BROADBAND QUASI-YAGI ANTENNAS FOR V-BAND APPLICATIONS

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1. INTRODUCTION

In order to realize high efficiency RF front-ends for mm-wave applications such as wireless LAN at 60 GHz and automotive radars at 76 GHz, it is advantageous to integrate planar antennas with mm-wave passive circuits and active devices monolithically, preferably on GaAs, Si or InP substrates. A major design challenge is the deterioration in antenna efficiency on high permittivity substrates, mostly due to significant surface wave effects.

The uniplanar quasi-Yagi antenna, which we developed at UCLA recently [1,2] can be made on a single high permittivity substrate with simple double side etching process, and thus the use of multiple dielectric layers, micro machining and other techniques used to enhance the bandwidth can be avoided and space is saved. In the uniplanar quasi-Yagi antenna the excited surface waves are integral part of the direction process, and thus no impedance surface is needed to eliminate leakage. This leads to good front-to-back ratio, very high radiation efficiency which eliminates the need of hermetic sealing in microstrip-to-waveguide transition, and compact size. The microstrip version of this antenna is studied here due to vast importance of this circuit technology, existing work is expanded to V-Band. Two basic radiators are considered, namely the regular stand alone antenna and the waveguide radiator (microstrip-to-waveguide transition).

2. V-BAND QUASI-YAGI ANTENNA RADIATING INTO WR-15 WAVEGUIDE

Quasi-Yagi antenna radiating into waveguide (microstrip-to-waveguide transition) has been reported previously at X-Band on 25 mil duroid ($?_r$=10.2) [3,4]. Direct scaling of this transition is not possible, because the scaling factor of the substrate thickness does not scale the bands and because the aspect ratio of the waveguides in X-Band and V-Band are not the same. The V-Band version on 5 mil alumina was optimized with full wave simulator HFSS. Transition was measured with the available mm-wave waveguide measurement system by placing the back-to-back cascaded transitions in the waveguide. Full port calibration could not be performed due to limitations of the measurement system. Reciprocity can be assumed as long as no severe mode conversion takes place. Later on this transition is used to measure antennas radiation into free space.

The layout of the transition version of the V-Band antenna is shown in fig. 1. The dipole and radiator lengths are shorter than in the free space radiator version due to predefined waveguide dimensions. Fig. 2 a) shows the return loss of two back-to-back connected antennas separated by 0.7 mm 50 ? transmission line (0.1 dB loss). Reflection data reference plane is in the waveguide at the substrate edge as shown in Fig. 1. Insertion data is with respect to waveguide section of length of the cascaded transitions. The waveguide insertion loss of this section is less than 0.05 dB. Almost whole V-Band is within the 3 dB bandwidth of single transition. At the center of the band insertion loss is 0.5 dB per transition including both return and dissipative loss.

At the low-frequency-end (< 55 GHz) power dissipation, as shown in Fig. 2 b), is lowest because incident wave does not couple into structure. At the high-frequency-end (> 70 GHz) power dissipation is largest even though return loss is relatively high, which suggest internal resonance or mode conversion. For this reason the used response calibration above 70 GHz is not accurate any more. At the mid-bandfrequencies when power is coupled effectively through the transitions power dissipation has a constant value of 0.5-0.6 dB. By assuming all the power dissipation is due to radiation inefficiency, the dissipative loss due to transition is half of the total loss, 0.25 dB at best indicating a radiation efficiency better than 94 %. To our best knowle dge, this is the lowest loss microstrip to waveguide transition with broadband coverage.

3. X-BAND QUASI-YAGI ANTENNA SCALED TO V-BAND

The broadband characteristics of the quasi-Yagi antenna has been shown already at X-Band [2], and 50% bandwidth was achieved with VSWR < 2. The antenna considered here is a direct scaling of the X-Band version on 25 mil duroid by a factor of 5 [2] to 5 mil alumina.

Fig. 3. a) shows the antenna layout on 25 mil duroid (?$_r$=10.2) [2], and Fig. 3. b) shows the result of coaxial measurement together with simulated data. The whole band was covered with return loss better than -10 dB. Fig. 4. shows the measured return loss of the cascaded V-Band transition and antenna connected back-to-back by conducting epoxy. Reference plane was at the substrate edge of the transition radiator end inserted in the waveguide as before. The figure shows that at the low- and high-frequency-end performance is limited by the transition. At the center of the band return loss is -10 dB, which is less than the simulated values.

