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A NOVEL MICROSTRIP-TO-WAVEGUIDE TRANSITION USING ELECTROMAGNETIC BANDGAP STRUCTURE

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Abstract

A novel microstrip-to-waveguide transition using mushroom-like electromagnetic bandgap (EBG) structure is proposed. The transition consists of a waveguide terminated with a mushroom-like EBG structure fabricated on a conductor-backed dielectric substrate and a strip probe inserted into the waveguide. The mushroom-like EBG structure can replace a quarter-wavelength waveguide back-short used in the conventional probe-type transitions. The transition has been designed on a single layered dielectric substrate by placing the EBG patches and the strip probe on the same surface of the substrate. The fabricated microstrip-to-waveguide transition has achieved a good performance with return loss greater than 15 dB over a bandwidth of 5% in the Ka-band.

I. Introduction

Although planar circuits such as monolithic microwave integrated circuits (MMICs) are widely used in microwave and millimeter-wave systems, metallic waveguide still play a major role in specific types of circuits requiring low-loss performances. Microstrip-to-waveguide transitions are key components for integrating waveguides with planar circuits. The well-known microstrip-to-waveguide transition is the E-plane probe-type transition [1][2][3] which consists of a microstrip probe and a quarter-wavelength waveguide back-short. It has a simple configuration and provides a good performance, but the waveguide back-short is bulky for compact modules and causes performance degradation due to manufacturing tolerance in positioning.

In this paper, a novel probe-type microstrip-to-waveguide transition without the waveguide back-short is proposed. The mushroom-like electromagnetic bandgap (EBG) structure is applied instead of the waveguide back-short, which provides a low-profile transition. The availability of the proposed transition is verified by electromagnetic simulations and experiments in the Ka-band.

II. Configuration

Figure 1 illustrates the proposed microstrip-to-waveguide transition with EBG structure. The microstrip probe is inserted into the waveguide through an aperture in the broad wall. The mushroom-like EBG structure [4] which consists of rectangular patches and through holes are formed around the microstrip probe. In this configuration, the waveguide back-short is not required because the EBG structure provides a high impedance surface. Since the microstrip probe and the EBG patches are placed on the same surface, the transition can be formed on a single layered dielectric substrate. Impedance matching is accomplished with microstrip impedance steps at the probe feed point.

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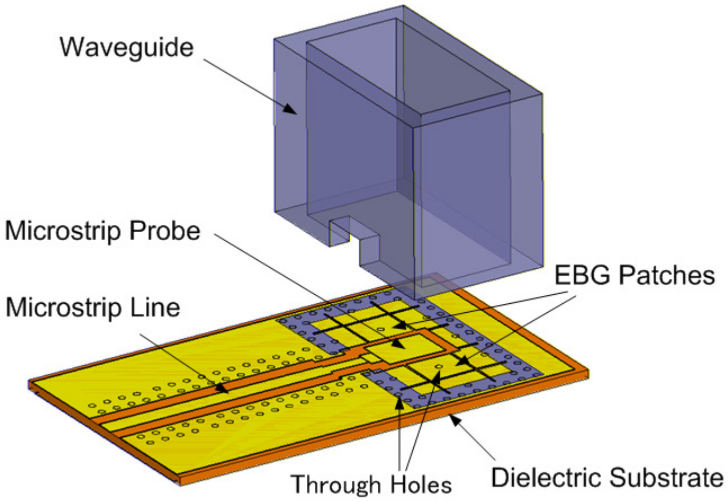


Fig. 1. Configuration of the microstrip-to-waveguide transition with EBG structure.

III. Design

The EBG structure has a surface impedance characterized by a parallel resonant LC circuit. The basic structure of mushroom-like EBG cell is shown in Fig. 2 [5]. This structure creates distributed inductance L and capacitance C which can be calculated with the following formulas, using the physical dimensions and the dielectric constants shown in Fig. 2:

$$L = \mu \frac{t \cdot l}{w} \tag{1}$$

$$C = \frac{w(\varepsilon_{d1} + \varepsilon_{d2})}{\pi} \cosh^{-1}\left(\frac{a}{g}\right). \tag{2}$$

A resultant resonant frequency is obtained by

$$f_r = \frac{1}{2\pi\sqrt{LC}}. \tag{3}$$

Near the resonant frequency, the EBG structure exhibits high surface impedance. The tangential electric field at the surface is finite, while the tangential magnetic field is zero, and electromagnetic waves are reflected without the phase reversal that occurs on a flat metal sheet.

The reflection phase for the EBG structure was calculated using the electromagnetic simulator (Ansoft HFSS$^{\text{TM}}$). The simulated model and the calculated result are shown in Fig. 3. At low frequency, the reflection phase is 180°, as it is on a flat metal surface. Near the resonant frequency, where the surface impedance is high, the reflection phase crosses through zero. At higher frequencies, the phase approaches $-180°$.

The design of the proposed transition is accomplished with the following procedure. The dimensions of the EBG structure are determined using the equivalent circuit to provide a high impedance surface at the design frequency. The microstrip probe, on the other hand, is roughly designed using a conventional design method for coaxial-to-waveguide transition with waveguide back-short [6], approximating the microstrip probe to a cylindrical probe. Then, arranging the EBG structure around the microstrip probe, both are optimized using a three-dimensional electromagnetic simulator such as Ansoft HFSS$^{\text{TM}}$.

