Broadband Millimeter-wave suspended microstrip antenna array

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Abstract — In this paper, we present a 64-patch suspended microstrip antenna array operating at 38GHz. It consists of a single-layer of suspended broadband antenna elements, a low-loss suspended microstrip corporate feed network and a ground-plane impedance transformer. The measured return loss is –36dB at 38GHz for a –10dB bandwidth of 30%. The antenna gain was measured at 21dB. The structure chosen for these millimeter-wave arrays is compatible with micromachined antenna technology employed elsewhere.

I. INTRODUCTION

Microstrip patch antennas have attractive features such as lightweight, low profile, relatively low manufacturing cost and can be fabricated using photolithographic techniques. However they have their own limitations imposed by printed circuit technology; where the patch and the ground plane form a lossy cavity, in which much of the field remains trapped and results in a narrow inherent bandwidth (2-5%). In addition, losses in the corporate feed network and the excitation of surface wave modes form a significant limit to the achievable gain in microstrip antenna arrays, especially at the millimeter wave frequencies.

A thick substrate with a low dielectric constant can normally be used to improve the bandwidth, yet it can also generate significant surface wave modes and deteriorate the performance of antenna radiation. Suspended microstrip transmission line (SMTL) is one of the most popular transmission media at higher microwave and mm-wave frequencies. The presence of an air gap between the ground plane and dielectric substrate results in reduction of the effective dielectric constant of the propagating medium. This leads to less stringent dimensional tolerances and increases the accuracy of fabrication. The presence of the air gap also reduces conductor loss in the ground plane, where most of the electromagnetic energy is diverted away and makes the total dissipation loss two to three times lower than conventional microstrip lines [1]. This planar-like transmission line structure has been used in broadband antenna designs [2,3,4,5] where fractional bandwidths of 18% have been achieved in addition to the elimination of surface wave propagation at millimeter-wave frequencies [6,7]. Katherine et al. [8] demonstrated that using micromachined finite ground coplanar waveguides as a low-loss interconnects could achieve loss reduction of 0.3-1.0dB, depending on circuit type and size in W-band.

In this paper, the authors present a broadband antenna array with low-loss planar corporate feed network at mm-wave frequency. The whole array is constructed by SMTL structure. The benefits of this structure are low loss interconnects, improved

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operational bandwidth, controlled mutual coupling and suppressed surface wave modes.

II. ANTENNA DESIGN

The basic setup of the 38GHz antenna array is shown in Fig.1(a), which is made by 8 × 8 subarray elements. The array consists of rectangular patches each centered over a cavity region, sized according to the effective dielectric constant of the cavity region and interconnected by corporate-feed network in an SMTL structure. The analysis of the structure was performed by Agilent's Momentum and HFSS. The antenna array was fabricated on a layer of RO3003 substrate with a thickness of 0.13mm and a dielectric constant of 3. The array is then sited on top of a 0.45mm thick chemically milled copper support fixture (CSF) as in Fig. 2 where copper is removed laterally underneath the whole array to create a cavity that consists of air and substrate.

The feed network is incorporated on the same layer as SMTL structure in order to reduce the feed line losses. It consists of 140Ω SMTL and a tapered Y-junction power splitter. There isn't any quarter-wave transformer used in the feed network to avoid additional radiation losses. In the array, 180° delay meandered lines are used to feed half of the reverse oriented elements, which was intended to improve the gain bandwidth and reduce the cross-polarization level [9]. A previously reported [5], a ground taper is then used to match the impedance of 140Ω SMTL to 50Ω Microstrip line for SSMA connection. It utilizes a smooth change of ground plane to the width of the air cavity, while keeping the transmission line width constant throughout the transition boundary.

The most demanding feature of the electrical design is that the feed network must be fitted into a confined space so that it is separated from the radiating patch by the supporting beam shown in Fig. 1(b). It separates the electromagnetic wave underneath patch antenna from the feed network, in order to reduce mutual coupling [7]. However, there is a limitation on etch-able size of the cavities on the CSF. Antenna patches have to maintain a maximum distance of one unit wavelength apart to avoid grating side lobes. It then sets the etch-able size on CSF to be one unit wavelength between patches.

