Novel MIC/MMIC Compatible Microstrip to Waveguide Transition for X Band without a Balun

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Abstract – **An MIC/MMIC compatible microstrip to waveguide transition for X band is presented. The transition has realized on novel low cost substrate and its main features are: wideband operation, low insertion loss and feeding without a balun directly by the microstrip line.**

I. Introduction

Current trends in RF/Microwave industry increase demands for component miniaturization and integration that leads to cheaper equipment production.

To achieve these goals SMT, hybrid and monolithic technologies are used. But such technologies do not offer high-Q components such as filters and diplexers, so waveguide components have to be used. This requires design of microstrip to waveguide transitions which are MIC/MMIC compatible [1].

Thus far many transitions for this purpose are proposed.

They generally consist of few sections of different types of transmission media. By them transverse electrical field distribution of the microstrip is transformed to field distribution of the waveguide dominant mode [2] and [3]. Such transitions give low insertion loss if lowloss substrates are used. These types of transitions also contain a balun to transit from symmetrical transmission media to unbalanced transmission media.

But such designs, although give lowloss, are long and unhandy so they are improper for integration purposes.

Other earlier designs also include tapered ridge waveguide sections [4] or use a slot as a coupling element [5]. The first one requires many precise mechanical operations, but the second enables only narrow band operation.

An interesting new design has recently proposed in [6] which attempts to eliminate drawbacks of existing transitions. However, such design, although smaller then previous and MIC/MMIC compatible also uses a balun which is built by many microstrip sections and bends so it will be improper for higher frequency applications as losses significantly increases. Also the transition has disadvantage as it will be difficult to realize it on low dielectric constant substrate, because the dipole exceeds the *b* waveguide dimension.

The paper presents a novel transition which overcomes all above drawbacks [1].

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II. Transition Description

The novel design is based on utilization of a Yagi-Uda antenna as a coupling element between guided wave of the microstrip and that of the waveguide, see Fig. 1.

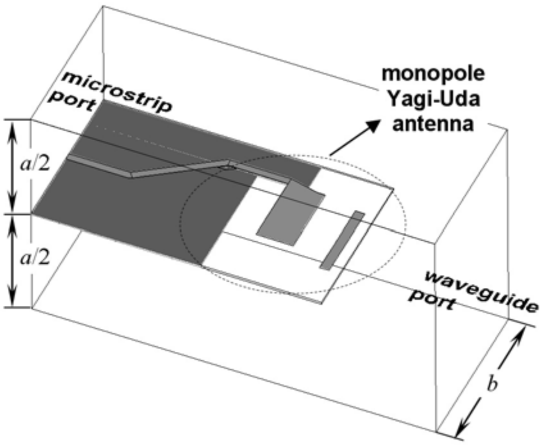

Fig. 1. The novel microstrip to waveguide transition.

Opposite to the design described in [6], which uses a quasi-Yagi antenna, the proposed design uses a classical Yagi-Uda antenna.

To avoid using a balun instead of a dipole the Yagi-Uda antenna driver is built as a monopole. Also instead of a thin monopole as in classic design, the proposed antenna uses a thick monopole driver [7]. As it is known from the antenna theory such a monopole enables wider frequency operation.

As a result of using the monopole, a balun is not required and the microstrip line can be directly connected to the antenna with a little matching.

The reflector element as usual for such an antenna is built as truncated ground plane of the microstrip line (edge at the driver element).

The proposed design is shown in Fig. 1 while in Fig. 2 PCB layout with dimensions is shown.

All transition is printed on low cost substrate, RO4003 H_{sub}=0.2 mm, ε_r=3.38, tgδ=$32\cdot10^{-4}$. PCB is mounted in the center of the waveguide WR90 (at half of the *a* waveguide dimension), Fig.1.

As a result of all above mentioned design points compact transition is realized. Transition is single layered, without a balun and it does not use any via.

The length of the PCB is 18 mm with the input microstrip line. The length of the transition only is 8 mm although it is realized on low dielectric constant substrate.

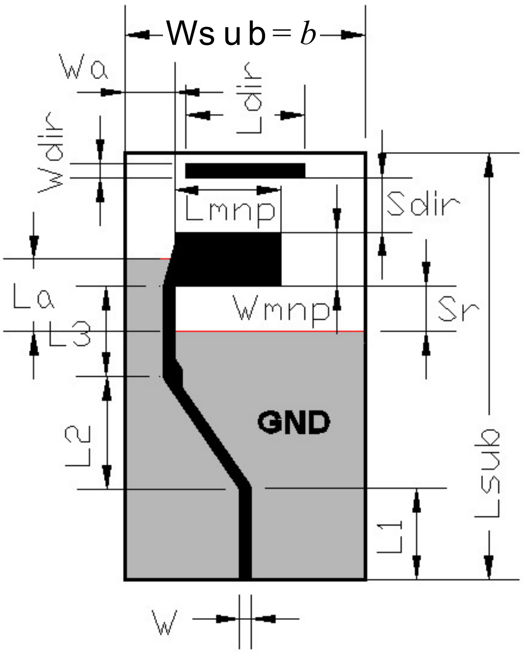

Fig. 2. Layout of proposed microstrip to waveguide transition. Dimensions are: *a*=0.90 inch, *b*=0.40 inch, *Lsub*≈18mm *Wsub*=*b*, *L1*=3.9mm, *L2*=4.7mm, *L3*=3.8mm, *La*=3mm, *Wa*=2.1mm, *W*=0.464mm, *Lmnp*=4.5mm, *Wmnp*=2.3mm, *Sref*=1.9mm, *Ldir*=5mm, *Wdir*=0.6mm, *Sdir*=2.1 mm.

