Waveguide-to-Coupled Fin-Line Transition in Ka Band

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Abstract— **A new broad-band transition from waveguide-to-coupled fin-line in its quasi-TEM mode is presented. The transition is proposed for low-noise amplifiers or low-noise converters in millimeter-wave bands. Experimental results on the Ka band show a 1 dB insertion loss for a back-to-back double transition over a 10 GHz band.**

I. Introduction

NEW SPECTRAL necessities and unique features associated with high directivity, together with mature semiconductor technology, are pushing for the realization of communication systems at progressively higher frequencies.

E-plane circuit technology can be used for millimeter-wave circuit realization and integration. To make these circuits compatible with standard waveguide accesses, transitions between both are required.

The coplanar transmission lines presents some advantages to mount or integrate active components, especially at the higher microwave frequencies and millimeter wavelengths [1]. Its interesting features have prompted the study of transitions between this one and another types of lines, such as slot-lines, fin-lines, etc. [2]–[4].

This letter presents an empirical design of waveguide-microstrip-coupled fin-line transition in which the quasi-TEM mode is excited.

II. Transition

The application of coupled fin-line structures with waveguide access ports makes necessary a transition between the waveguide and the circuit. The design of the transition must present low reflection, low attenuation, broad band, and reproducibility among its performances.

This letter presents a waveguide-to-coupled fin-line transition design (Fig. 1) with a microstrip interval to excite the even mode (quasi-TEM) [5] in the coupled fin-line structure, in which the lateral conductors constitute the ground planes.

The placement of fin circuits in the waveguide is that proposed by Meier [6], [7], where the substrate protrudes out through the broad wall of the guide and the fins are easily accessible for dc biasing of any semiconductor device mounted in the circuit. The thickness of the broad walls of the guide is chosen as one-quarter wavelength in the dielectric to present an RF choke at the inner wall of the guide. This quarter-wave choke prevents any TEM-mode propagation out through the broad walls; thin insulators are needed to prevent conduction between the printed pattern and the housing when dc bias accesses are used.

An antipodal fin-line taper was used to get 90° progressive rotation of the electric field from the waveguide E-plane [8]–[13] as it is shown in Fig. 1. The transition has been designed taking into account the trade-off between short length for low ohmic losses and long transition with progressive impedance variations for low reflection coefficient in a broad frequency band, attending to the classical tapered transition design. Progressive changes in the impedance are achieved through gradual changes in the form so as to obtain a smooth outline. The antipodal fin-line taper matches the high "impedance" of the waveguide to the low impedance of the microstrip line. The two fins on opposite sides of the substrate are tapered to form an approximately circular arc. Beyond the arc, one of the fins forms the ground plane of the microstrip, with the outline variations being sinusoidal functions. The additional metallization in the circular arc of Fig. 1 serves to prevent the metal-free space below the taper from resonating in the operating frequency band, which would limit the transition bandwidth. Another consideration is to make the microstrip line as short as possible because of the big microstrip line losses at those frequencies (Ka band).

In relation with the microstrip to coupled fin-line passage, a tapered transition with gradual impedance variation is made again. The taper is made with a small gap in the ground plane under the centre conductor of the microstrip line [14], [15]. The capacitance is reduced and the inductance is increased as the slot width progressively increases in the ground plane of the microstrip line so that its characteristic impedance is augmented. On the other hand, if the central strip is widened the characteristic impedance is reduced. Therefore, the characteristic impedance can be smoothly tapered if the slot and the strip are gradually enlarged in a suitable way. As previously commented, smooth impedance variations are equivalent to smooth outline variations. To achieve this, mathematic interpolation techniques (Hermite interpolation) were used by adjusting the gap spacing at the ends and making the first derivative null at the seams. A plot of the center conductor width and the ground plane is shown in Fig 1. One

