Design of Low Cost Microstrip Antenna Arrays for mm-Wave Applications

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***Abstract*—A planar, low profile, low cost microstrip patch array antenna is developed in the millimeter-wave band for large gain applications. A simple edge feeding is used for a sub-array of 16x1 elements, and finally a matching network or power divider/splitter is designed for a 32x16 elements with a gain of 27dBi for the design frequency of 79GHz and 26dBi at 80GHz. A method to reduce the slightly high "shoulder" radiation due to the feed network is introduced through a shielded feed.**

Index Terms: millimeter-wave, microstrip antenna, array antenna.

I. INTRODUCTION

The advantage of mm-Wave frequencies is better resolution and higher data rates if compared with applications in the lower frequency spectrum.; both which are necessary for systems with better capabilities and higher levels of functionality such as broadband and Gigabit wireless networks, vehicular radars, remote sensing of clouds and terrain, as well as imaging systems. Millimeter-wave antennas are being developed for several of these applications and research has been focused on the realization of mm-Wave hardware [1]. It is the result of the enabling technologies such as MMICs developed using SiGe and GaAs up till frequencies above 100 GHz as well as CMOS around 60 GHz that created this need for antennas and packaging considerations for these frequencies [2].

The focus to date therefore is directed towards successful hardware demonstration that fulfils required functionalities for mm-Wave technologies such as high gain, low profile, and low cost or the potential for low manufacturing costs. The work in this paper is targeted towards a simple design for a large antenna array characterized by a low profile for 79GHz and 80GHz frequencies [3] for the mm-Wave UWB applications such as Short Range Radar (SRR) for vehicles. The structure is designed and simulated in the 3D electromagnetic simulator CST Microwave Studio and utilizes the parameters of commercially available substrate RO3003.

II. SUB-ARRAY ANTENNA DESIGN

A. Sub-Array Design 16x1

A 16x1 sub-array of individual patch antennas of size 1.2 mm x 1 mm is designed in this section. The size of the individual element was chosen for the successful operation of the sub-array at the two frequencies 79GHz and 80GHz. The element spacing was chose to have a spacing that is close to $\lambda_g/2$ or equivalently to create an in phase excitation among all of the elements at the given design frequencies. The layout of the design and its dimensions are shown in Figure 1. This sub-array is designed on a 5 mil thick (0.127 mm) RO3003 material with dielectric constant (ε_r) 3.0 and dielectric loss tangent (tanδ) 0.0013. It is also to be noted that the metallization was modeled as copper with a thickness of 9 μm; a common metallization thickness for mm-Wave circuitry [4].

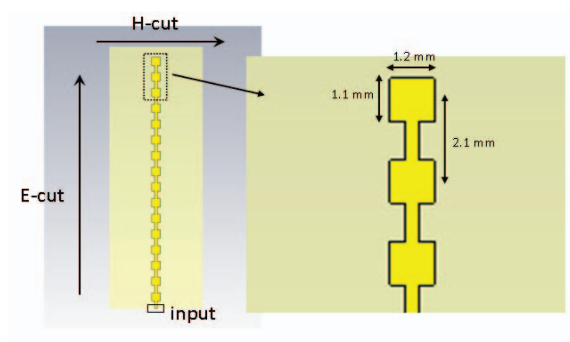

Figure 1. Layout of the 16x1 Sub-array.

B. S-parameter and gain simulation results.

The S-parameter results for the 16x1 sub-array is shown in Figure 2 demonstrating a very good matching for the design frequencies. Figure 3 shows the gain pattern for the E-cut (as defined in Figure 1). In the following figures theta resembles the elevation plane and phi resembles the azimuth plane. The pattern shows a maximum gain of 17.8 dBi, 3dB angular width of 5.6°, and a side-lobe level (SLL) -10.7dB. For sake of space limitation the rest of the paper will focus on the 80GHz frequency but it is to be noted that the 79GHz has equivalently good performance. Figure 4 shows the gain pattern for the E-cut at 80 GHz with a maximum gain of

17.9dBi, 3dB angular width of 5.8°, and a side-lobe level (SLL) -12.1dB. Figure 5 shows the H-cut (Phi=0) of the 16x1 sub-array at 80GHz with a 3dB angular width of 75°.

