Hybrid Metallo-Dielectric Waveguide and its Applications in THz Circuits Design

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***Abstract*—This report introduces a hybrid metallo-dielectric waveguide (HMDW) architecture, where non-radiative dielectric (NRD) waveguide is deployed at circuit discontinuities to suppress leakage, while dielectric waveguide (DW) is applied to discontinuity-free circuit sections to minimize conductor loss related to metal layers with finite conductivity, and applies it to THz circuit design. With the hybrid waveguide architecture, the dielectric waveguide bend can be made compact (about 0.19 space wavelength at the center operating frequency) with a reasonable insertion loss. The hybrid waveguide is also employed to reduce the crosstalk of crossover enabled by mode conversion and mode selectivity. The HMDW architecture enables flexible routing, simplifying the circuit design. Moreover, its metallized-via-free structure significantly relaxes the requirement for THz manufacturing process.**

***Index Terms*—Compact, dielectric waveguides (DWs), hybrid metallo-dielectric waveguides (HMDWs), leakage reduction, low-loss, non-radiative dielectric (NRD) waveguides, metallized-via -free, terahertz (THz).**

I. INTRODUCTION

DIFFERENT types of the transmission guide [1], such as microstrip line, co-planar waveguide, metallic waveguide, and substrate-integrated waveguide (SIW) [2], are successfully applied in previous communication systems. However, these transmission lines, which are metal-supporting structures, are not practical in THz band circuits because of the frequency-dependent conductor loss. Dielectric waveguide (DW) [3], widely used in optic circuits, exhibits a potential in the THz circuit due to the absence of the conductor loss. However, it suffers from radiation leakage whenever discontinuities occur. A developed waveguide at last century, namely, non-radiative dielectric (NRD) waveguide [4], exhibits an attractive feature: radiation free over discontinuities with a reasonable conductor loss when operating at LSM_{01} mode. Moreover, its metallized-via-free property also reduces the fabrication complexity, which is very important for THz band circuits.

Obviously, each transmission guides show certain advantages and imperfections for the highly-integrated circuits. Therefore, disruptive solutions are needed to make a paradigm shift in THz band platform, all the while preserving the attractiveness of the different transmission guides. The main research goals of this work are to propose, study and explore hybrid waveguide architectures and technologies with the enabling integration platforms of wireless functions and hardware structures.

II. HYBRID METALLO-DIELECTRIC WAVEGUIDE ARCHITECHTURE

Although NRD waveguides allow sharp discontinuities, they show higher loss than DWs because of the finite conductivity of two metal layers and the more compressed electric field inside the lossy dielectric materials [5], [6]. A hybrid metallo-dielectric waveguide (HMDW) is proposed, studied and applied to compact circuits design and to suppress undesired crosstalk [7-10].

A. Straight HMDW

A back-to-back HMDW is shown in Fig. 1(a), consisting NRD waveguide and DWs. The mode compatibility between the $\mathrm{LSM}_{01}{}^{x}$ mode of the NRD waveguide and the fundamental $\mathrm{E}_{11}{}^{x}$ mode of the DW is verified by checking the three conditions that guarantee an efficient coupling when connecting two dissimilar waveguides, namely field matching, phase velocity matching and impedance matching [7]. Thanks to the good matching between two modes involved, the electromagnetic (EM) waves can pass through the interface between NRD and DW with a negligible insertion loss. Parasite structures can be used to further improve the transmission performance.

B. HMDW Bend

Instead of placing numerous metalized via holes around or fully shielding the discontinuities with metal coating or dielectric coating, we sandwich the DW bends with two parallel metal layers to form a non-radiative channel as shown in Fig. 1(b). Thus, EM waves can be confined between the two metal layers because of the boundary conditions. Meanwhile, the leakage over the bending area can be significantly suppressed because the field outside the dielectric strip is evanescent. Measured results in Fig. 1(c) suggest that the waveguide with NRD bends has comparable transmission performance to the straight hybrid waveguide, indicating the bending area is non-radiative. With the assistance of NRD, the radius of bend can be made 10 times smaller than that of DW bend with an expense of limited bandwidth [8]. Compact dividers and couplers based on the HMDW architecture can be developed, resulting in highly integrated topology in system level.

