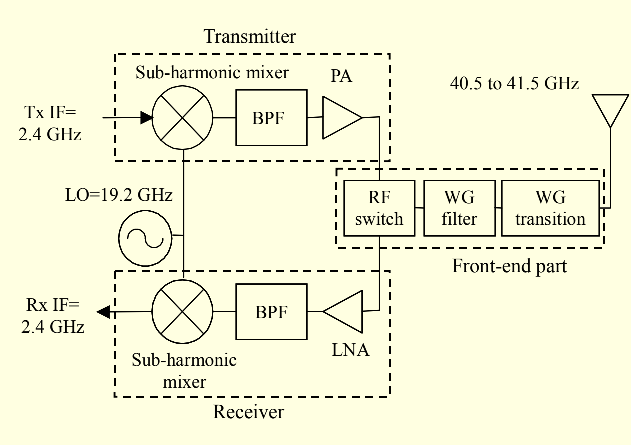


Fig. 1. Block diagram of a 40 GHz transceiver [11].

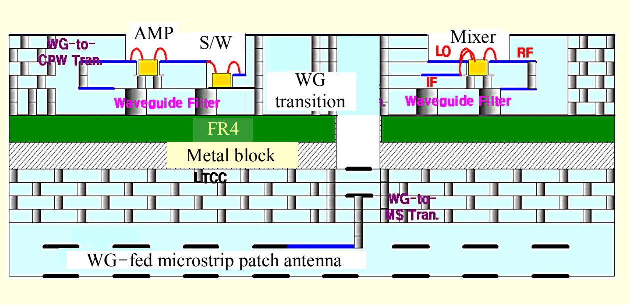


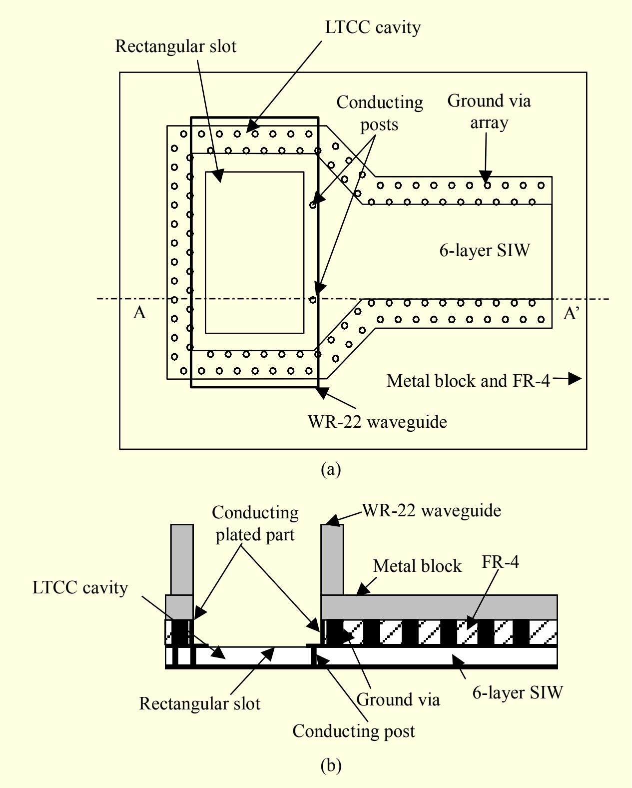
Fig. 2. Concept of a 3D transceiver module using LTCC and FR-4 PCB.

III. Design of a 40 GHz Vertical Transition

1. Configuration of a 40 GHz Vertical Transition

Figure 3 shows the top and side views of the proposed transition along reference line A-A’. The SIW and LTCC cavity resonator use via fences at the side wall with periodic shapes to prevent signal leakage from the space between the nearest vias. The LTCC cavity is used to connect the SIW, which is composed of a six-layer LTCC, to the WR-22 waveguide. The operating frequency of the waveguide transition is determined by the resonant frequency of the LTCC cavity. The mm-wave signal is coupled from the SIW through a rectangular slot etched on the top of the LTCC cavity, and through the openings of the FR-4 PCB and metal block, to the WR-22 waveguide.