4. DISCUSSION

The quasi-Yagi based microstrip-to-waveguide transition is simpler than the cavity backed transitions in [5,6], and offers wider band width with comparable or better return and insertion loss. Meanwhile, the V-Band quasi-Yagi antenna operated satisfactorily, even though broadband agreement with simulation performance at 60 GHz could not be demonstrated due to limitations of the test equipment.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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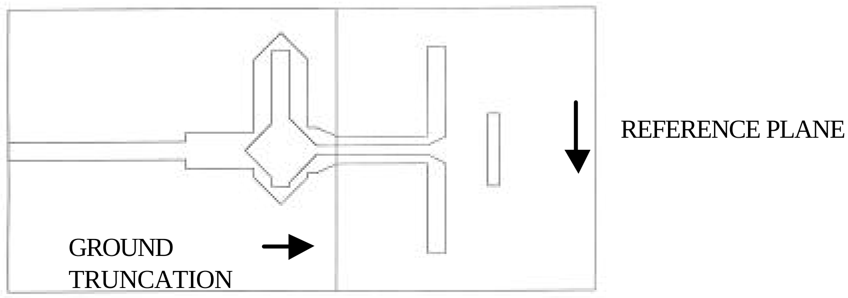
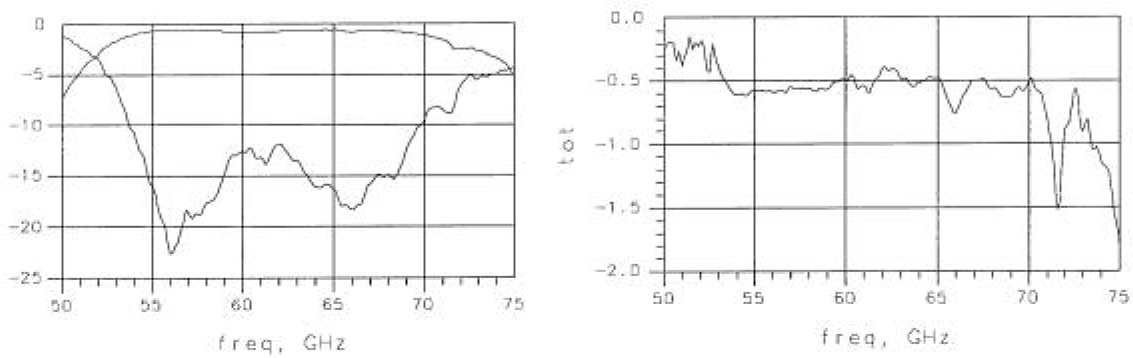
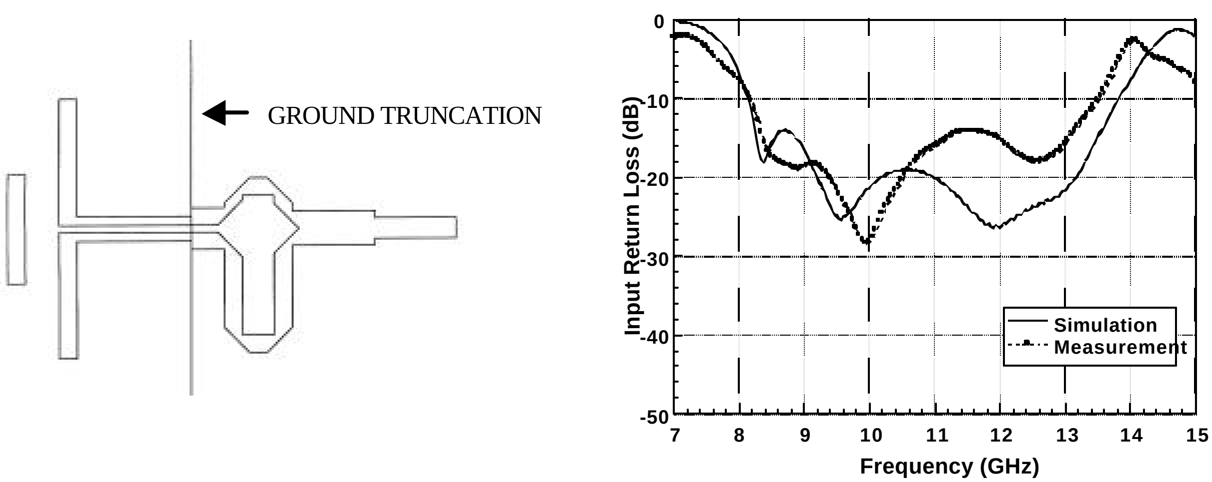


Fig. 1. Quasi-Yagi antenna optimized to radiate into WR-15 waveguide.



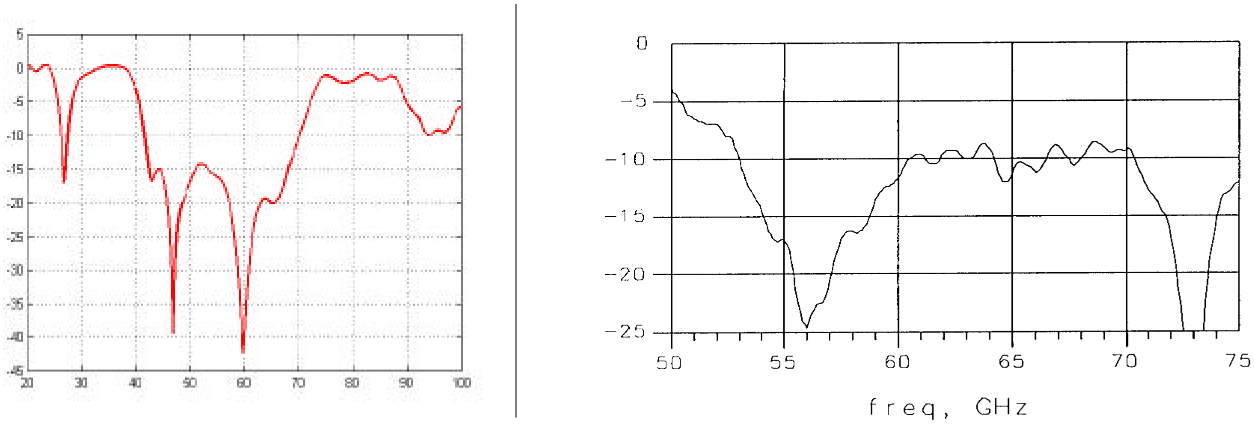
a) b)

Fig. 2. a) Insertion and return loss, and b) total power dissipation (insertion loss + return loss) of two cascaded transitions.



a) b)

Fig. 3. a) X-Band quasi-Yagi antenna, and b) simulated and measured return loss.



a) b)

Fig. 4. a) Simulated return loss of the V-Band quasi-Yagi antenna and b) measured return loss of the V-Band cascaded transition and antenna.