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# Linearly Tapered Slot Antenna Radiation Characteristics at Millimeter-Wave Frequencies

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# LINEARLY TAPERED SLOT ANTENNA RADIATION CHARACTERISTICS AT MILLIMETER-WAVE FREQUENCIES

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## 1. INTRODUCTION

The dimensions of the conventional resonant microstrip patch antenna become very small as the frequency of operation shifts into the higher millimeter-wave (mm-wave) frequency band. This results in increased cost of manufacturing because of fabrication tolerance. In addition, the skin effect conductor losses in the microstrip feed network tend to become excessive, thus lowering the antenna efficiency. An endfire traveling wave antenna, such as, a linearly tapered slot antenna (LTSA) (ref. 1) is a viable alternative to a patch antenna at higher mm-wave frequencies. The dimensions of the LTSA are several times the free space wavelength,  $\lambda_0$  at the frequency of operation which eases fabrication tolerance. In addition, the attenuation due to conductor losses are smaller for a rectangular waveguide which is typically used at mm-wave frequencies in the feed network of LTSA. Lower losses enhances the antenna efficiency.

The LTSA has been extensively characterized in the past by measuring the radiation patterns in the E- and H-planes, beam widths, cross-polarization levels and gain over the frequency range of 8 to 35 GHz (refs. 2 to 4). The LTSA in these experiments are fabricated on a Kapton ( $\epsilon_r = 3.5$ ) and Duroid ( $\epsilon_r = 10.0$  and 2.2) substrates. At 35 GHz the LTSAs are excited by a finline-to-rectangular waveguide transition. Some preliminary measurements on imaging arrays at 94 GHz with LTSAs on Kapton substrates as receiving antennas and with biased beam lead diodes soldered at the end of the slots as detectors are reported in references 2 and 5.

In this paper we present the radiation characteristics of LTSA at frequencies of 50, 77, and 94 GHz which have been recently designated by the Federal Communications Commission (FCC) for several emerging wireless communications. Our studies differ from that in reference 5 in several ways. First, the operating frequency is different. Second, the width  $W$  of the ground plane is kept small typically about  $0.25$  to  $0.39 \lambda_0$  to reduce inter-element spacing in an array. Third, a unilateral finline-to-rectangular waveguide in-line transition is integrated with the LTSA on the same dielectric substrate for loss reduction. Fourth, a sensitive waveguide detector is attached to the finline for detecting the response.

## II. TAPERED SLOT ANTENNA

### Construction

Figure 1 illustrates a typical LTSA fed by a fin line-to-waveguide transition. The length, width of the ground plane and the width of the opening are designated as  $L$ ,  $W$ , and  $H$  respectively. Figure 2 shows the picture of the LTSA with integrated slotline-to-finline-to-waveguide transition fabricated on a 5 mil thick RT/Duroid 5880 ( $\epsilon_r = 2.22$ ) substrate. The dimensions of the slotline and finline are determined as explained in reference 6. Three LTSAs are fabricated and their radiation patterns are measured at 50, 77, and 94 GHz respectively.

### Results and Discussions

Figures 3(a), (b) and (c) show the measured co-pol and cross-pol radiation patterns for the E-, H- and D-planes respectively of the LTSA at 50 GHz. Figure 4 shows the measured E- and H-plane radiation patterns of the LTSA at 77 GHz. The patterns are well behaved and symmetric with the main beam in the endfire direction. The measured gain is about 10 dB. The measured pattern for the 94 GHz LTSA shows a dip of about 2 dB at endfire. To correct

this problem a LTSA on a thinner substrate is being fabricated. Figure 5 shows the measured return loss of the LTSA as a function of the frequency obtained using an RF probe station . Experiments are also under way to measure the feed losses.

### III. CONCLUSIONS

The LTSA has been experimentally characterized by measuring the radiation patterns at frequencies of 50, 77, and 94 GHz designated for wireless communications. The patterns are well behaved and symmetric. The measured gain of the LTSAs are about 10 dB.

