Ground Coplanar Waveguide to Rectangular Waveguide Transition

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Introduction

The ever-increasing interest towards microwave and millimeter-wave monolithic integrated circuits has led to employing coplanar waveguide (CPW) due to its many advantages such as compact size and capability to incorporate shunt and series elements without the need to process backside and integrate via holes. On the other hand, rectangular waveguides are widely used at higher frequencies for their low loss characteristics in applications such as high Q filters, resonators and antenna feed networks. Therefore at millimeter- and submillimeter-wave applications in which active and passive components are integrated, often waveguide structures are to be combined with CPW lines. For those applications, low loss transitions are required.

Several different CPW to rectangular waveguide transitions have been proposed in the past. These transitions are either along or perpendicular to the propagation direction. The cosine tapered ridge [1] and ridge-through waveguide have been studied at X- and Ka-bands and although shown to be broadband, involve a high degree of fabrication complexity which cannot be easily adopted by microfabrication. The transitions transverse to the direction of propagation are mainly based on the extension of the probe from one guiding structure to another. However, they include a suspended antenna probe inside the waveguide which poses many challenges in microfabrication processes. A transition using uniplanar quasi-Yagi antenna has been reported for wide bandwidth and easy integration at X-band, but suffers from utilizing high permittivity substrate in order to fit the antenna inside the rectangular waveguide [2]. At W-band, a transition using microfabrication processes with separately fabricated and assembled probe has been reported for both diamond and rectangular waveguide with 20% bandwidth [3]. Another high-precision silicon micromachined transition with a capability to integrate filters has been proposed in [4] and shows wideband characteristics at the same frequency range. However, microfabrication of these transitions turns out to be extremely complex at higher frequencies.

In this study, we propose a very simple and easy-to-fabricate transition from a low loss ground coplanar waveguide (GCPW) with sidewalls to rectangular waveguide. It consists of two steps of transition, one from an ordinary CPW to GCPW with side walls, and the other from GCPW to rectangular waveguide. Since the design is very simple and the features are aligned with the Cartesian coordinates, it highly compatible with microfabrication processes and can be fabricated using either lithography of thick photoresists or multi-step deep reactive ion etching (DRIE) of silicon. A back to back structure is fabricated by conventional machining methods at Ka-band to validate the results.

CPW to rectangular Waveguide Transition

A back to back design of the structure from probe to probe is shown in Fig. 1. It consists of a waveguide section which includes three guiding structures: a rectangular channel for the GCPW with sidewalls, a transition and the standard rectangular waveguide. These guiding parts are covered on top by a substrate instead of a thin metal layer so that the substrate supports the metal layer in order not to collapse. The top metal layer of the substrate is also patterned with a CPW line which is connected to the bottom line using via-holes. The GSG probes feed the structure by making a contact with the top ordinary CPW line.

A. GCPW to rectangular Waveguide transition

The GCPW to rectangular waveguide transition is shown in Fig. 2. In this transition, a GCPW waveguide with sidewalls is connected to the rectangular waveguide through a reduced-height rectangular waveguide which includes a pin connected to the center strip of the GCPW line. This pin serves as a wire antenna which couples CPW mode to the waveguide mode. This antenna had been left suspended in the previous versions of E-plane probe transitions. A resonance resulting from two reflections, one from the discontinuity from the GCPW line to the reduced-height waveguide and the other from the discontinuity of the reduced-height waveguide to the conventional waveguide causes a minimum reflection and maximum transmission to the waveguide mode. At this resonance, an efficient conversion to the waveguide mode occurs. Fig. 3 shows the field distribution at the resonance frequencies. The CPW line width is narrowed down inside the reduced height waveguide in order to decrease the radiation off of the slots.

B. CPW to GCPW with sidewalls

In order to be able to handle the top suspended thin metal surface and prevent it from collapsing, a metal-covered substrate is placed on top of the waveguide section. On the other hand, since a thick substrate might change the field distribution and fundamental propagating mode of the line drastically, a very thin one is used as a membrane to maintain nearly the same field distribution. However, this dielectric substrate blocks the access to the CPW line for us to further place the probes for excitation. To resolve this problem, the top side of the substrate is also patterned with an ordinary CPW line matched to a 50 ohm probe. Then, the top and bottom lines are connected through gold-plated via holes. The patterned substrate and the via holes connecting the lines are represented in Fig. 1. Using this technique, by placing GSG probe in contact with the top layer, we excite the GCPW line.