The openings in the FR-4 PCB and metal block are rectangular, and their dimensions are the same as those of a



(a)

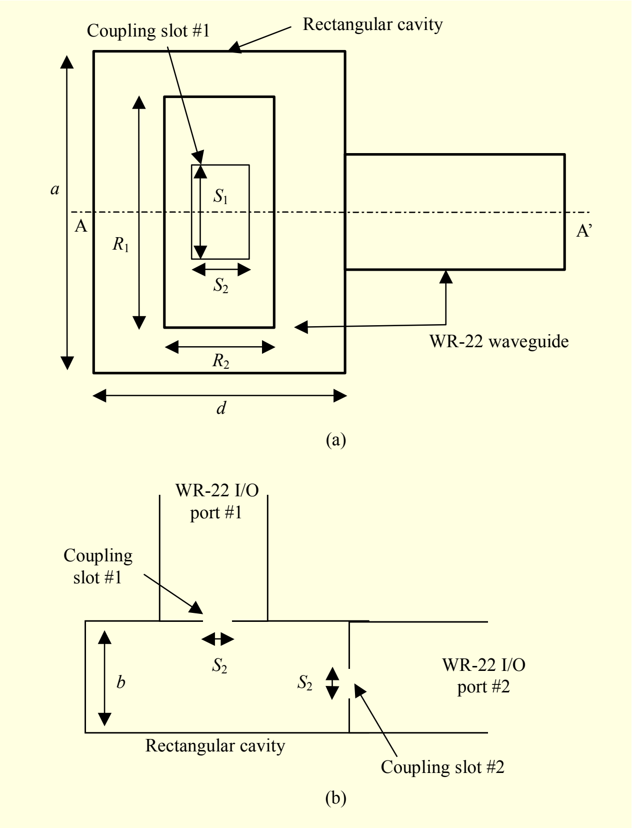
(b)

Fig. 3. Structure of a 40 GHz vertical transition: (a) top and (b) side views along reference line A-A'.

standard WR-22 waveguide. The size of the rectangular slot is optimized to obtain the proper pass-band characteristics. Because the dielectric loss of the FR-4 PCB becomes very large, the edge of the opening is conductively plated with copper to reduce transmission losses by using a standard FR-4 fabrication process. Two conducting posts are used to improve the impedance matching characteristics by compensating a discontinuity of the H plane SIW junction. In summary, the design principles of the SIW to WR-22 standard waveguide are the following: behavior of the WR-22 waveguide to WR-22 transition having an air-filled metallic cavity, determination of the resonant frequency for the LTCC cavity, control of the amount of coupling from the LTCC cavity to WR-22 waveguide, and impedance matching using two conducting posts.

2. WR-22 Waveguide to WR-22 Waveguide Transition

To initially obtain the design concept of the proposed vertical transition, an air-filled metallic standard WR-22 waveguide to WR-22 waveguide transition with a rectangular cavity was considered as shown in Fig. 4. The cross-sectional dimensions of the WR-22 standard waveguide are 5.68 mm (R_1)×2.84 mm (R_2).



(a)

(b)

Fig. 4. WR-22 standard waveguide transition: (a) top and (b) side views along reference line A-A'.

The rectangular air-filled metallic cavity is first designed to obtain the resonance phenomena of two orthogonal modes (TE_{102} and TE_{301}) in the 40 GHz band. Modes generated inside the cavity are coupled through two coupling slots to each WR-22 waveguide, respectively.

To determine the geometrical parameters a, b, and d of the air-filled rectangular metallic cavity providing two orthogonal modes of TE_{102} and TE_{301}, the resonant frequencies of the air-filled cavity can be exactly calculated, as in [14] by

$$f_{mnl} = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{l\pi}{d}\right)^2}, \qquad (1)$$

where c is the speed of light, and m, n, and l are the indices of the resonant modes.

