Proximity Coupled Fed Antenna Arrays on LCP for mm-Wave Applications

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Abstract- In this paper, a novel configuration of a microstrip antenna that uses proximity coupling is designed, fabricated, and characterized for its performance in the mm-Wave frequencies. The S-parameters show a Bandwidth of 4% for a 16x1 sub-array and the gain of 25.3 dBi (16x16 array including corporate feed) at the center frequency 76.5GHz has been designed. Measurements are introduced and are in agreement with the theory.

Introduction

Recent advancements in the mm-Wave circuits such as HBT MMIC and GaAs MMIC could be felt in several aspects not just in the current research areas but also in the state of the art applications such as wireless personal area network (mm WPAN from IEEE 802.15.3c), wireless MAN IEEE 802.16, mm-Wave automotive RADAR, and passive mm-Wave imaging [1]. This in turn, places stringent requirements on the antenna design in terms of bandwidth (for high speed communications and in order to account for fabrication tolerances) and gain (for point to point communications and for target detection in long range RADAR). In this work, a novel antenna multilayer configuration uses proximity coupling to feed the resonance structures from a microstrip Transmission Line resulting in 4% (covering 75.1 GHz → 78.3 GHz) bandwidth for a 16x1 subarray versus 1-2% for that of a typical microstrip array channel. The gain of such sub-array was simulated to be ~17dBi accounting for 1.22 dB loss in material.

The choice of the mm-Wave high performance substrate is Liquid Crystal Polymer (LCP). The low loss ($\tan \delta = 0.002$-0.005) up to 110 GHz, near hermetic nature (water absorption < 0.04%), low-temperature and low-cost-large-format processing on an organic platform, make LCP appealing for mm-Wave designs where excellent performance is required for minimal cost [2]. LCP's low water absorption makes it stable across a wide range of environments by preventing changes in the relative dielectric constant (ε_r) and loss tangent ($\tan \delta$). Its Coefficient of Thermal Expansion (CTE) can also be engineered in the x-y plane to match integration with other materials such as Si or GaAs which gives LCP a broad range of applications. In addition, multilayer circuits are possible with LCP due to two types of LCP material (core layers and bond ply) with different melting temperatures.

Antenna Design, Measurements, and Discussion of Results

The schematic of the antenna is shown in Fig. 1. A 50 Ohm microstrip or embedded microstrip line on a 4 mils LCP substrate feeds the resonant microstrip

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patch elements sitting on another 4 mils LCP substrate (8 mils from ground). The fabricated photo of this antenna is shown in Fig. 2 along with the plot of the S11 results. It can be observed that around the frequency of interest (76-77 GHz for mm-Wave automotive application) the simulations cover a -10 dB bandwidth of 75.1 GHz → 78.3 GHz while the measurements covers 74 GHz → 77.5 GHz as shown in Fig. 3. The discrepancy between the simulation and measurement results could be explained by any fabrication errors or tolerances as well as towards the feeding CPW line that was used for probing the Antenna Under Test (AUT) which is also shown in Fig. 3 and which may have introduced some reflections due to any misalignments with the top layer on which the resonance elements sit.

A 16x16 element array for a total gain (E-plane) of 28 dBi for ideal feeding, a 25 dBi gain with corporate feeding was designed for the center frequency of 76.5 GHz. This is shown in Fig. 4. The radiation measurement was performed in an anechoic chamber for the calibrated frequency at 78 GHz and the results are shown in Fig. 5 showing good agreement (at peak location the simulated gain 23.6dBi and the measured gain 21.16 dBi for the E-plane). It is to be noted that 2.26 dB need to be accounted for the microstrip and transition loss used for the connection to the oscillator as shown in Fig. 5.

Conclusion

A novel configuration microstrip antenna array using proximity coupling has been designed, fabricated, and characterized for its performance in the mm-Wave frequencies. The S-parameters and gain measurements show good agreement of ~4% bandwidth for each channel and a 23.6 dBi gain at 78 GHz for the array.

References:

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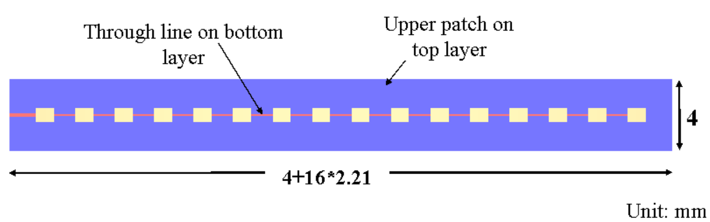

Fig. 1. Schematic of the proposed dual layer Sub-Array Antenna.