Simulation Results

To analyze this structure at Ka-band, a very thin Rogers substrate is used as the membrane, and a 50 ohm GCPW with sidewalls is designed. A back to back design of the structure is simulated using Ansoft HFSS. Considering the dimensions of WR-28 standard waveguide, all the other parameters such as the length and height of the reduced-height waveguide, the distance of the pin from the step and the backshort, the dimensions of narrowed CPW line and the length of the open-circuited CPW lines are optimized to achieve a very low reflection as well as a high transmission. Fig. 4 represents the reflection and transmission of the back to back structure. It shows a bandwidth of 13% for reflection coefficients of less than -10 dB, while achieving a very good back to back transmission of less than -1 dB.

Fabrication

To fabricate this structure at Ka-band, the guiding parts excluding the top layer, are machined on an ultra-machinable Alloy 360 brass plate. A 5 mil Rogers Duroid 5880 with ¼ oz. (8 μm) electrodeposited copper foil serves as the top cover of the waveguide. Both sides of the substrate are patterned with open circuited CPW lines which are connected together by drilling via holes in substrate. There are some extra vias on the substrate in order to suppress the substrate mode. The substrate is further soldered to the brass unit using solder paste. In order to do that, the brass unit is first gold-plated to prevent brass from oxidizing when it is put in the hot oven and to somehow improve loss properties. Before electroplating, it is cleaned using acetone and IPA (isopropyl alcohol), the backside is painted with photoresist in order to uniformly gold-plate the front side and a Al-Nickle wire is soldered to it to serve as the cathode.

References

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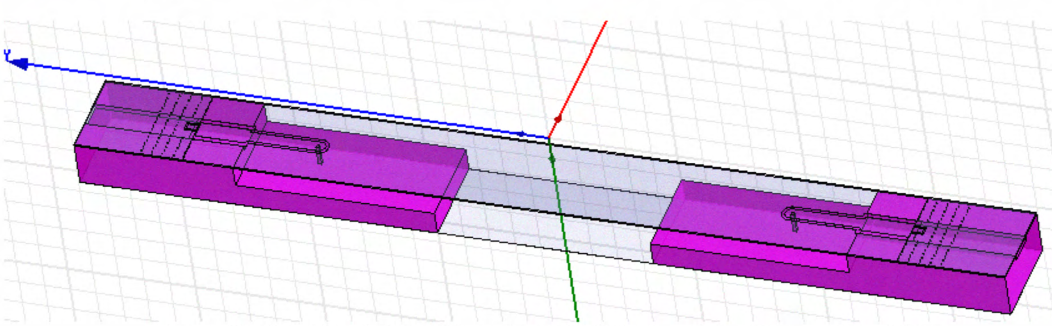

Fig. 1. Back to back transition from CPW to rectangular waveguide.