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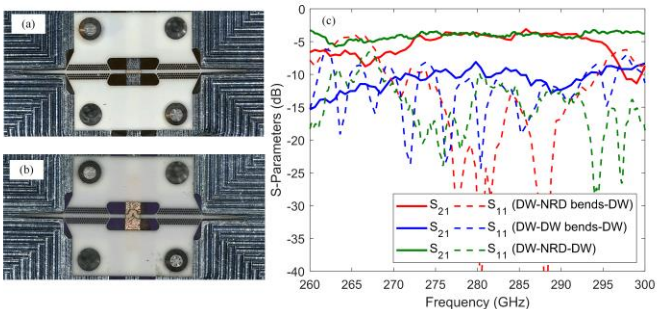

Fig. 1. (a) Straight HMDW, (b) HMDW bend, (c) measured performance.

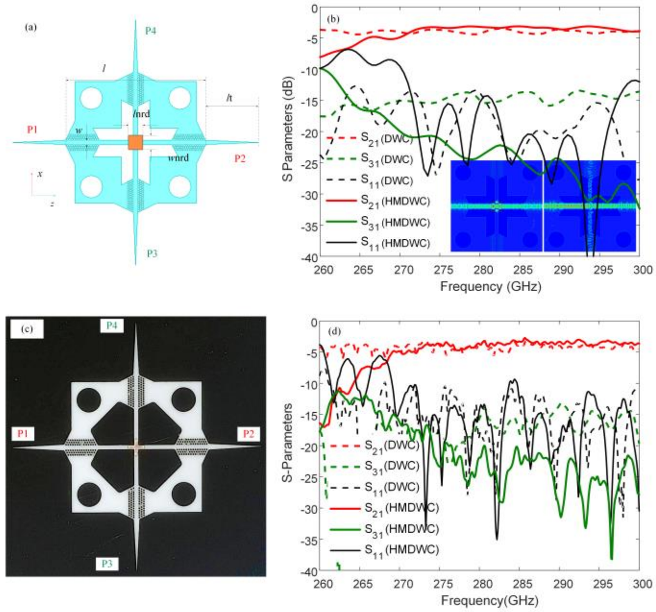

Fig. 2. (a) Simulation model of the proposed HMDW crossover, (b) simulation performance comparison between DW crossover and HMDW crossover, inset: simulated electric field distributions at 280 GHz, (c) alumina circuit of the proposed HMDW crossover, (d) measured performance.

C. HMDW Crossover

Hybrid waveguide architecture is also deployed to reduce crosstalk in crossover enabled by the mode selectivity of the HMDW architecture [9], [10]. As shown in Fig. 2(a), two parallel metal patches sandwich the intersection of two intersecting guides, and the rest of the crossover is exposed to air to minimize the conductor loss. Mode-selective interfaces between the NRD and DW are created. The interfaces allow the LSM_{01} mode pass through, as mentioned earlier. However, the LSE_{11} mode coming from the NRD side cannot pass through the interfaces because it cannot find a guiding mode with a similar field pattern at the DW side. Therefore, the coupled EM waves associated with the LSE_{11} mode from the through guide into the orthogonal guide are reflected back to the through guide, thus reducing the undesired crosstalk.

III. CONCLUSION

This report presents the recent progress of the awardee's project in part supported by the MTT-S Graduate Fellowship Program. Hybrid metallo-dielectric waveguide (HMDW) architecture is presented. The mode conversion and mode selectivity of the HMDW architecture is studied. The NRD sections of the HMDW allow sharp discontinuities, giving more flexibility for the circuit design. Meanwhile, the DWs minimize the power dissipation. An optimized blending of different waveguides could maximally elevate the performance in system level.

IV. CAREER PLAN AND FELLOWSHIP IMPACT

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