Wideband Transition from Coaxial Cable to Half-Mode Substrate Integrated Waveguide

Nghia Nguyen-Trong, *Student Member, IEEE,* Thomas Kaufmann, *Member, IEEE,* and Christophe Fumeaux, *Senior Member, IEEE*

***Abstract*—In this report, a perpendicular transition from coaxial cable to Half-Mode Substrate Integrated Waveguide (HMSIW) is proposed for wideband operation. The design places emphasis on the robustness and manufacturability of the transition, in particular with a reproducible realization of a matching capacitive gap. A prototype of back-to-back transitions with 64 mm length of HMSIW in-between is realized for operation in the frequency range of 10 GHz to 16 GHz. The return loss of the back-to-back transitions is measured to be close to 20 dB. A reasonable agreement between experimental and simulation results is achieved, validating the proposed transition geometry.**

***Index Terms*—Half-Mode Substrate Integrated Waveguide (HMSIW), coaxial cable, wideband transition**

I. Introduction

HALF-MODE Substrate Integrated Waveguides (HMSIWs) have attracted much attention as low-loss wave guiding structures for the designs of higher microwave and mm-wave frequency components [1]. Accordingly, transition techniques to transfer power from other types of transmission lines into HMSIW structures are essentially required. A popular feeding mechanism is the implementation of a tapered microstrip line [2]. An improvement in terms of reflection coefficient in the microstrip-HMSIW transition is provided in [3] which is inspired by a similar method applied to Substrate Integrated Waveguide (SIW) [4]. With the motivation to reduce the dimensions of the structures and remove the significant radiation losses from the microstrip line, the project investigates the use of a perpendicular transition from a coaxial line to the HMSIW. The results were summarized in a conference paper, which was submitted to the APMC 2013 [5].

The proposed transition, as shown in Fig. 1, is designed using electromagnetic simulations towards wideband operation. The achieved bandwidth corresponds to $[1.67f_c, 2.67f_c]$ where f_c is the cut-off frequency of the HMSIW, i.e. it covers a large portion of the technical frequency range realized by HMSIW at a fundamental $\mathrm{TE}_{0.5,0}$ mode, i.e. from around $1.5f_c$ to $3f_c$. This transition was utilized successfully to feed a wideband travelling-wave antenna based on an HMSIW in [6].

This report will summarize the design features and design guidelines based on the results achieved with numerical electromagnetic simulation tools. The effect of the substrate permittivity on the gap's realization will then be briefly demonstrated. Finally, experimental results for a realized prototype will be shown and compared with simulations to verify the proposed feeding technique.

The authors are with the School of Electrical and Electronic Engineering, University of Adelaide, Adelaide, SA, 5005, Australia (e-mail: nghia.nguyentrong@student.adelaide.edu.au)

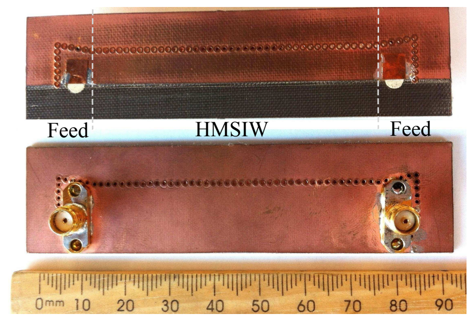

Fig. 1. Manufactured back-to-back coaxial-HMSIW transitions with an HMSIW of length 64 mm in-between; top view of the HMSIW shown on top; SMA connectors below the ground plane shown at the bottom.

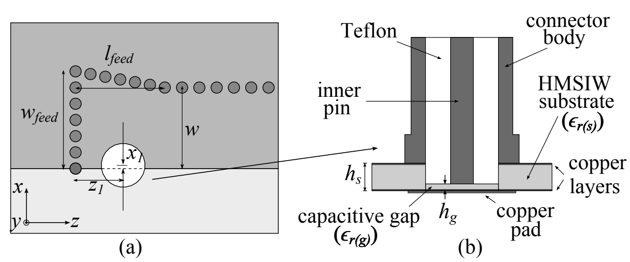

Fig. 2. (a) Feeding structures, (b) Coaxial-HMSIW transition from side view.

II. Design features and guidelines

The structure of the suggested transition is shown schematically in Fig. 2. The coaxial line is connected perpendicularly to the HMSIW through a capacitive gap, which decreases the imaginary part of the input impedance. This technique is adapted from previous realizations of coaxial-SIW transitions [7], [8] where the feeds were designed for rather thick substrates, i.e. about 3 mm. In order to provide a coaxial transition to waveguides (SIW or HMSIW) in thinner substrates, the present design employs another substrate material with high permittivity to fill the capacitive gap (Fig. 2(b)). This proposed feature reduces the sensitivity of the gap thickness and allows an easier and more accurate manufacturing process.

In order to provide a better match between the coaxial line and HMSIW for a wide range of frequencies, the shape of the feeding structure is also modified, by adding a tapering which is described by two parameters w_{feed} and l_{feed} (Fig 2(a)).