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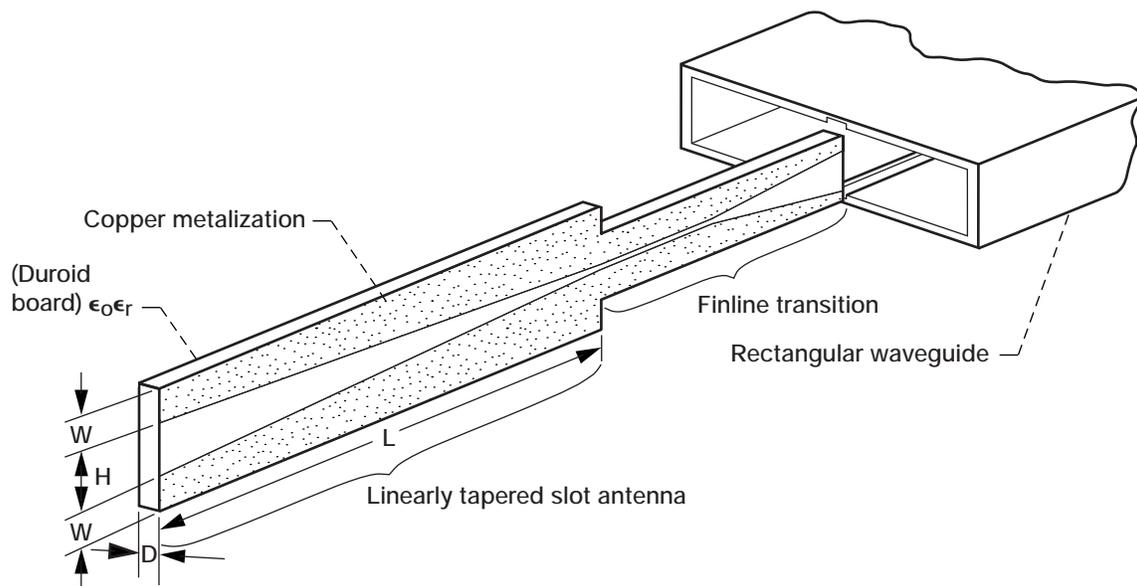


Figure 1.—LTSA fed by a finline-to-waveguide transition:  $L = 1.1811$  in.,  $W = 0.0591$  in.,  $H = 0.1181$  in.

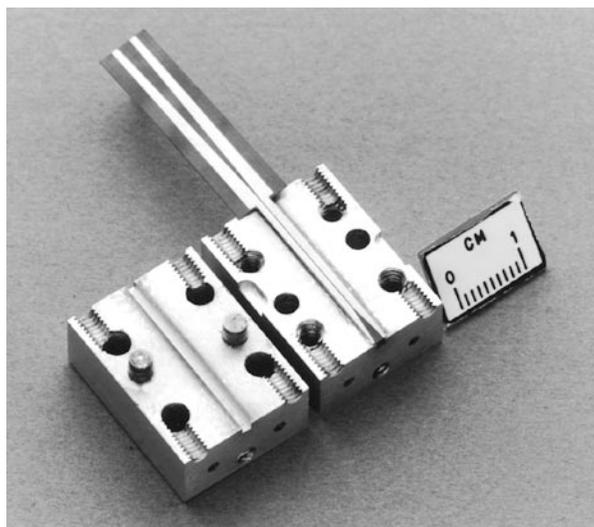


Figure 2.—LTSA mounted in a split block housing.