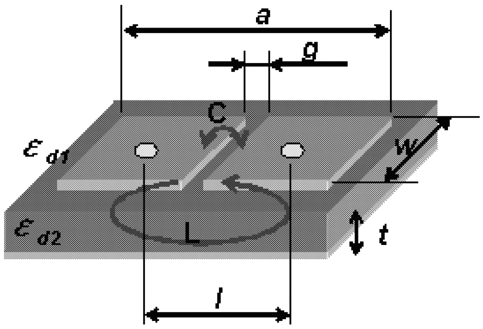
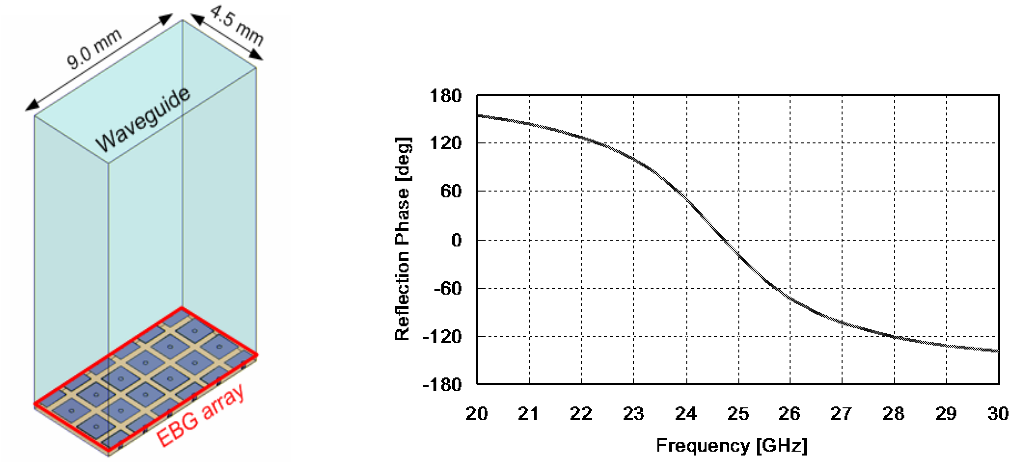


Fig. 2. A unit cell of the EBG structure.



(a) HFSS$^{\mathrm{TM}}$ model

(b) Calculated result

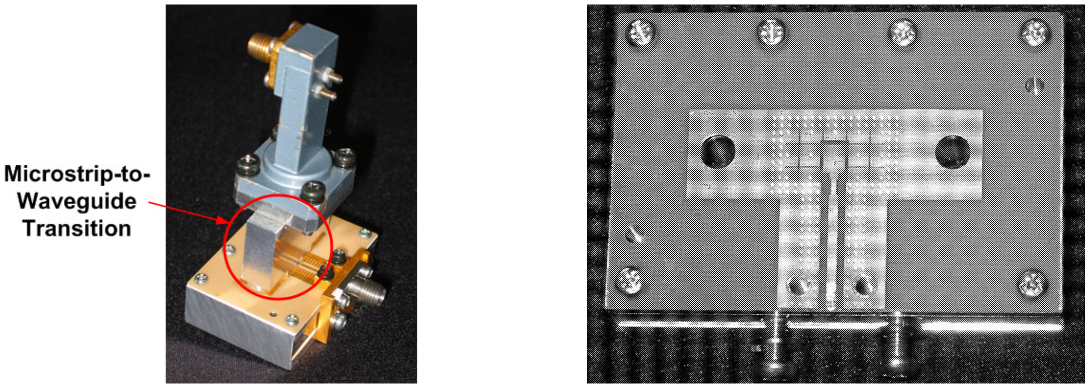
Fig. 3. Reflection phase characteristics of the EBG structure with the following dimensions: $a = 4.5$ mm, $g = 0.1$ mm, $t = 0.4$ mm, $w = 2.2$ mm, $l = 2.3$ mm, $\varepsilon_{d1} = 1.0$, $\varepsilon_{d2} = 3.39$.

IV. EXPERIMENTAL RESULTS

The proposed microstrip-to-waveguide transition has been designed in the Ka-band. Figure 4 shows the fabricated transition. A metallic waveguide is placed on a conductor pattern of the dielectric substrate. The waveguide is terminated with a commercial coax-to-waveguide transition. as shown in Fig. 4(a). The reflection characteristic of the transition was measured through coaxial connector attached to the microstrip line. Figure 5 shows the measured result compared with the simulated result. The experimental result generally agrees with the simulated result. The return loss is better than 15 dB over a bandwidth of 5% in the Ka-band.

V. CONCLUSIONS

A compact microstrip-to-waveguide transition with the mushroom-like EBG structure on a single layered substrate has been presented. The performance has been verified by the simulated and experimental results at the Ka-band. The proposed transition which is free of waveguide back-short structure realizes low profile and easy manufacturing.



(a) Measurement configuration (b) Conductor pattern

Fig. 4. The fabricated microstrip-to-waveguide transition.

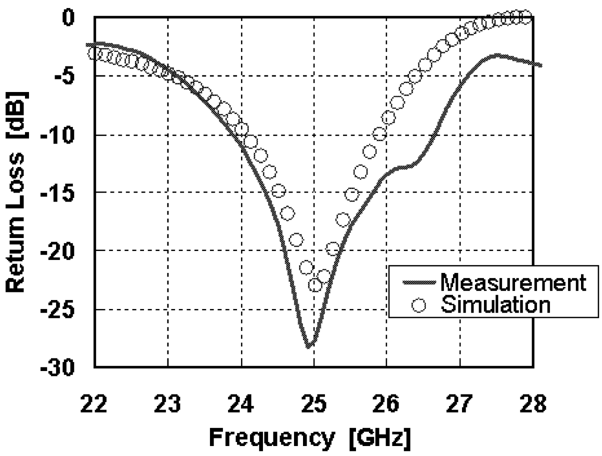


Fig. 5. Reflection characteristics of the microstrip-to-waveguide transition.

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