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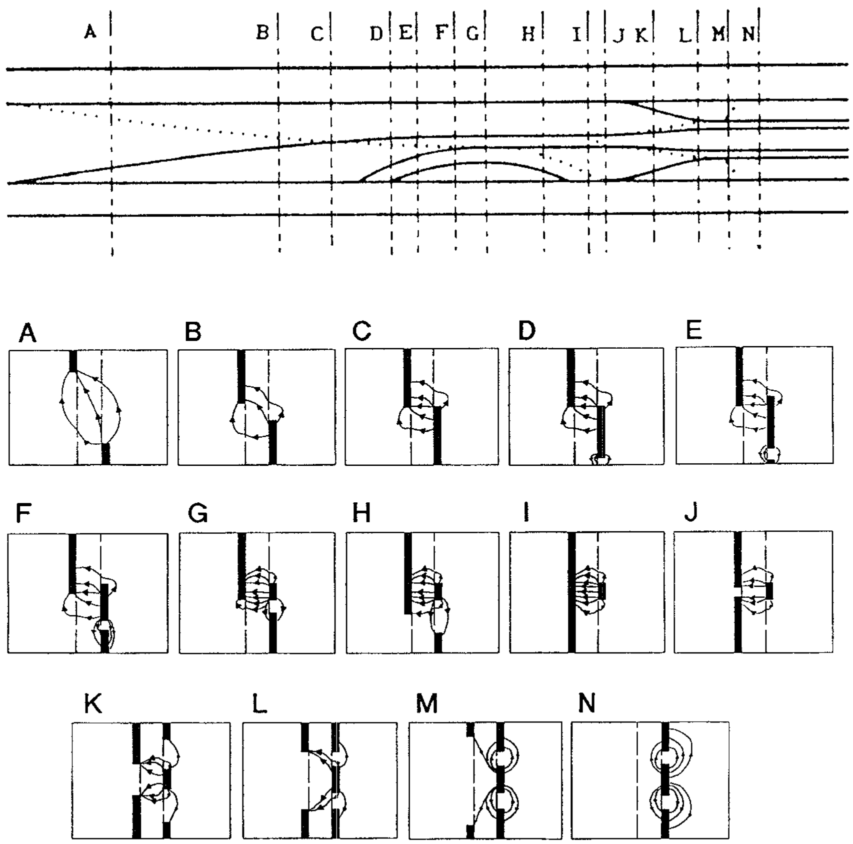

Fig. 1. WR28 waveguide-to-coupled fin-line transition process.

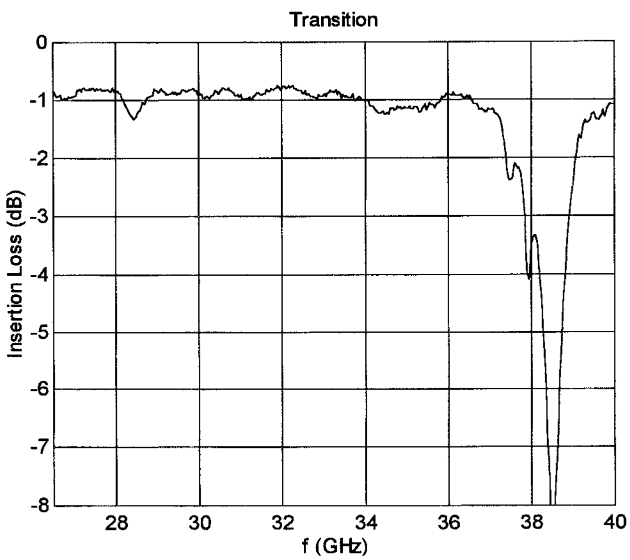

Fig. 2. Insertion loss of a double symmetric transition WR28 waveguide-to-coupled fin-line connected back to back.