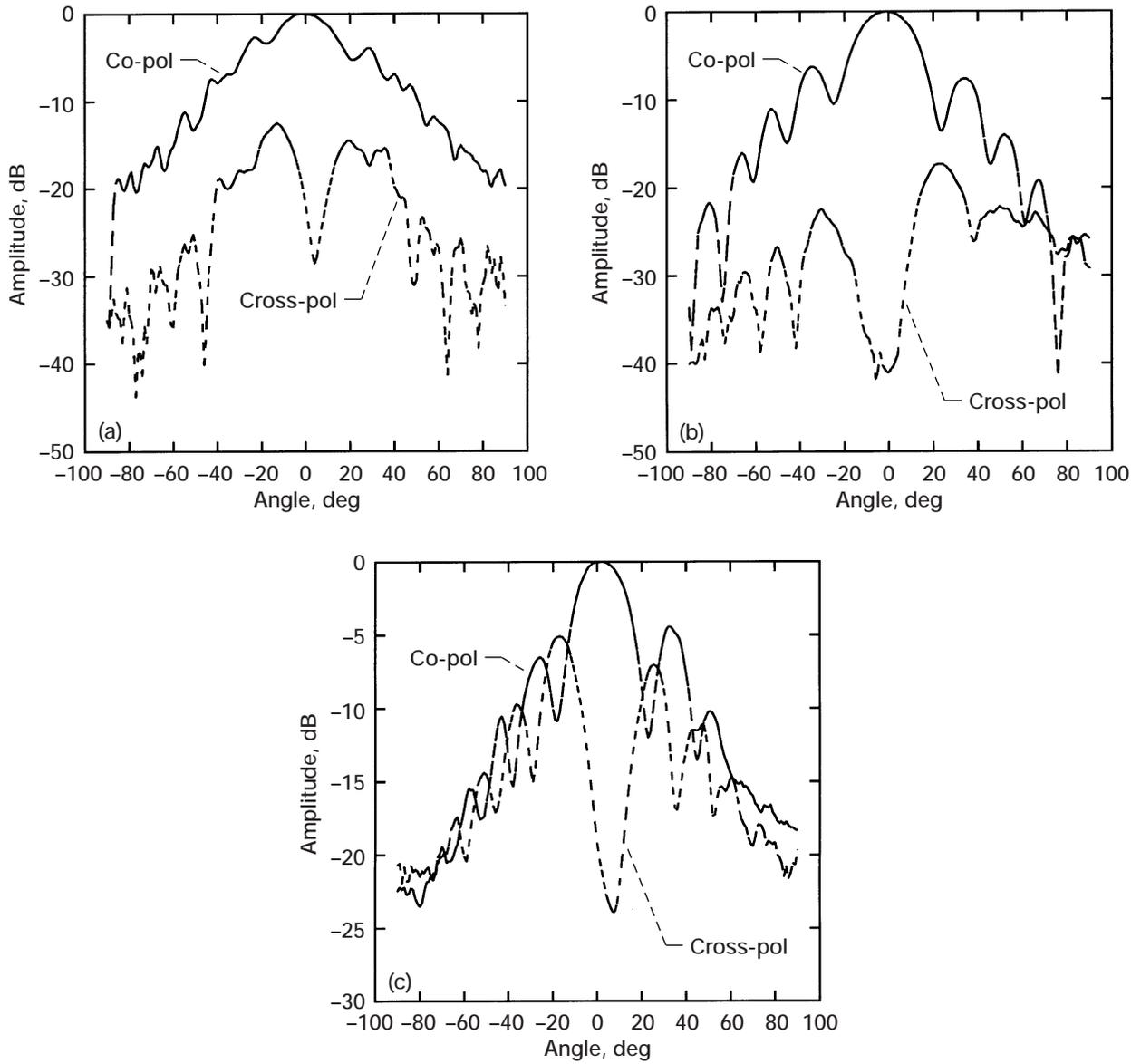


Figure 3.—Co-pol and cross-pol radiation patterns at 50 GHz. (a) E-plane. (b) H-plane. (c) D-plane.

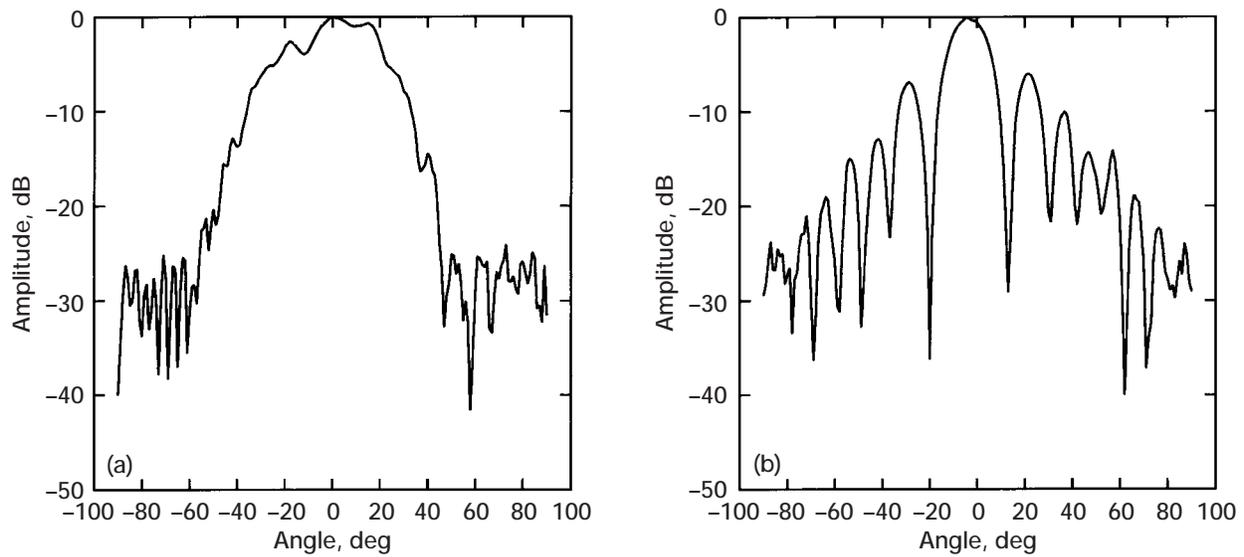


Figure 4.—Radiation patterns at 77 GHz. (a) E-plane. (b) H-plane.

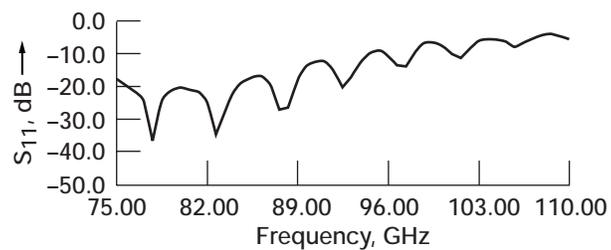


Figure 5.—Measured return loss of LTSA as a function of frequency obtained using a RF probe station.

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