A L-Band Superstrate Lens Enhanced Antenna and Array for Tactical Operations

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***Abstract*—The design of a 1.2 GHz microstrip antenna utilizing a superstrate layer for gain enhancement is presented. An 4 x 1 antenna array is also studied with the effects of various inter-elemental spacings investigated. The single antenna element achieves 5.74 dB of gain enhancement in simulation through the use of the superstrate lens. The 4 x 1 superstrate array achieves approximately 2.5 dB of gain enhancement in simulation.**

I. Introduction

Directional communications in the L-Band (1 - 2 GHz) can be challenging. Directionality is proportional to aperture size, and in the L-Band, often times space/area limitations (xy-plane) determine the maximum directionality that can be realized. The microstrip patch antenna is a widely used antenna in this regime as it is light weight and is easily scalable for increased gains.

It has been demonstrated that in addition to increasing the aperture size in the xy-dimension in order to increase the gain, a superstrate dielectric lens can be used in the z-dimension in order to boost the gain. This method was first introduced in [1] and has subsequently been demonstrated in various configurations. In [2] operation is demonstrated in the X-band and in [3] extended to demonstrate a 4 x 2 array. In [3] the frequency of operation is increased to the millimeter-wave frequency regime at around 60 GHz.

In this paper, we demonstrate an aperture coupled stacked patch antenna and array with gain enhancement through the use of a spaced dielectric superstrate lens.

II. Design

A. Single Antenna with Superstrate

In order to obtain a wider bandwidth, an aperture coupled stacked patch antenna topology was adopted. Figure 1 shows the side profile of the printed circuit board stackup. The dimension of the driven patch is 80 mm x 80 mm. The dimension of the parasitic patch is 70 mm x 70 mm. Under the resonance conditions for high gain the thickness of the superstrate should be approximately $\lambda_g/4$. In addition the height of the superstrate lens should be separated from the ground plane by a distance of $\lambda/2$. This was used as a baseline starting point, for which optimization routines were used in HFSS to fine tune those parameters. The size of the superstrate lens was 420 mm x 420 mm.

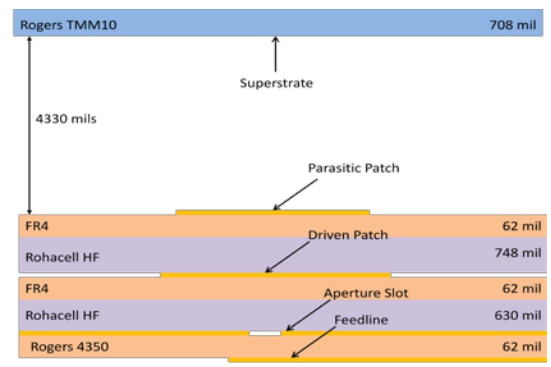

Figure 1. Side cross-section and stackup for superstrate aperture coupled stacked patch antenna

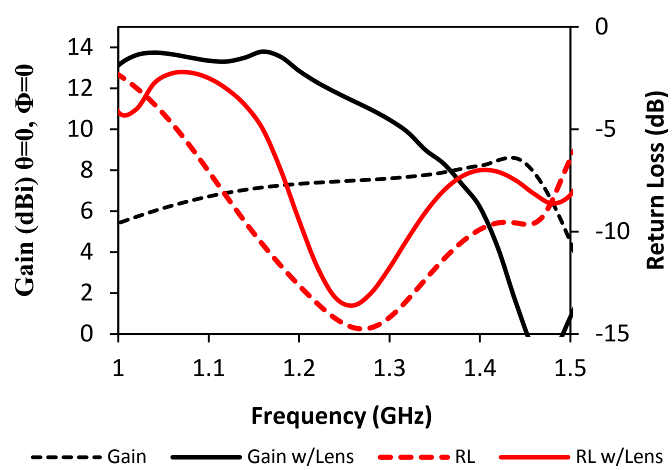

Figure 2. Simulated Gain and Return Loss with and without the superstrate lens

As can be seen in Figure 2, without the lens the single antenna has a 1.9:1 VSWR bandwidth of 19% with a gain of 7.11 dBi at 1.2 GHz. When the superstrate lens is added, the VSWR bandwidth reduces to 9.5%, however the gain at 1.2 GHz increases to 12.85 dBi, an improvement of 5.74 dB. Finally Figure 3 shows the simulated radiation patterns at 1.2 GHz in the *E*-Plane.