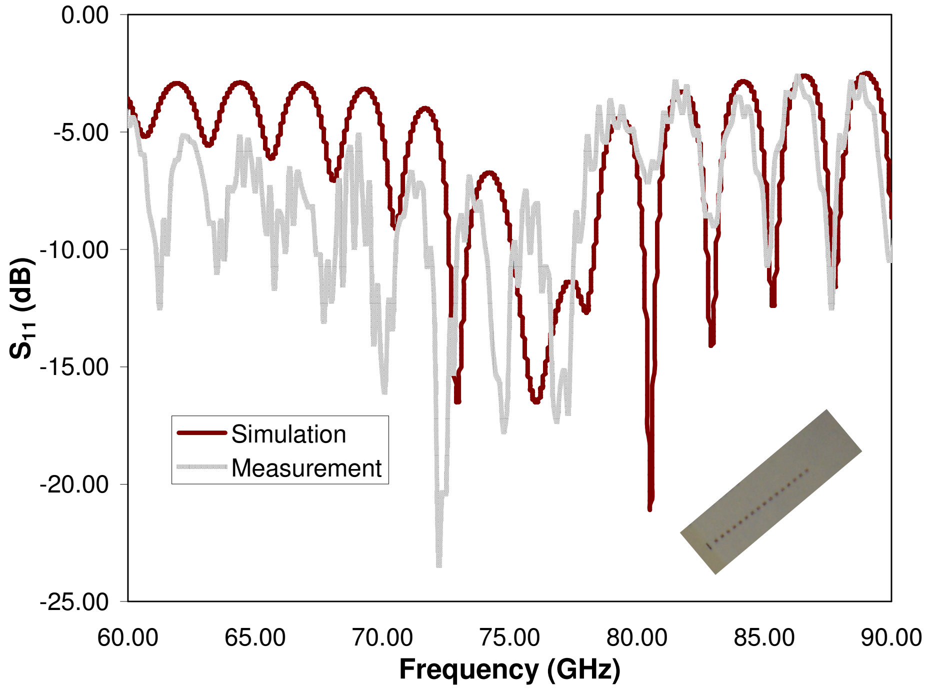

Fig. 2. S11 results for the 16x1 sub-array antenna and a photo of the fabricated subarray structure

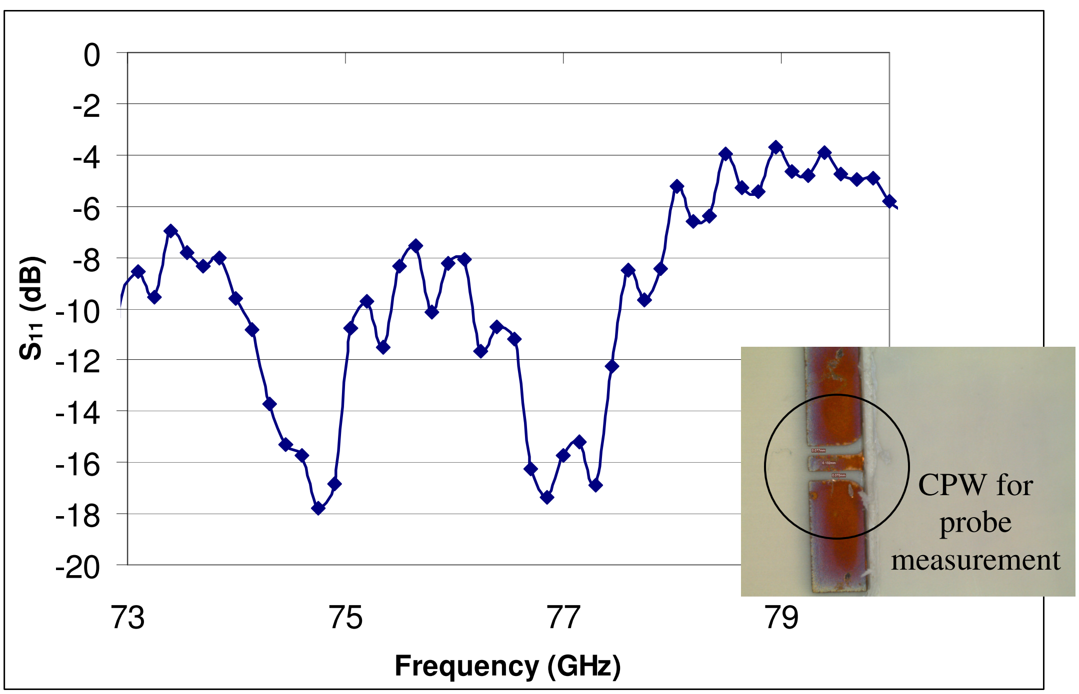

Fig. 3. Measured S11 for the 16x1 subarray (same as Fig. 2) and a microscopic photo of the feeding (CPW TL) to the AUT.