The geometrical parameters of the air-filled waveguide cavity are determined to be a=11.14 mm, b=2.84 mm, and d=7.25 mm to resonate at 43.5 GHz (TE_{102}) and 45.4 GHz (TE_{301}). Note that the height of the air-filled waveguide cavity is equal to that of the WR-22 waveguide. This enables other modes except TE_{n0l} modes to be far from the 40 GHz band.

For efficient coupling of TE_{102} and TE_{301} modes generated inside the air-filled waveguide cavity, rectangular coupling

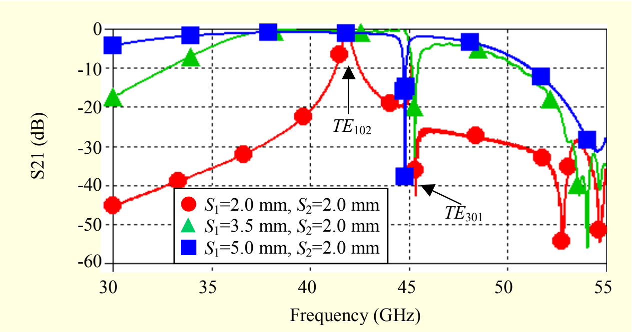


Fig. 5. Transfer characteristics of a WR-22 waveguide transition.

slots are used as shown in Fig. 4. To control the amount of mixed (both electric and magnetic) coupling by the rectangular coupling slots [15], we perform a numerical parametric simulation by varying the size of two coupling slots.

As shown in Fig. 5, two peaks at 41.88 GHz and 45.23 GHz from the transfer characteristic of the WR-22 to WR-22 transition are generated inside the air-filled metallic cavity having parameters S_1=2 mm and S_2=2 mm for the two coupling slots. The resonance frequencies of the air-filled waveguide cavity are shifted down due to the loading effects of the coupling slots.

By properly tuning the size of the two slots (S_2=2 mm remains unchanged), we obtain a flat transfer characteristic of around the 40 GHz band.

3. Resonant Frequencies of the LTCC Cavity

The same design principle explained in the previous subsection can be applied to the design of an SIW to WR-22 vertical transition with a rectangular LTCC cavity.

To form the LTCC cavity, the dielectric waveguide should be shielded by conductive top and bottom layers as well as conductive via arrays as shown in Fig. 4. In case of an SIW, the guided modes are only TE_{m0} modes [16]. Here, TM_{mn} and TE_{mn} ($n \neq 0$) modes do not exist due to radiation through gaps between each via of the SIW. Therefore, the thickness of the LTCC cavity has no effect on the resonant frequency.

To obtain the resonant frequency of the LTCC cavity, its dimensions are roughly calculated from (1) as

$$f_{m0l}=\frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{\left(\frac{m\pi}{W_1}\right)^2+\left(\frac{l\pi}{2L_1}\right)^2}, \qquad (2)$$

where W_1 and L_1 are the width and length of the cavity, respectively, and ε_r is the relative dielectric constant. Thus, compared with the size of the air-filled metallic cavity, the size of the LTCC cavity is reduced by $\sqrt{\varepsilon_r}$. Given parameters such as W_1, L_1, g_1, and g_2 in Fig. 6, the resonant frequencies can be roughly calculated from (2) and optimized by the eigenmode solver of a commercial 3D simulator.

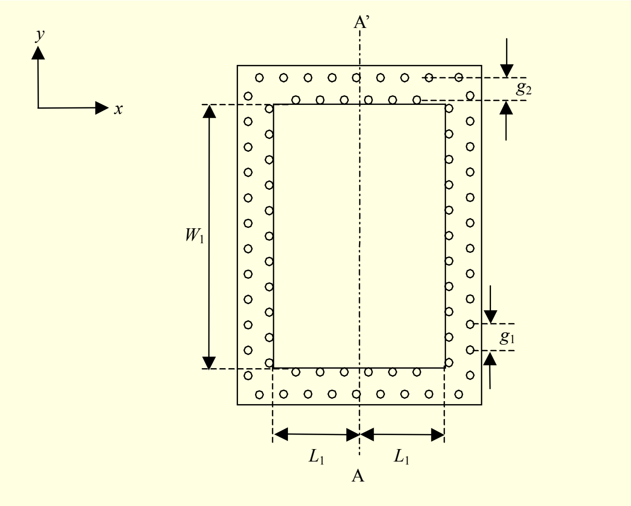


Fig. 6. Structure of an LTCC cavity (top view).

