TUNABLE WAVEGUIDE-TO-MICROSTRIP TRANSITION FOR MILLIMETER-WAVE APPLICATIONS

J-27

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ABSTRACT

A novel waveguide-to-microstrip transition suitable for narrow as well as wide band applications at millimeter-wave frequencies is presented. It consists of a planar circuit having tapered sections of antipodal fin line and longitudinal slots whose length can be varied by tuning blocks placed underneath them. By selecting appropriate position of the tuning blocks, the transition can be optimized to achieve the desired bandwidth and center frequency. The tunability feature makes it very useful in test fixtures for device and circuit characterization.

INTRODUCTION

Millimeter-wave integrated circuits using microstrip transmission lines must include waveguide-to-microstrip transitions to provide proper interfaces with test and measurement equipment, as well as other components in a system. There are several different types of transitions available which can be used depending upon the application.

For narrow band applications, a waveguide-to-microstrip transition using printed electric probe on a dielectric substrate is a small and simple structure obtained with an antenna type transition [1]. It consists of a microstrip line on a substrate which is inserted in the E-plane of a rectangular waveguide. The optimum depth of the penetration of the probe depends on the substrate thickness and dielectric constant. A maximum electric field at the electric probe is attained by the use of a tunable short.

A transition with wider bandwidth can be achieved by transforming the waveguide impedance to the microstrip impedance by the use of stepped ridged-waveguide [2]. It is connected to the microstrip line by pressure contact and soldering. Its performance, however, depends critically on the structural dimensions and tab contact with the microstrip line.

Another broadband waveguide-to-microstrip transition, introduced by van Heuven [3], consists of a dielectric substrate which has been metallized with conductor patterns on both sides and placed in the E-plane of a rectangular waveguide. The electric field of the dominant TE_{10} mode is rotated by $\pi/2$ to obtain the electric field of the quasi-TEM mode in a balanced transmission line. This is achieved by gradual tapering of an antipodal fin line which is later transformed into a broadside coupled microstrip line. The balanced microstrip line is converted into unbalanced microstrip line using a balun.

TUNABLE TRANSITION

The broadband waveguide-to-microstrip transition described above is an implementation of the two wire balun shown in Fig. 1 (a), where 1 is an unbalanced port, 2 and 3 are balanced ports. Its equivalent circuit, as shown in Fig. 1 (b), consists of a transmission line connected to the unbalanced port and an ideal balun with transformer turns ratio 1:1, and secondary side isolated from the ground. This is essentially an all-pass network and it can match balanced to unbalanced impedances of the same magnitude [4]. The realizability condition to have an ideal balun is that the conductors (1) and (2) should have no capacitance to ground. In practice, however, these lines do have some stray capacitances. Consequently, the three port can not behave as an ideal balun.

This waveguide-to-microstrip transition can be designed using the procedure presented by Lavedan [5]. The length of the balun section is theoretically $\lambda/4$. In practice, this is slightly modified by such factors as junction and fringing capacitances. Since these quantities can not be easily defined, the length and width of the balun must be determined experimentally to achieve an optimum transition. In addition, due to propagating modes existing on the broadside coupled microstrip line [6], there exists some capacitance between these lines and ground. Also, the gradual tranformation from dominant TE_{10} waveguide mode to quasi-TEM mode of the balanced transmission line produces several higher order and surface wave modes. These modes may cause low Q resonances in the enclosure. Therefore, it requires extensive experimental evaluation to determine the structural parameters of an optimum transition with the desired bandwidth at a given center frequency. This is both expensive and time consuming.

To alleviate this problem and to provide tunability to this transition, the balun section is formed by juxtaposition of a tuning block on the longitudinal slots of width *w*, as shown in Fig. 2. This arrangement provides optimum balun configuration by selecting appropriate position of the tuning block.