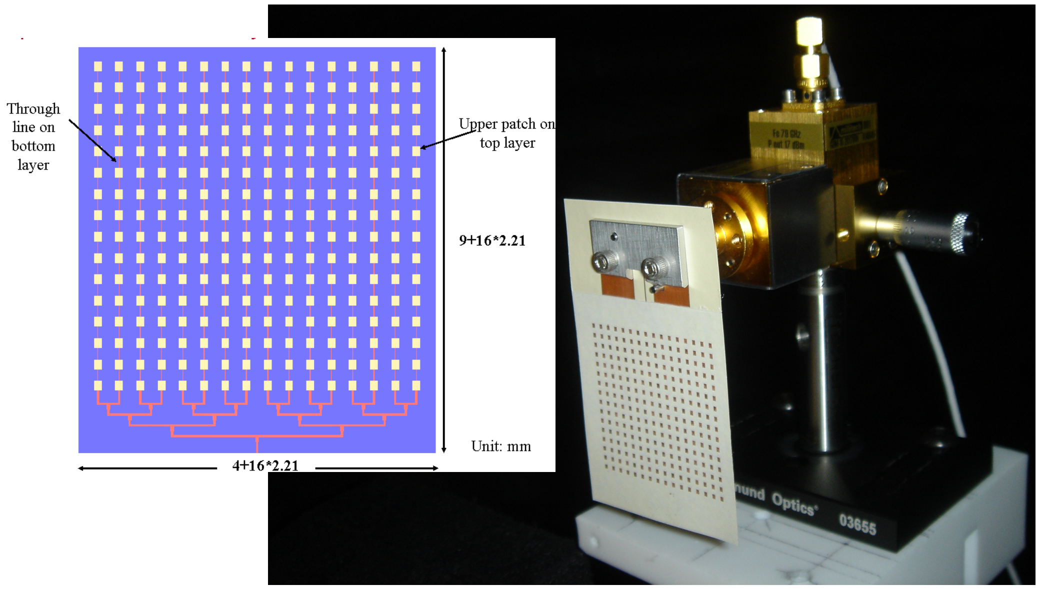

Fig. 4. Schematic of the 16 x 16 Antenna Array with corporate feeding (left) and a photo of this antenna with a transition to Waveguide input to oscillator for radiation pattern measurement.

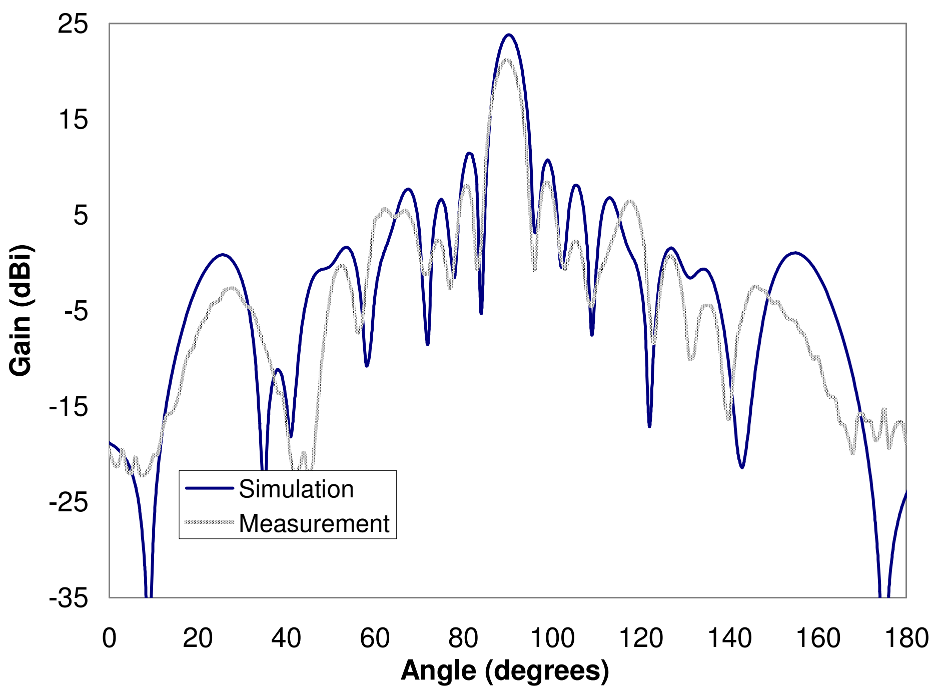

Fig.5. Antenna Total Gain for the structure shown in Fig. 4.