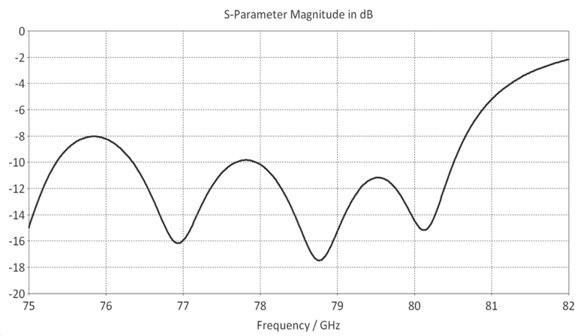

Figure 2. S_{11} for the 16x1 Sub-array shown in Figure 1.

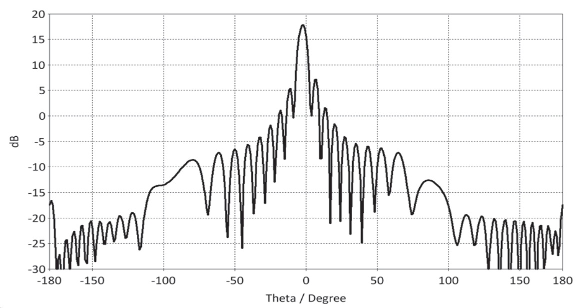

Figure 3. Gain (E-cut, Phi=90) for the 16x1 Sub-array at 79 GHz.

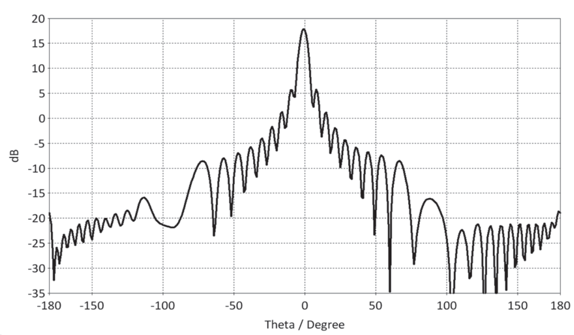

Figure 4. Gain (E-cut, Phi=90) for the 16x1 Sub-array at 80 GHz.

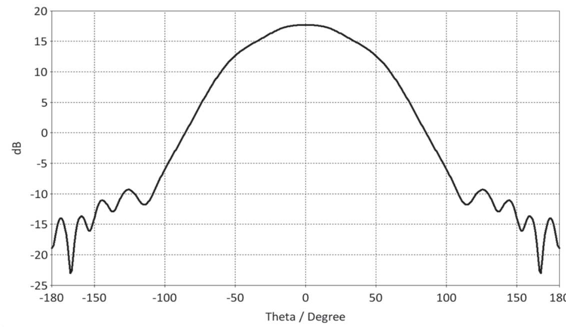

Figure 5. Gain (H-cut, Phi=0) for the 16x1 Sub-array at 80 GHz.

III. Large Antenna Array Design

An ideal phased array antenna may utilize phase shifters at the input of each channel or sub-array; something which is also ideal for lower loss performance. An ideal 16x32 array with center to center spacing of 1.9mm of adjacent sub-arrays was simulated for a total gain of 31.5 dBi at 80 GHz and a SLL of -12dB. The next section talks about the same 16x32 array but with a feeding network in order to have a 1-Port device for measurement purposes.

A. Array Design 16x32

A corporate feed was designed using quarter wavelength sections at the design frequencies and tapered corners to eliminate any undesired radiation due to sharp edges at such high frequencies. The design is shown in Figure 6.

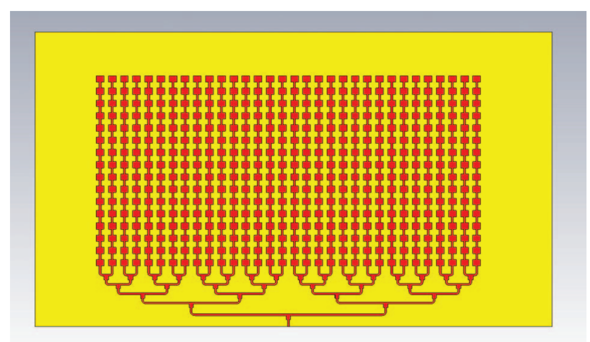

Figure 6. Layout of the 16x32 Array with feeding network.

B. S-parameter and gain simulation results.

The S-parameter results for the 16x32 array including the corporate feeding network is shown in Figure 7 demonstrating a very good matching for the design frequencies. The S_{11} at 79GHz is -13dB and at 80 GHz is -12 dB. Figure 8 shows the gain pattern (E-cut) of the array of Figure 6 with a maximum gain of 26.2 dBi, a 3dB angular width of 6.1°, and a SLL of -11.1dB and a radiation efficiency of 78%. An observation worth mentioning here is the increased level of the side lobes due to the feeding network as its dimensions starts to affect the radiation performance in the mm-Wave frequencies.