Table 1. Resonant frequencies of an LTCC cavity.

Mode	From (2)	3D simulation
TE_{102}	43.57 GHz	41.52 GHz
TE_{202}	49.53 GHz	47.51 GHz
TE_{301}	45.74 GHz	44.58 GHz

In Table 1, the calculated resonant frequencies of the LTCC cavity with W_1=4.14 mm, L_1=1.36 mm, g_1=g_2=400 μm, and ε_r=7.1 are compared with the simulated resonance frequencies. The table shows that the simulated resonant frequencies are shifted downward due to the use of the metallic via arrays. The diameter of the via used for the LTCC process is 130 μm.

4. Simulation of Modes Generated inside the LTCC Cavity

As shown in Fig. 7, for simulation of the resonance phenomena inside the LTCC cavity, two coupling slots are used to efficiently couple modes generated inside the cavity. One of the two coupling slots is etched on the top ground plane of the LTCC cavity. The other is a slotted conducting plane formed inside the SIW. The cross-sectional dimensions of the SIW with a cut-off frequency of 28.15 GHz are 2.0 mm (W_3) × 0.6 mm (D_1).

Similar to that conducted with the air-filled waveguide cavity explained earlier, a numerical parametric simulation is performed by varying the size of the two coupling slots. As shown in Fig. 8, several peaks at 39.13 GHz (TE_{102}) and 44.5 GHz (TE_{301}) are generated inside the LTCC cavity, which has the following parameters for the two coupling slots:

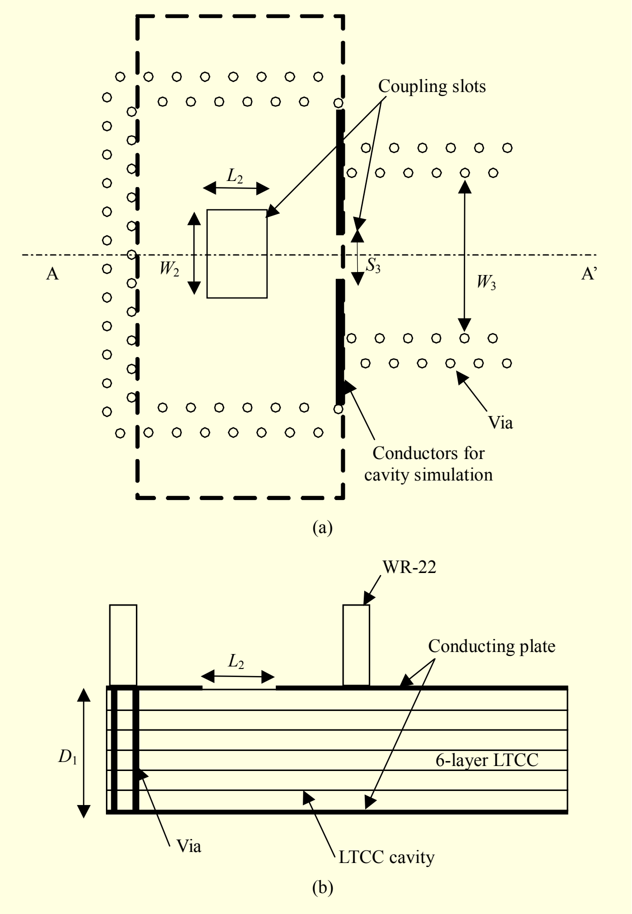


Fig. 7. Structure of the proposed vertical transition with two coupling slots: (a) top and (b) side views along reference line A-A'.