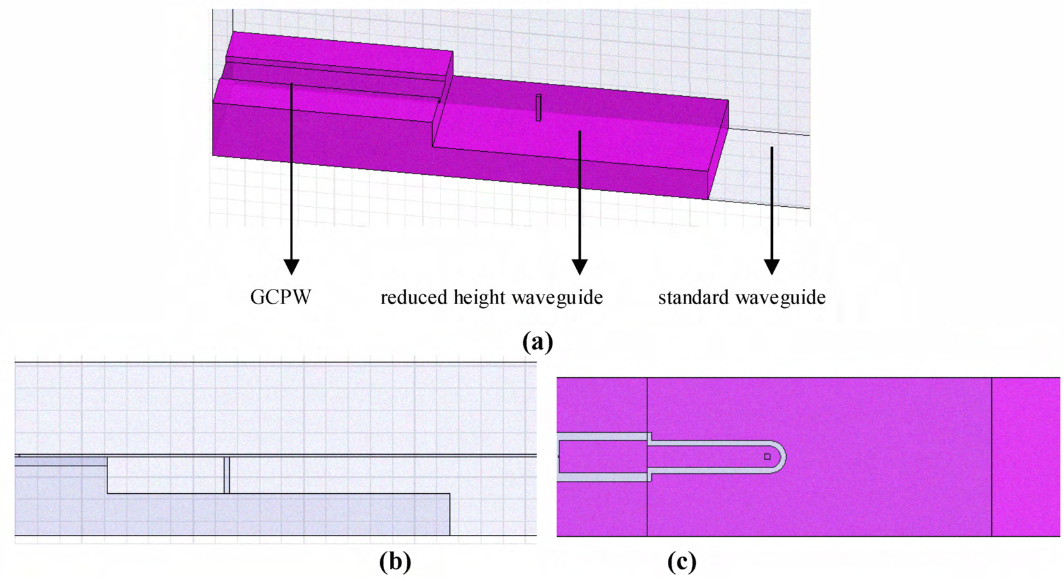

Fig. 2. GCPW to RWG Transition. (a) The waveguide section without the top cover. It consists of a GCPW waveguide with sidewalls, a reduced height waveguide with a pin and the rectangular waveguide. (b) side view. (c) top view of the cover consisting GCPW which is connected to the pin.

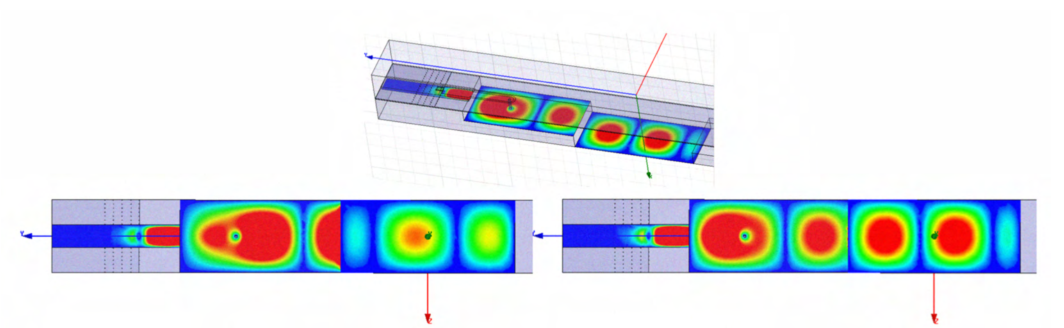

Fig. 3. Electric field distribution inside the GCPW with sidewalls, reduced height waveguide, and the WR-28 waveguide at (a) 28.6 GHz and (b) 30.6 GHz

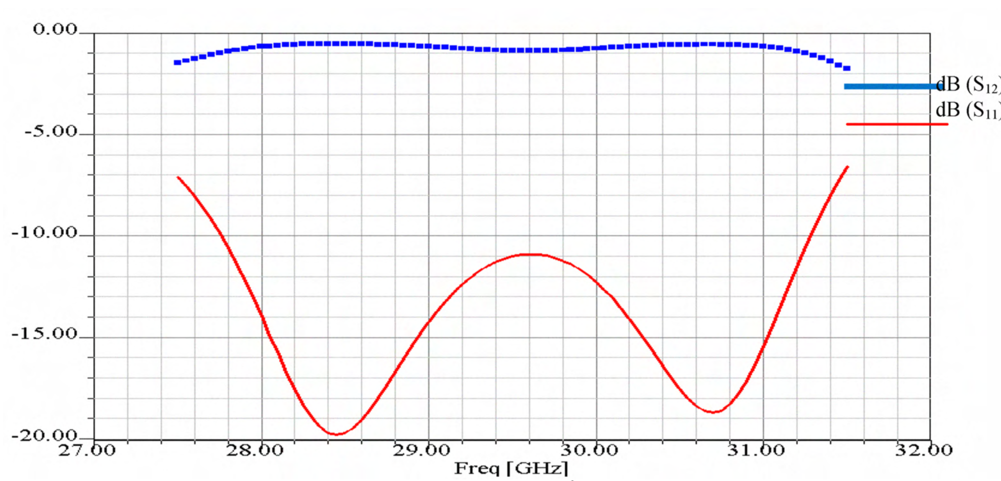

Fig. 4. Reflection and transmission coefficients of the transition from GCPW to rectangular waveguide.