The substrate used in our design is Rogers Ultralam 2000 with relative permittivity $\epsilon_{r(s)} = 2.5$ and thickness of $h_s = 1.524$ mm (60 mil). The width of the HMSIW is chosen to be $w = 7.5$ mm to provide a cut-off at approximately 6 GHz with a via diameter of $d = 1.05$ mm and spacing of $s = 1.6$ mm. For a given substrate and HMSIW width, the

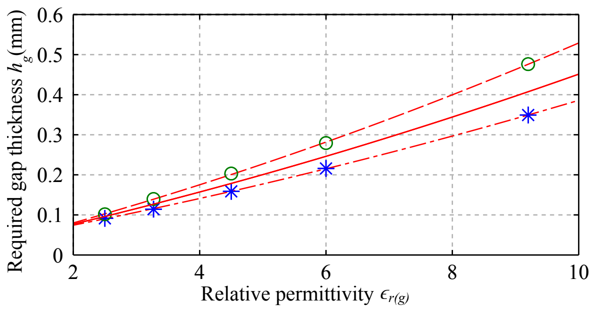

Fig. 3. Range of gap thickness versus gap relative permittivity.

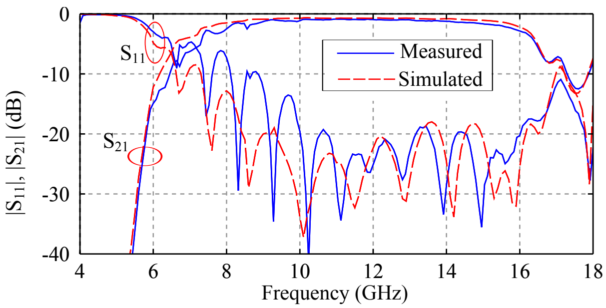

Fig. 4. Simulated and measured $|S_{11}|$, $|S_{12}|$ parameters of the back-to-back coaxial-HMSIW transitions with HMSIW length of 64 mm.

parameters x_1, h_g, z_1, w_{feed} and z_{feed} shown in Fig. 2(a) need to be optimized. The effects of varying these parameters on the transition performance are decribed in detail in [5]. The guidelines are summarized as follows:

1) Choose x_1 close to but greater than zero.
2) Optimize h_g and z_1 together, adjust x_1 if necessary.
3) Optimize w_{feed} and l_{feed} together.
4) Fine-tune all parameters of the final design.

III. Relationship between Gap Thickness and Permittivity of Capacitive Gap

In this section, a brief study on how the gap permittivity affects the required gap thickness is conducted. To investigate this, the same feeding dimensions, i.e. w_{feed}, l_{feed}, and x_1 are used in all cases. For each chosen gap permittivity, z_1 and h_g are optimized to achieve a bandwidth from 9 GHz to 16 GHz with $|S_{11}| < -17$ dB for a 32 mm back-to-back coaxial-HMSIW transition. The upper and lower bounds of h_g are recorded where this specification can still be met by varying z_1. The results are shown in Fig. 3. It can be observed that increasing the permittivity of the capacitive gap increases the robustness of the design by relaxing the tolerance the gap thickness.

IV. Simulation and Experimental Results

A prototype of back-to-back coaxial-HMSIW transitions with 64 mm length of HMSIW in-between has been fabricated and measured. A careful manual assembly process of SMA connectors is required to ensure that all air-gaps are avoided. Nevertheless, the manufacture process could be easily realized with standard techniques such as LTCC technology.

Fig. 4 shows a reasonable agreement between the simulation and experiment. The discrepancies at low frequencies can be explained by the uncertainties in the permittivity of the substrate and in the diameter of the via holes used to manufacture the HMSIW. However, the discrepancies mainly affect the lower frequencies, i.e. just above cut-off where the HMSIW is not usable because of radiation losses [1], and the measured result still shows a wide bandwidth from 10 GHz to 16 GHz with $|S_{11}|$ close to or below -20 dB.

V. Conclusion

A transition from coaxial line to HMSIW has been demonstrated, which provides reflection coefficients below or close to -20 dB in a wide bandwidth extending from 10 GHz to 16 GHz. Compared to the microstrip transition, the suggested design reduces the structure dimensions and possibly radiation losses at microstrip-HMSIW transitions. The transition bandwidth covers most of the technically usable frequency range specified by the HMSIW fundamental mode. The technique can also be used as an improvement for feeding SIW structures, and can be scaled to other frequency bands, e.g. in the mm-wave range.

VI. Career Plans

Throughout the project, I have read a wide range of literature references and obtained much more understanding about microwave integrated circuits. The project finally results in a successful outcome with a working realized prototype and a conference paper submitted to the APMC 2013. The proposed transition was also utilized successfully to feed an antenna based on HMSIW and this paper was accepted to be published in the AWPL 2013 [6]. I am currently studying the Honor year of the Bachelor of Engineering at the University of Adelaide. My aim is to work towards a Ph.D. degree in the field of microwave theory and techniques in the future. The MTT-S scholarship has brought me a great chance to demonstrate my ability and boost my confidence as well as enthusiasm to pursue a research career in this field.

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