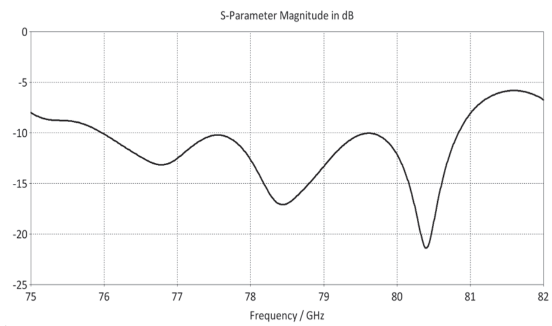

Figure 7. S_{11} for the 16x32 Sub-array shown in Figure 6.

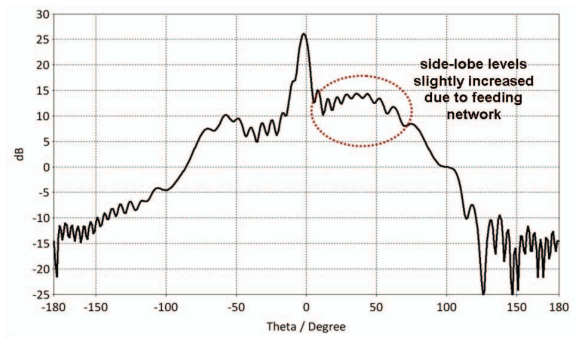

Figure 8. Gain (E-cut, Phi=90) for the 16x32 Antenna Array at 80 GHz.

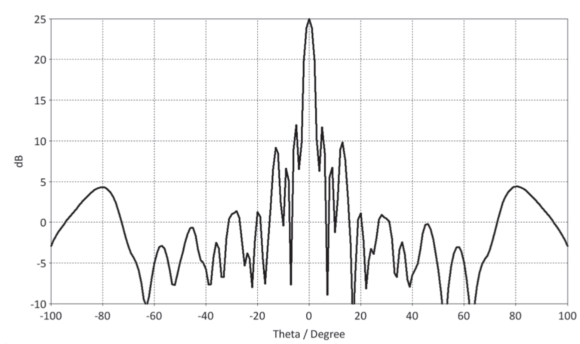

Figure 9. Gain (H-cut, Phi=0) for the 16x32 Antenna Array at 80 GHz.

The H-cut gain plot is also shown in Figure 9 resembling the array factor for 32 sub-arrays or elements with spacing (center to center) of 1.9mm having a 3dB angular width of 3° and a SLL of -14dB.

IV. "SHOULDER" RADIATION REDUCTION DUE TO CORPORATE FEEDING

In order to reduce the effect of the feeding network RF 3D interconnections may be utilized [4] or simply a shielded corporate feeding such as the one shown in Figure 10 which includes an unsymmetrical strip line configuration for the corporate feeding (15 mils substrate above the microstrip line, 5 mils below it). The gain pattern in Figure 10 has a major shoulder radiation improvement when compared to that shown in Figure 8 and a slight increase in the maximum gain from 26.2dBi to 26.5dBi.

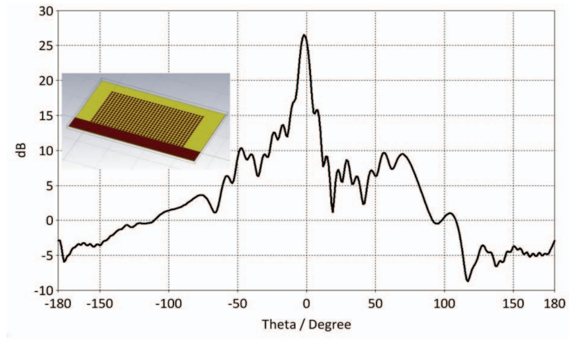

Figure 10. Gain (E-cut, Phi=90) for the 16x32 Antenna Array at 80 GHz.

V. CONCLUSION AND FUTURE WORK

A planar, low profile, low cost microstrip patch array antenna has been developed for the millimeter-wave band. A simple edge feeding has been used for a sub-array of 16x1 elements, and a matching network was designed for a 32x16 elements with a gain of 27dBi for the design frequency of 79GHz and 26dBi at 80GHz with a radiation efficiency of 78%. A method to reduce the slightly high "shoulder" radiation due to the feed network has been introduced through an un-symmetric strip line configuration feeding. Future work includes the experimental characterization of the work mentioned in this paper and the possibility of a lower loss feeding network.

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