A DOUBLE LAYER MICROSTRIP RADIATING ELEMENT FOR HIGH GAIN FLAT ARRAYS

G. Biffi Gentili

Dipartimento di Elettronica e Telecomunicazioni, Università di Firenze
via S. Marta, 3 50139, Firenze
biffi@det.unifi.it

Abstract

A double layered microstrip antenna operating in the 25.5 to 27.5 GHz frequency band is here proposed and analyzed. The radiating structure is composed of four patches electromagnetically coupled to a microstrip line though a slot etched on the common ground plane separating the radiative layer from the feeding one. Essentially the antenna is structured as a square sub-array aperture whose side is slightly smaller than the free-space wavelength. The two thin soft dielectric layer are sustained and stiffened by a metallic sheet through the interposition of a nearly quarter-wavelength thick foam material. The metallic sheet performs also as a reflector to prevent the back radiation.
The proposed sub-array antenna is suitable for implementing high gain, low cross-polarization flat arrays for the emerging wireless applications.

1. INTRODUCTION

Several single layer microstrip sub-array structures have been recently investigated with the aim of fabricate simple and inexpensive planar arrays for LMDS [1] and satellite subscriber [2] applications. The single layer array, avoiding the problem of stacked fabrication, represents the most attractive solution in term of cost reduction. Nevertheless, its compliance to the ETSI standards [3] for point to multipoint fixed radio systems become problematic because the feeding network etched on the same side of the radiating patches increases the cross-polarization levels in the H plane.

A double layered structure inherently fulfills the separation between radiating elements and feeding lines, thus allowing a better control of the cross-polarization levels and an almost perfect symmetry of the radiation pattern in both E and H planes. Moreover, the two layer structure adds flexibility in designing the feeding and matching networks, due to the large space availability on the back layer side.

2. DESCRIPTION

This paper presents a novel two-layer radiating element, sketched in Fig. 1, where the non-radiating edges of four rectangular patches printed on the top substrate layer, are connected by a minimum length coplanar H shaped microstrip lines. Both dielectric layer are 0.397 mm thick and have a permittivity of 2.5. Patches are driven in phase by coupling the vertical connecting line to a feeding microstrip printed on the lower substrate layer, through a slot etched on the common ground plane. Slot feeding allows eliminating vias through the substrate, thus reducing the count of the manufacturing processes and then fabrication costs.

In view of its use in flat array antennas, the overall dimensions of the radiating element were maintained slightly below the free-space wavelength. The inter-element spacing was then reduced as little as possible to avoid an excessive coupling among the adjacent elements in the array rows ad columns. By cutting a short slot on each patch near the insertion point of the microstrip feeding line, the patch phase center was empirically adjusted to maintain the best symmetry and invariance of the beam with changing frequency.

3. NUMERICAL ANALYSIS AND RESULTS

A complete 2X2 sub-array with its feeding network, sketched in Fig. 2 and two 8X1 (horizontal) and 1X8 (vertical) linear sub-arrays where numerically analyzed using the MOM approach to study the effects of the coupling between the adjacent elements, which are spaced 0.96 λ in air.

Fig. 3 shows the computed input VSWR of the 2X2 sub-array, in the frequency range between 25.5 and 27.5 GHz.

It is worth noting that the impedance bandwidth for a VSWR < 2 was found in excess of 7.5% and a realized gain of 15.3 +/- 0.2 dBi was achieved, corresponding to an aperture efficiency better than 70% in the whole frequency band.

By removing the feeding network, the four-port sub-array was analyzed to calculate the inter-element coupling. The behavior of the scattering parameters versus frequency is shown in Fig. 4. As expected, the higher coupling arises among elements belonging to a column, while the lower is observed among crossed elements.

Figs. 5a and b depict respectively the E-plane and the H-plane patterns of the horizontal 8X1 and vertical 1X8 sub-arrays. The envelope of the side and grating lobes resulted quite higher compared to that of the corresponding uniform arrays of 8X1 and 1X8 patches. This growth may be attributed to the inter-element coupling effects as well as the radiation of the H shaped feeding networks. For instance, at +/- 60° from the boresight, an envelope growth of about 4 dB was observed.

The separation between the radiating and feeding structure allows to obtain very low (<-50 dB) cross-polarization (XP) levels in the ideal case of an infinite separating ground plane. With finite ground plane the XP level is however better than –30 dB.

A prototype of a 16x16 diamond array was fabricated and tested. The E-plane pattern measured at the lower 25.5 GHz frequency is depicted in Fig. 6. Despite the effects of the feeding network unbalances and ground-plane truncation, the measured pattern stays below the ETSI TS1 mask.