EXPERIMENTAL RESULTS

To experimentally evaluate the performance of this tunable microstrip-to-waveguide transition, two back-to-back transitions, separated by a 22.86 mm long 50 Ω microstrip line, were fabricated on 0.254 mm thick Duroid substrate (ε_r =2.22). The conductor patterns on the front and back of the substrate are shown in Fig. 2(a). The length of the cosine-squared tapered section is 11.38 mm. The width of the slot is varied from 0.127 mm to 0.508 mm in steps of 0.127 mm. The length of the balun section is several wavelengths long. It is placed in a WR-22 split block housing, as shown in Fig. 2(b), for experimental evaluation at Q-band using a millimeter-wave network analyzer. The performance of such a transition depends on the position of the tuning blocks. This is shown in Fig. 3(a) to (d) where insertion loss is plotted as a function of frequency for a given position 1 and a near-optimum position 2. Both narrow as well as broadband performance can be obtained depending on the position of the tuning blocks. The insertion loss per transition is typically about 0.5 dB, asssuming microstrip line losses of about 0.15 dB/wavelength. The measured return loss is 16 dB or more.

CONCLUSIONS

The performance of this tunable waveguide-to-microstrip transition is essentially comparable to the one with a balun etched on the substrate. By selecting appropriate positions of the tuning blocks experimentally, one can easily realize a transition that can be tuned and set to the required bandwidth and center frequency. The tunability of this transition makes it extremely useful in test fixtures for device and circuit characterization. One important advantage of this transition is that it eliminates the need to experimentally evaluate several transitions with different structural parameters to achieve an optimum transition.

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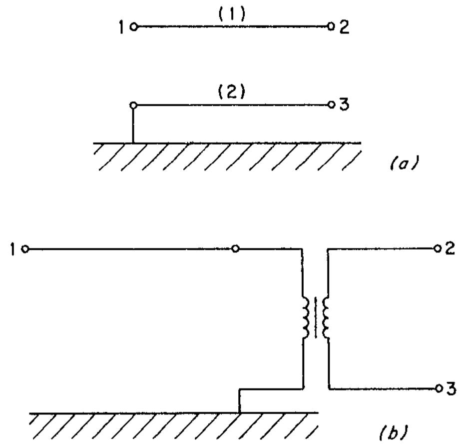

Fig. 1

Fig.1 (a) Configuration of a ideal two wire balun, (b) equivalent circuit.

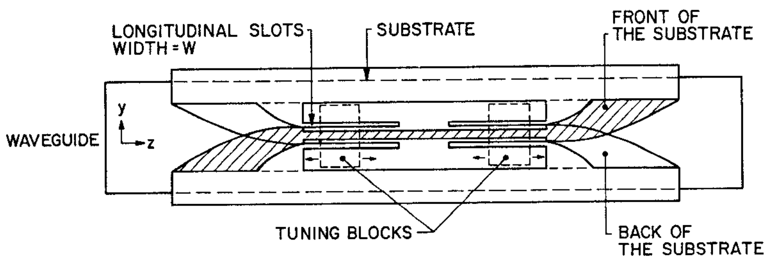

Fig. 2 (a)

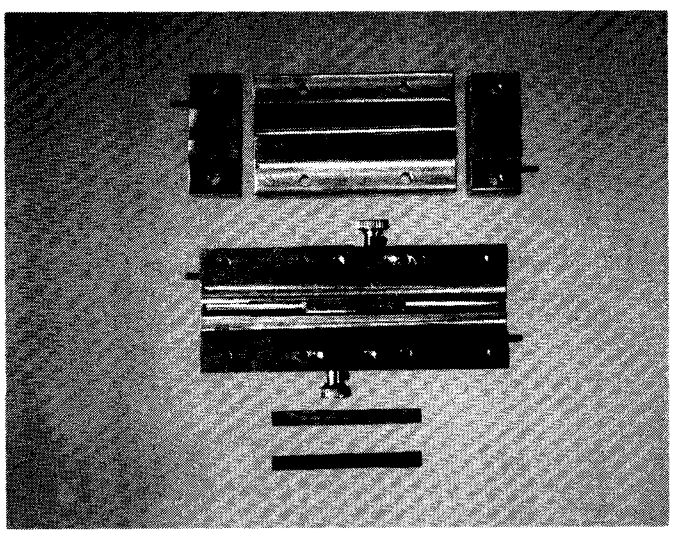

Fig. 2 (b)

Fig.2 (a) Schematic of a tunable waveguide-to-microstrip transition, (b) photograph of split-block housing with tuning blocks.