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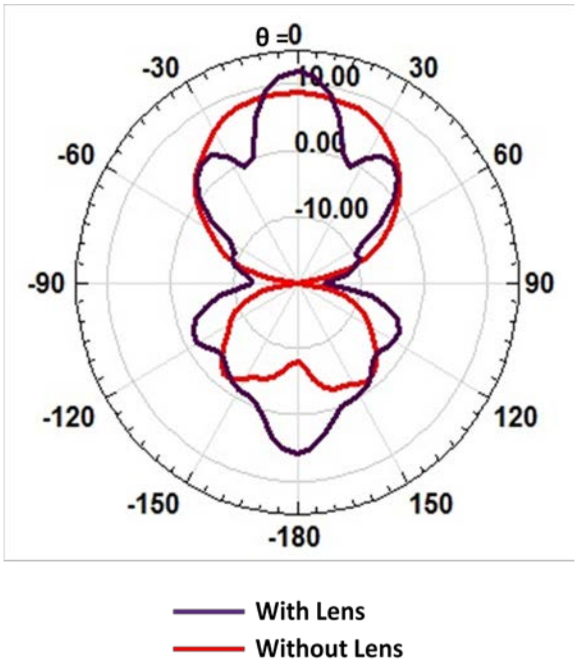

Figure 3. Simulated radiation pattern at 1.2 GHz with and without the superstrate lens in the *E*-plane

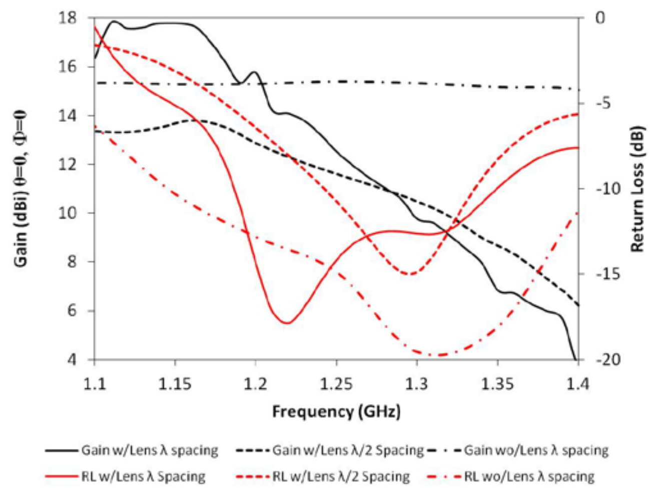

Figure 4. Simulated Gain and Return Loss of the 4 x 1 array with and without the superstrate lens

B. 4 x 1 Array

The simplest way to increase gain for microstrip type antennas is to configure them into an array. When in an array configuration, effects such as mutual coupling and ground plane shadowing can adversely affect the performance when a superstrate lens is used. In order to understand the effects, we simulated two cases. The first in which the antenna elements are spaced 1λ apart, and another in which the inter-elemental spacing is λ/2. In all cases, a T-Junction corporate feed network is used.

Figure 4 shows the simulated return loss and gain of the 4 x 1 array with and without the superstrate lens. It becomes apparent that when the array is spaced closely, $\lambda_o/2$, then the benefits of the superstrate is absent, and the gain is actually degraded as compared without the superstrate. This is primarily attributed to mutual coupling and ground plane shadowing effects [5]. However, when the inter-elemental spacing increases to 1λ, performance enhancement is observed. The total size of the 1λ array is 420 mm x 1070 mm.

The true benefits of the superstrate are seen at below 1.2 GHz. The main reason is attributed to the spacing of the superstrate and the ground plane. From 1.1 – 1.2 GHz, the gain is enhanced by approximately 2.5 dB. It is however, acknowledged that the matching efficiency is low in this regime. This can be remedied by tuning either the antenna or superstrate. It is apparent that the gain bandwidth becomes narrowband with the superstrate lens.

III. CONCLUSION

We present the design of an aperture coupled stacked patch antenna and array with a gain enhancing superstrate lens. Such an antenna can be used to improve the gain without sacrificing area in the xy-plane. For the single antenna, 5.74 dB of gain improvement is observed with a 9.5% reduction in the VSWR bandwidth. For the 4 x 1 array, 2.5 dB of gain improvement was observed, however with a minimized gain bandwidth.

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