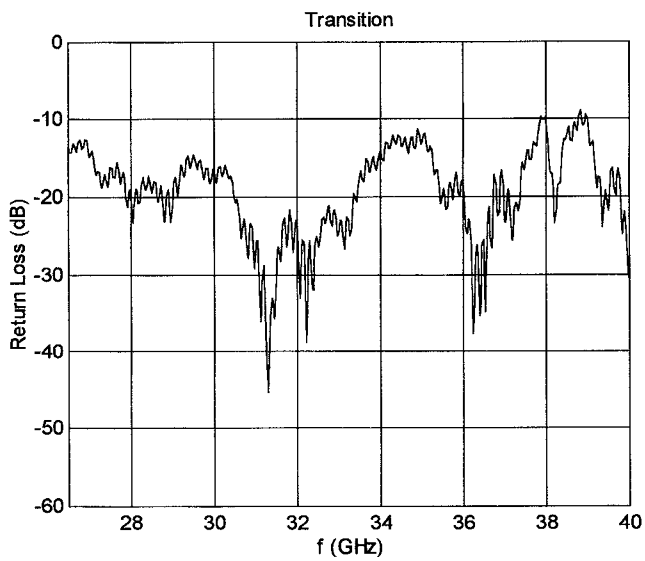

Fig. 3. Return loss of a double symmetric transition WR28 waveguide-to-coupled fin-line connected back to back.

of the most important advantages of this kind of transition is the simplicity in the assembling, because of the absence of via holes connecting both sides of the substrate.

III. Test Results

A double symmetric transition WR28 waveguide-to-coupled fin-line connected back to back was made to be characterized in transmission (insertion loss) and in reflection (return loss). The substrate was RT Duroid, with permittivity $\varepsilon_r = 2.17$ and 0.254 mm thickness; the length of the waveguide-to-microstrip transition was about twice the wavelength in the WR28 guide at the 26.5 to 40 GHz midband frequency (approximately 21 mm); the width of the microstrip line was 0.65 mm, yielding a characteristic impedance $Z_0 = 56.34\ \Omega$; the width of the gap in the circular arc was 0.65 mm, with the length and the width of the equivalent circular slot coupled to microstrip being adjusted to displace the resonance to the upper end of the 26.5 to 40 GHz band; the length of the microstrip-to-coupled fin-line transition was 6.1 mm; the width of the slots in the coupled fin-line section was 0.25 mm, and the central strip width was 1.52 mm, yielding an even (quasi-TEM) mode characteristic impedance $Z_{\text{even}} = 73.55\ \Omega$ and a cutoff frequency of the odd mode $f_{\text{codd}} = 15.12$ GHz. All the parameters were computed using the expressions in [16], and all the lengths on the taper were optimized empirically. The waveguide width along the section occupied by the coupled fin-line was reduced to 1.71 mm to increase the cutoff frequency of the odd mode to 38.9 GHz so as to ensure it is not excited. The total length of the double back-to-back transition was 66 mm. The insertion and return loss in the 26.5 to 40 GHz band were measured with a HP8510B automatic network analyzer. Full two-port calibration was made with WR28 waveguide standards. The measurements are shown in Figs. 2 and 3. The double transition insertion loss was around 1 dB in the 26.5 to 37.3 GHz band, including the approximately 12 mm length of coupled fin-line between both transitions. The almost periodic variation of the return loss with approximately 5 GHz period, shown in Fig. 3, is produced by slight mismatches at the beginning of the microstrip-coupled fin-line transitions.

IV. Conclusions

A broad-band waveguide-microstrip-coupled fin-line transition exciting the even (quasi-TEM) mode of the coupled fin-line has been presented. The transition is tapered using the two sides of the substrate in a fin-line structure and consists of a waveguide-to-microstrip transition and of a microstrip-to-coupled fin-line transition without the use of via holes. Experimental results of a back-to-back symmetrical double transition show a frequency range from 26.5 to 37 GHz with low insertion and high return losses. Possible applications include balanced mixers and front-end preamplifiers using chip transistors mounted in the coupled fin-line.

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