The distance between the edges of the antenna and cavity, *'a=1.8mm'* was proposed to be at least twice the substrate thickness, *'h'* due to the presence of fringing fields [4]. The CSF has to provide a rigid support to the whole suspended microstrip antenna array structure, that means there is a limit on the minimum size of the supporting beam, 'b=*1.2mm'*. Also, Gupta et al. [10] suggested that the spacing between the supporting structures, '*c=1.9mm*' needs to be at least three times that of the width of the conducting strip so that the propagation characteristics of SMTL remain unchanged.

III. RESULTS AND DISCUSSIONS

A 8 x 8-element array was designed, fabricated and tested, a photograph of this array is shown in Fig. 3. Silver epoxy is used to glue and seal the edges of CSF onto the ground plane. Good radiation patterns are obtained at the frequency of 38GHz, as shown in Fig 4. Similar results are observed on E-and H-planes where both have a 3dB beam-width of 5°. The H-plane has a symmetrical side lobe level of –

10dB, where E-plane has a slightly higher asymmetrical side lobe level of –7dB. We believe this is due to the contribution of radiation from the main feed line connected to the SSMA connector. E-plane has a better cross-polarization level of well below –28dB than the H-plane of –16dB.

The overall return loss of the antenna array (Fig. 5) has a –10dB bandwidth of 12GHz (30%). It is worth noting that the multiple dips in the measurement results could be due to the unevenness of the substrate surface. This has created differing cavity heights and subsequently changes the resonant frequency of individual patches. The measured antenna gain was measured at 38 GHz and found to be 21dB this is lower than anticipated. Further gain measurements above this frequency as well as the efficiency will be discussed in the full paper.

IV. CONCLUSION

The suspended microstrip antenna array has an excellent bandwidth (30%), good radiation patterns and is compatible with micromachined antenna technology employed elsewhere. Chemical etching of the CSF is proven here to be an extremely efficient methodology, which has greatly reduced the manufacturing cost and shortened the turnover time for the designs.

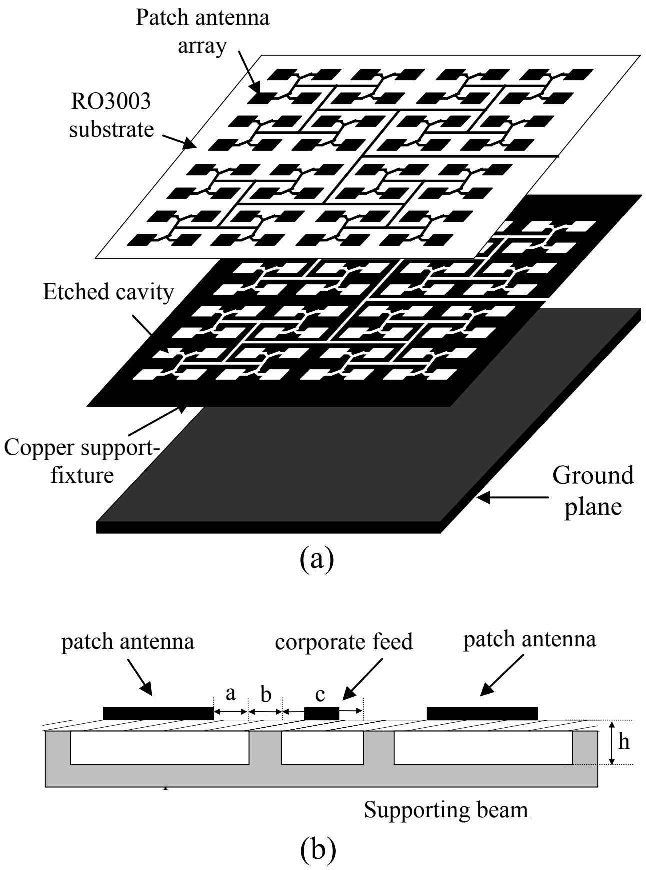


Fig. 1. (a) perspective view and (b) cross section view of the suspended patch antenna array, where *a*=1.8mm, *b*=1.2mm, *c*=1.9mm, *h*=0.57mm