The length of the PCB is 18 mm with the input microstrip line. The length of the transition only is 8 mm although it is realized on low dielectric constant substrate.

III. Simulation Results

Theoretical tool for design and optimization of the transition were software: FEM HFSS [8].

The simulation model of the transition is shown in Fig. 1. In simulation complete waveguide is closed at the microstrip port. The ground plane (gnd) of the microstrip is connected to waveguide walls along the PCB.

Simulated results are shown in Fig. 3. The metal loss is neglected while the dielectric loss is included in simulation. Simulation shows that s_{11} and s_{22} are better than -16 dB in almost all X band ($s_{11} \approx s_{22}$), while insertion loss is about 0.15dB at the center of the band.

IV. Measured Results

As the transition is small and losses from long tapered lines and balun are avoided good performances are achieved although the substrate has relatively high tangent loss.

Fig. 4 shows measured *s* parameters of the realized transition while Fig. 5 shows the measurement setup.

The insertion loss is between 0.3 and 0.6 dB and return loss is better than 13dB in almost entire X band for both ports.

For 10dB level of return loss of s_{11} and s_{22} bandwidth is 43.6%. For 13dB level of s_{11} and s_{22} bandwidth is about 42%, while s_{21} is between -0.3 and -0.6 dB in almost entire band (peak to peak ripple).

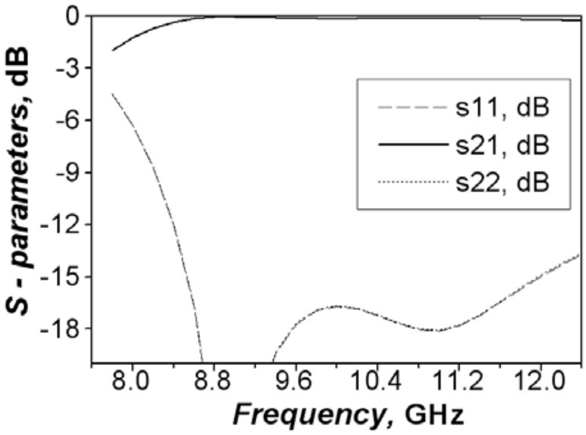

Fig. 3. Simulated S-parameters of the transition:
– – – s_{11} [dB], □ s_{21} [dB], ······ s_{22} [dB]

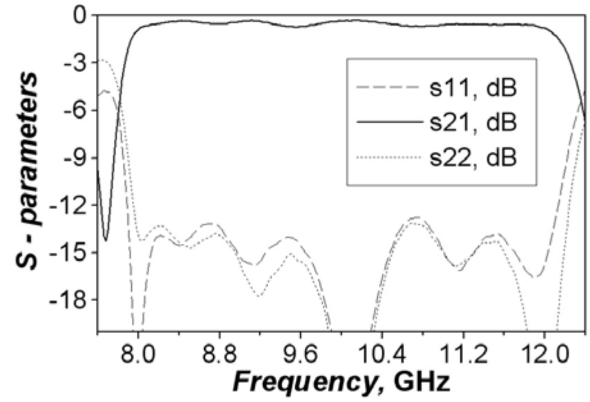

Fig. 4. Measured S-parameters of the transition:
– – – s_{11} [dB], □ s_{21} [dB], ······ s_{22} [dB]

Fig. 5. Measurement setup

In simulation waveguide at the microstrip port is completely closed by metal cover. However, it has been found experimentally only partially closing (by metallic plate) of the waveguide at the microstrip port is enough to achieve good performances.

Compared to the transition [6] the proposed transition has 50% size reduction (even on 3 times lower ε_r of the substrate), lower insertion loss and it is constructively much simpler.

In difference to the transition [6] which can be realized only on high dielectric constant substrates the proposed transition has a potential for realization on both low and high dielectric constant substrates. Also as it does not contain a balun with microstrip dividers and many bends it has great potential for higher frequency application even on lossy low cost substrates.

V. CONCLUSION

A novel compact X-band microstrip to waveguide transition has been described in this paper.

The transition is realized on low cost substrate RO4003 and its main features are: wideband operation, low insertion loss and feeding without a balun directly by a microstrip line.

The transition is MIC/MMIC compatible, single layered and it does not require any via. Compared to present designs it is much simpler, has 50% size reduction, considerably smaller losses and great potential for higher frequency application. The novel transition can be realized on both low and high dielectric constant substrates. As a result it can find a wide spectrum of applications in wireless industry.

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Patent pending for the transition described in this paper.

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