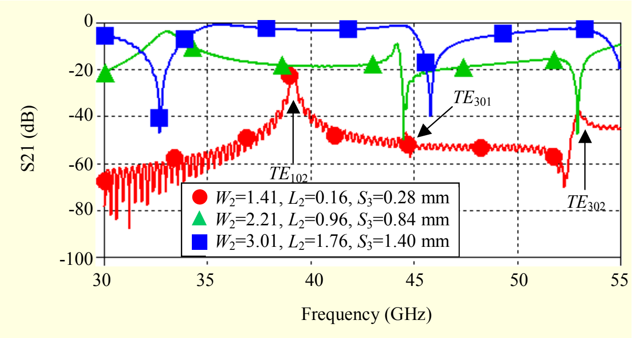


Fig. 8. Transfer characteristics of the proposed vertical transition.

W_2 = 1.41 mm, L_2 = 0.16 mm, and S_3 = 0.28 mm. The resonance frequencies of the air-filled waveguide cavity are shifted down due to the loading effects of the coupling slots. Additionally, Fig. 8 shows the TE_{302} mode around 53.5 GHz generated inside the LTCC cavity. However, the TE_{302} mode is quite perturbed due to the two coupling slots.

The electrical field patterns of the TE_{102} and TE_{301} modes (at 39.13 GHz and 44.5 GHz) are shown in Fig. 9.

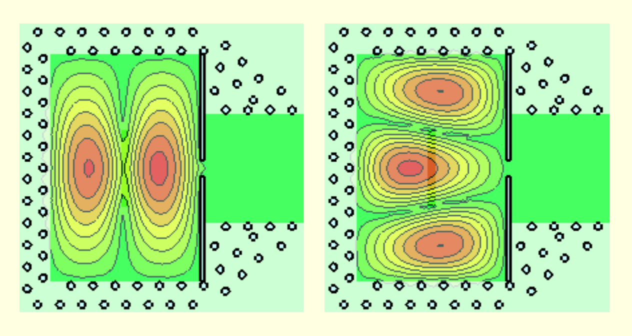


Fig. 9. Electrical field patterns of modes inside an LTCC cavity: (a) TE_{102} and (b) TE_{301}.

5. Optimization of Electrical Performance for a 40 GHz Vertical Transition

Instead of using a slotted conducting plane inside the SIW, a mitered bending with W_5 = 1.08 mm and two conducting posts were used to improve the electrical performance of the proposed vertical transition as shown in Fig. 10.

Figure 11 shows the simulated insertion loss when the dimension of the rectangular aperture, W_2 and L_2, were varied simultaneously, where two conducting posts were not included inside the LTCC cavity.

We observe that the optimum coupling for the waveguide transition is obtained at W_2 = 3.47 mm and L_2 = 2.16 mm.

Figure 12 shows the simulated return loss when the gap between two conducting posts (W_4) was varied with fixed parameters W_2 = 3.47 mm and L_2 = 2.16 mm.

In general, conducting posts inside the waveguide, which have been mainly used to match the impedance of the waveguide T-junction, can be equivalently modeled as an inductor and capacitors [17]. However, two conducting posts can be effectively modeled as inductors because the diameter of the conducting posts is very small compared with the size of

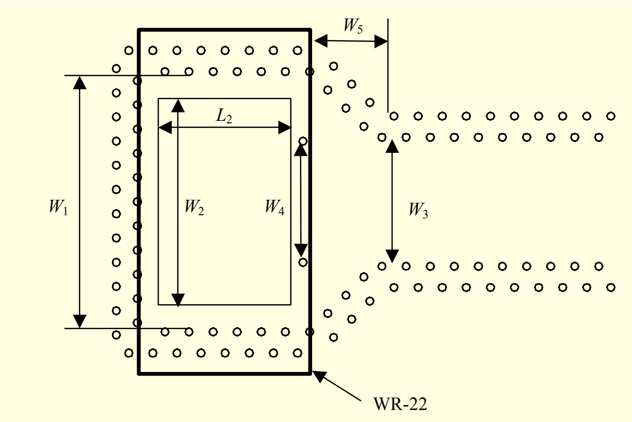


Fig. 10. Structure of the proposed vertical transition with mitered bend and two conducting posts.

