Design of W-Band Ridge Waveguide to Slotline Transition for High-Tc Superconducting MMIC and Antenna Integration

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The W-band has brought a lot of interest in recent years to many millimetre-wave applications, such as automotive radars, 5G communication networks, sensing, and defence systems. Successful integration of antennas and monolithic microwave integrated circuit (MMIC)-based RF passive and active circuits is also very critical in mm-wave RF modules [1]-[3]. High-performance interfaces between different components, especial between waveguide and the chip substrate, are highly demanded. In the traditional method, WR-10 waveguides are used as the interconnection between W-band antennas and circuit modules. However, WR-10 waveguides are too bulky to integrate with small size MMICs, such as the recent demonstrated a high-Tc superconducting (HTS) W-band MMIC mixer [1], in a limited space. Although transitions from MMICs to waveguides have been reported with microstrip lines or finlines, it remains quite challenging to assemble the probe transition of slotline from MMIC to waveguides.

In this abstract, we propose a new type of transition structure to connect waveguide components with slotline interfaces of the HTS MMIC devices in the W-band. The aim of this design is to realise the transition of RF signals from a horn antenna to a third-harmonic MMIC mixer in which two Josephson junctions are placed in between the two conductors of a slotline. This transition should have a wide operating bandwidth with low loss, be compact in size, and produce a good impedance match. Since the HTS MMIC chip substrate, which is MgO material, has a large dielectric constant (ε_r = 9.63) and large board thickness (0.3 mm), traditional standard WR-10 waveguides would cause strong resonances and significant mismatch due to its high wave impedance; i.e., it is over 300 Ω. How to eliminate the spurious resonances and match the wave impedance with the slotline becomes a rather difficult scientific problem in practice.

The transition structure shown in Fig. 1 has been designed, modelled, and simulated to overcome this problem The 3D configuration and side-view of the developed W-band transition are illustrated. It transforms the E-fields of a standard waveguide to the E-fields of a slotline on the MgO board. A double-ridge waveguide is designed to gradually transform the standard WR-10 interface to a ridge waveguide interface, which is much smaller in size. The connecting area between the waveguide interface and the edge of the MgO substrate is reduced in this manner. The characteristic wave impedance also decreases from over 300 Ω to around 80 Ω, which is very close to the typical characteristic impedance of a slotline. Three double-sided ridges functioning as impedance transformers are embedded within the waveguide, and each ridge is quarter wavelength long around 90 GHz. Another quarter-wavelength rectangular waveguide section is needed to be in series of the double-ridged sections. It confines the RF signals to be within the waveguide, and hence, prevent any loss due to radiated fields. Two metallic lumps touching both the two conductors of the slotline and the outer facet of the waveguide are added to eliminate the spurious resonances within the band. Simulation of the waveguide-to-slotline transition is carried out with an electromagnetic full-wave simulation tool. The simulated results reveal that the transition covers the whole W-band from 75 GHz to 110 GHz with less than -10 dB return loss. The insertion loss is less than 1.6 dB within the target frequency band from 80 GHz to 100 GHz, which is very favourable for our HTS MMIC design. Measurement result of the transition and details of the relevant HTS MMIC design would be reported at the symposium.

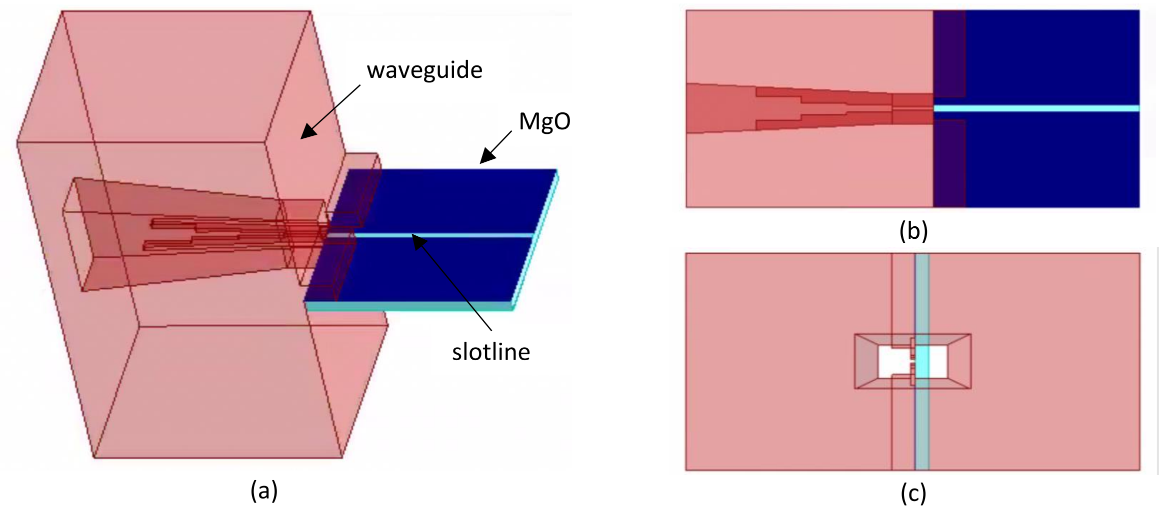

Fig. 1: The configuration of the waveguide-to-slotline transition: (a) 3D view; (b) top view; (c) side view.

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