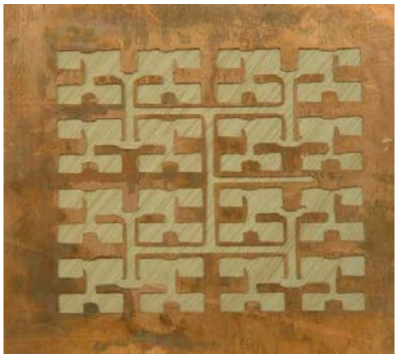


Fig. 2. Photograph of the micromachined copper support fixture (CSF).

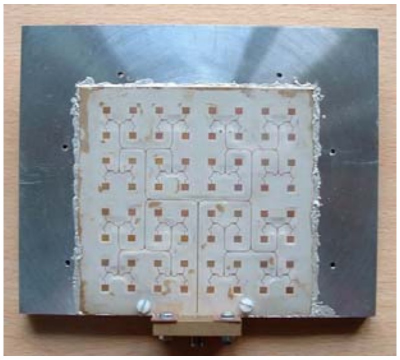
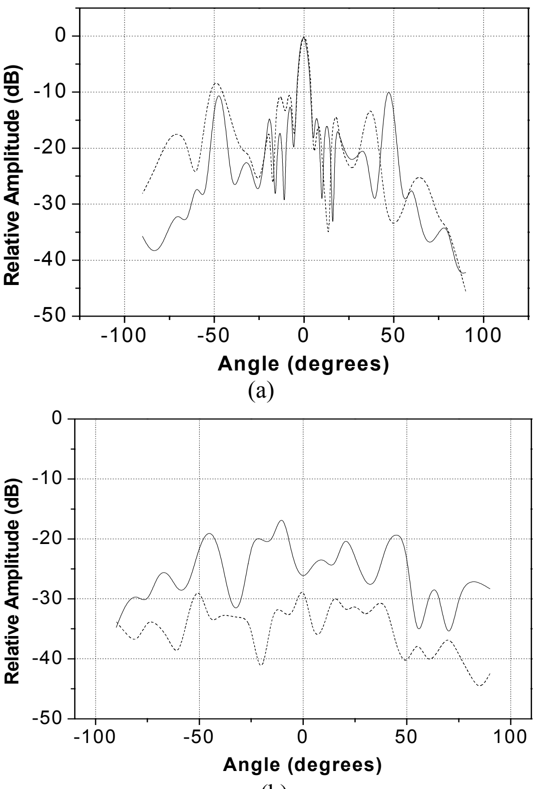


Fig. 3. Photograph of the complete suspended microstrip antenna array



(a)

(b)

Fig. 4. (a) H plane(—) and E plane(---) co-polarization radiation patterns (b) H plane(—) and E plane(---) cross-polarization radiation patterns of the 38GHz antenna array

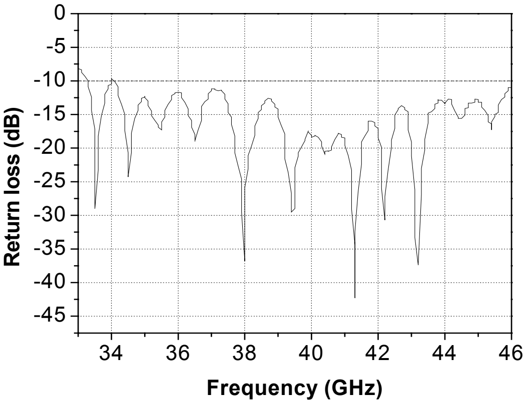


Fig. 5. Measured return loss of the of the 38GHz antenna array.

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