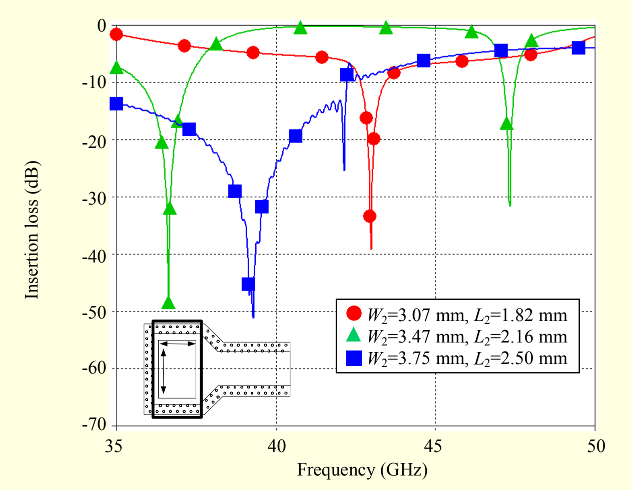


Fig. 11. Properties of a vertical transition with respect to the size of a rectangular slot.

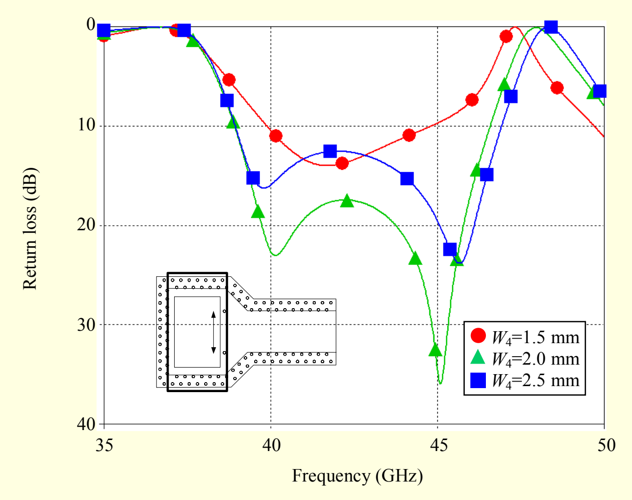
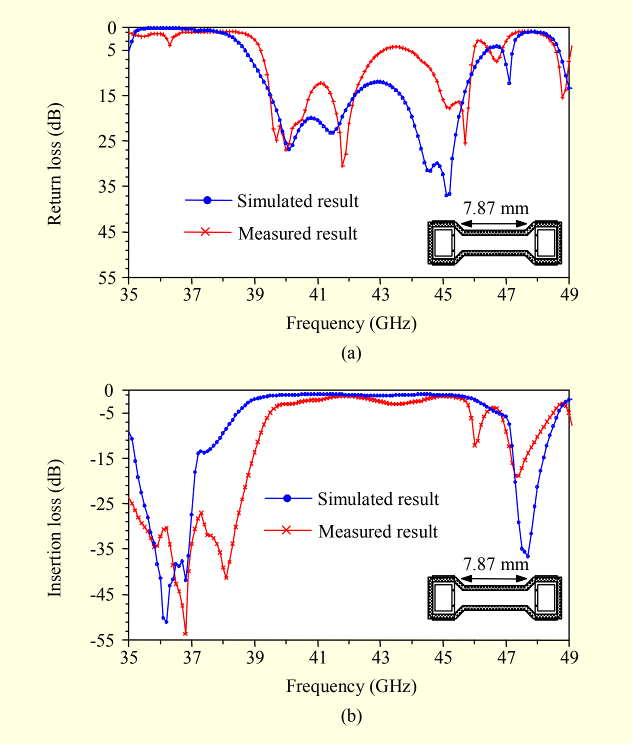


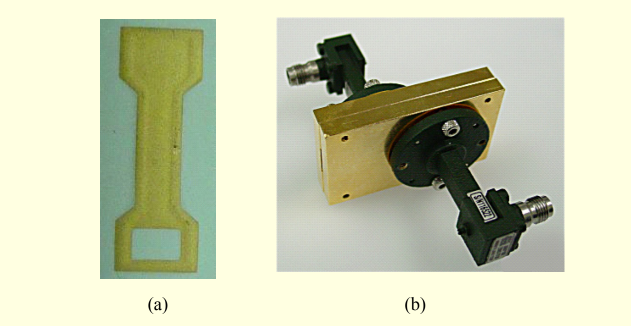
Fig. 12. Properties of a vertical transition with respect to the gap between two conducting posts.