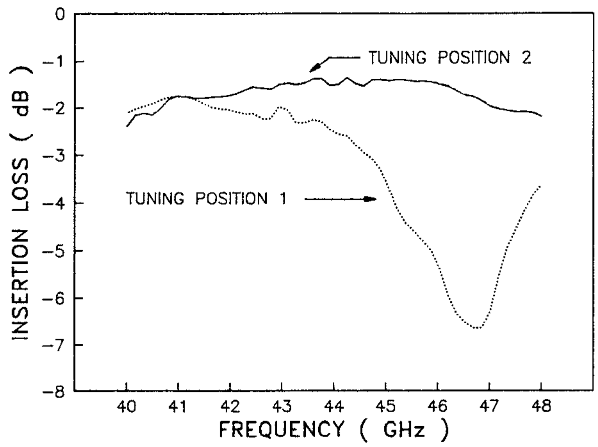

Fig. 3 (a)

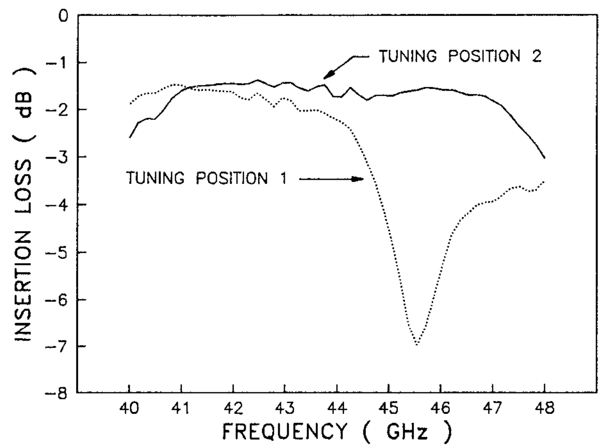

Fig. 3 (b)

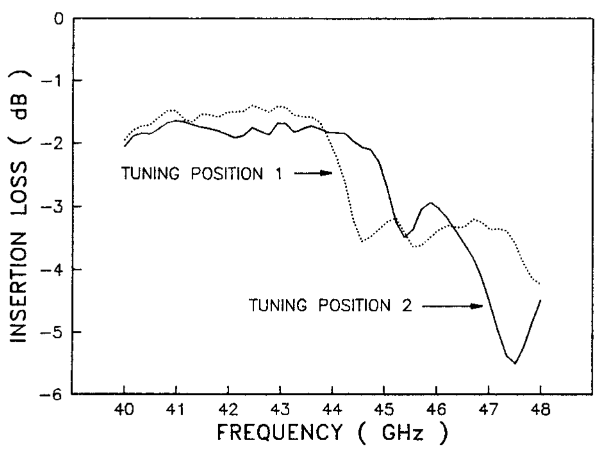

Fig. 3 (c)

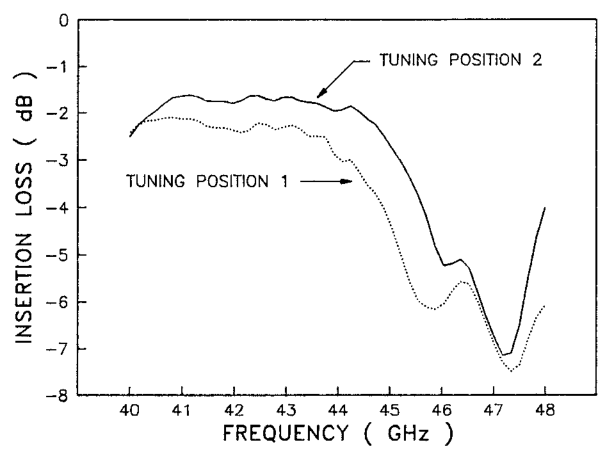

Fig. 3 (d)

Fig.3 Measured insertion loss as a function of frequency for waveguide-to-microstrip transitions fabricated on 0.254 mm thick Duroid substrate (ε_r = 2.22) having slot widths of (a) 0.127 mm, (b) 0.254 mm, (c) 0.381 mm, and (d) 0.508 mm.