(a)

(b)

Fig. 13. Measured and simulated results of the back-to-back waveguide transition: (a) return loss and (b) insertion loss.



(a) (b)

Fig. 14. Photograph of back-to-back waveguide transition module (a) and measurement setup (b).

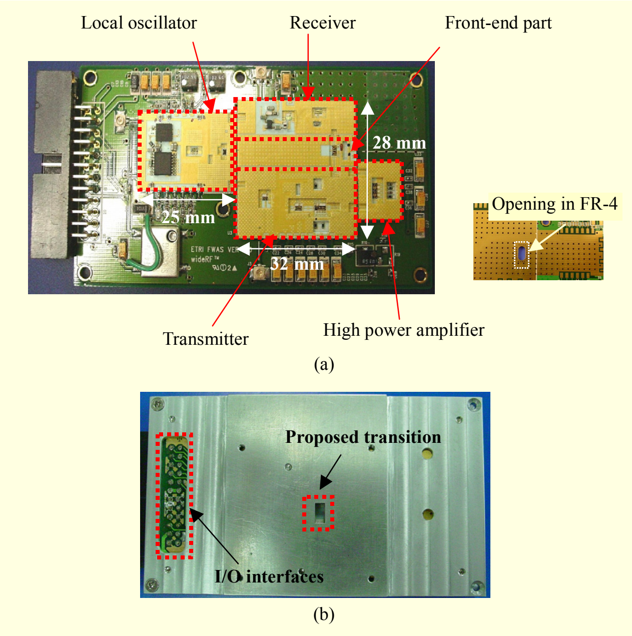
an SIW. We can obtain the optimum reflection characteristic of the waveguide transition for the gap of two conducting posts, W_4= 2 mm.

IV. Fabrication and Measurement

A back-to-back waveguide transition module using a six-layer LTCC with two identical WR-22 standard waveguide interfaces was fabricated to verify the simulation results of the proposed structure.

Figure 13 shows a comparison of the simulated and measured return loss and insertion loss of the back-to-back waveguide transition. The return loss abruptly increased at 43.2 GHz due to the fabrication tolerances and misalignment between the two waveguide transition interfaces; however, by and large, the results show a good correlation between the measured and simulated results. An insertion loss of about −1.3 dB at 42 GHz as the best case over 39.5 GHz to 45.7 GHz with a 10 dB return loss is obtained. The back-to-back transition is 7.87 mm longer than that of the single transition. Therefore, additional loss for the SIW is included due to the added length of the SIW. In addition, it should be noted that the insertion loss of about −0.2 dB of two coaxial-to-WR-22 standard waveguide transitions is included in the back-to-back waveguide transition.

Figure 14 shows a photograph of the back-to-back waveguide transition with two coaxial-to-WR-22 waveguide



(a)

(b)

Fig. 15. Photograph of a 40 GHz transceiver module with the proposed waveguide transition: (a) top and (b) bottom views.

transition interfaces for measurement.

With the proposed waveguide transition, a 40 GHz compact transceiver module (28 mm × 57 mm × 3.3 mm) was also implemented as shown in Fig. 15. The SIW filter of the front-end part was directly connected to the proposed waveguide transition.

V. Conclusion

An SIW to WR-22 standard waveguide transition has been proposed and verified by both simulations and experiments. The physical mechanism of the proposed transition has been discussed with the simulation results. The configuration of a compact transceiver module operating at 40 GHz has also been presented. Low-cost module solutions using an FR-4 PCB and LTCC to efficiently transfer a mm-wave signal are expected to be widely used for application in WPAN and other mm-wave systems.

References

[1] C.H. Lee et al., "A Compact LTCC-Based Ku-Band Transmitter Module," *IEEE Trans. Adv. Packag.*, vol. 25, no. 3, Aug. 2002, pp. 374-384.

[2] K.L. Wu et al., "LTCC Technology and Its Applications in High Frequency Front End Modules," *6th Int. Symp. Antennas, Propagat. EM Theory Proc.*, Oct. 2003, pp. 730-734.

[3] W. Simon et al., "Interconnects and Transitions in Multilayer LTCC Multichip Modules for 24 GHz ISM-Band Applications," *IEEE MTT-S Int. Microw. Symp. Dig.*, vol. 2, June 2000, pp. 1047-1050.

[4] X.G. Wang, Y. Yun, and I.H. Kang, "Compact Multi-Harmonic Suppression LTCC Bandpass Filter Using Parallel Short-Ended Coupled-Line Structure," *ETRI J.*, vol. 31, no. 3, June 2009, pp. 254-262.

[5] J.H. Lee et al., "Design and Development of Advanced Cavity-Based Dual-Mode Filters Using Low-Temperature Co-Fired Ceramic Technology for V-Band Gigabit Wireless Systems," *IEEE Trans. Microw. Theory Tech.*, vol. 55, no. 9, Sept. 2007, pp. 1869-1879.

[6] R. Li et al., "Design of Compact Stacked-Patch Antennas in LTCC Multilayer Packaging Modules for Wireless Applications," *IEEE Trans. Adv. Packag.*, vol. 27, no. 4, Nov. 2004, pp. 581-589.

[7] Y. Huang et al., "An Integrated LTCC Millimeter-Wave Planar Array Antenna with Low-Loss Feeding Network," *IEEE Trans. Antennas Propagat.*, vol. 53, no. 3, Mar. 2005, pp. 1232-1234.

[8] R. Kulke et al., "Frontend Components for 40 GHz FWA Applications in Multilayer LTCC," *IMAPS (Wireless/RF Session) Proc.*, Oct. 2006, pp. 596-602.

[9] W. Byun et al., "LTCC Microstrip Patch Array Antenna with WR-22 Feeding Structure for an Integrated Transceiver Module," *Proc. IEEE AP-S Int. Symp.*, July 2006, pp. 1495-1498.

[10] Y. Huang and K.L. Wu, "A Broadband LTCC Integrated Transition of Laminated Waveguide to Air-Filled Waveguide for Millimeter Wave Applications," *IEEE Trans. Microw. Theory Tech.*, vol. 51, no. 5, May 2003, pp. 1613-1617.

[11] J. Xu et al., "94-GHz Substrate Integrated Waveguide Multiple Antennas with High Isolation Characteristic for MIMO Application," *Proc. APMC*, Dec. 2008.

[12] T. Kai, J. Hirokawa, and M. Ando, "A Stepped Post-Wall Waveguide with Aperture Interface to Standard Waveguide," *Proc. IEEE AP-S Int. Symp.*, June 2004, pp. 1527-1530.

[13] W. Byun et al., "Design of Vertical Transition for 40 GHz Transceiver Module Using LTCC Technology," *37th Eur. Microw. Conf.*, Oct. 2007, pp. 1353-1356.

[14] D.M. Pozar, *Microwave Engineering*, 2nd ed., New York, Wiley, 1998, ch. 6.

[15] J.S. Hong and M.J. Lancaster, "Couplings of Microstrip Square Open Loop Resonator for Cross-Couple Planar Microwave Filters," *IEEE Trans. Microw. Theory Tech.*, vol. 44, no. 12, Dec. 1996, pp. 2099-2109.

[16] F. Xu and K. Wu, "Guided-Wave and Leakage Characteristics of Substrate Integrated Waveguide," *IEEE Trans. Microw. Theory Tech.*, vol. 53, no. 1, Jan. 2005, pp. 66-73.

[17] N. Marcuviz, *Waveguide Handbook*, vol. 10, MIT Radiation Laboratory Series, New York: McGraw-Hill, 1951.

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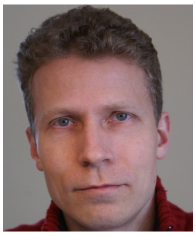

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