4. CONCLUSIONS

A novel wideband double-layered microstrip antenna suitable for implementing high gain, low cross-polarization flat arrays has been proposed. Compared to the single-layer implementation, the new antenna offers a better control of the cross-polarization level on both E and H planes and higher radiation efficiency. Grating and side-lobes can be maintained below the ETSI TS1 class mask, by employing a diamond array configuration. Because no metallic vias are used for connecting the radiating element with the feeding network, the manufacturing process can be greatly simplified.

REFERENCES

1. M. Clenet and L. Shafai, “Comparison of wideband single-layer microstrip array antennas for LMCS/LMDS applications”, *Millennium Conference on Antennas and Propagation*, Davos, Switzerland, 9-4 April 2000.
2. A.L. Zaghloul, E.C. Kohls and R.K. Gupta, “Flat antennas for mobile and wireless communications”, *Millennium Conference on Antennas and Propagation*, Davos, Switzerland, 9-4 April 2000.
3. ETSI EN 301 215-2 V1.2.1 (2000-11) specifications.

Work supported by Compel Electronic Spa, Coronate d’Adda (Mi), Italy

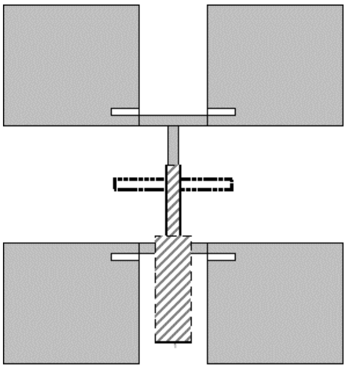

Fig. 1: Geometry of the proposed dual-layer four-patch radiating element.

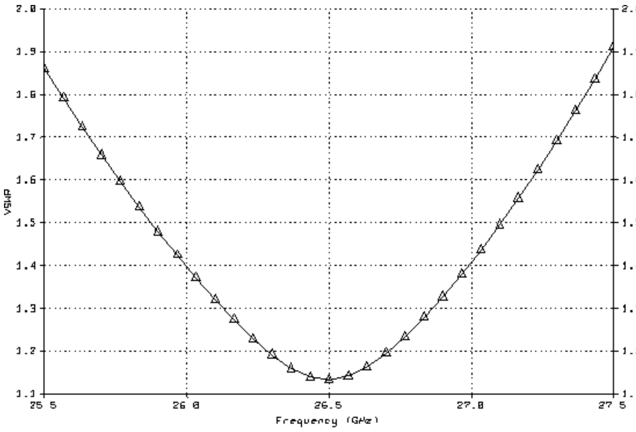

Fig. 2: Calculated input VSWR of the radiating element.

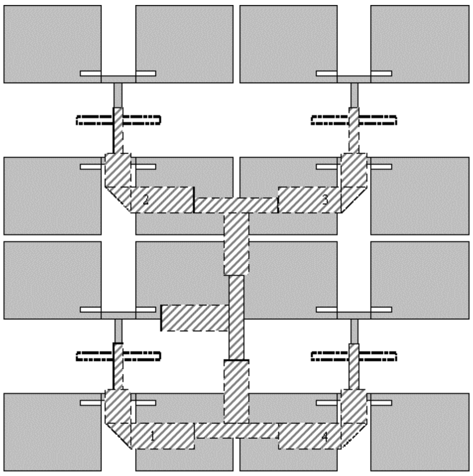

Fig. 3: Geometry of the 2X2 sub-array with the pertinent microstrip feeding network.

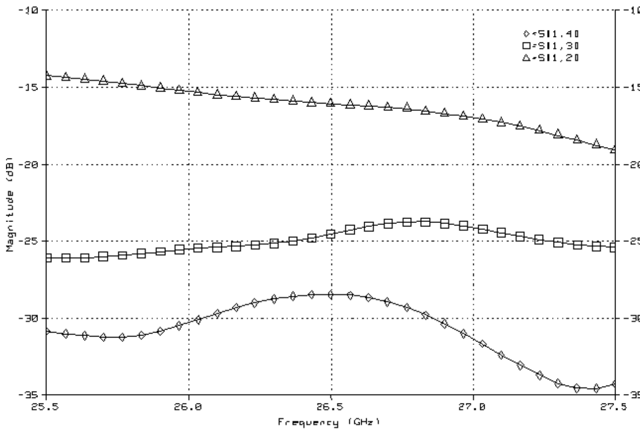

Fig.4: Inter-element coupling among the input ports of the 2X2 sub-array.

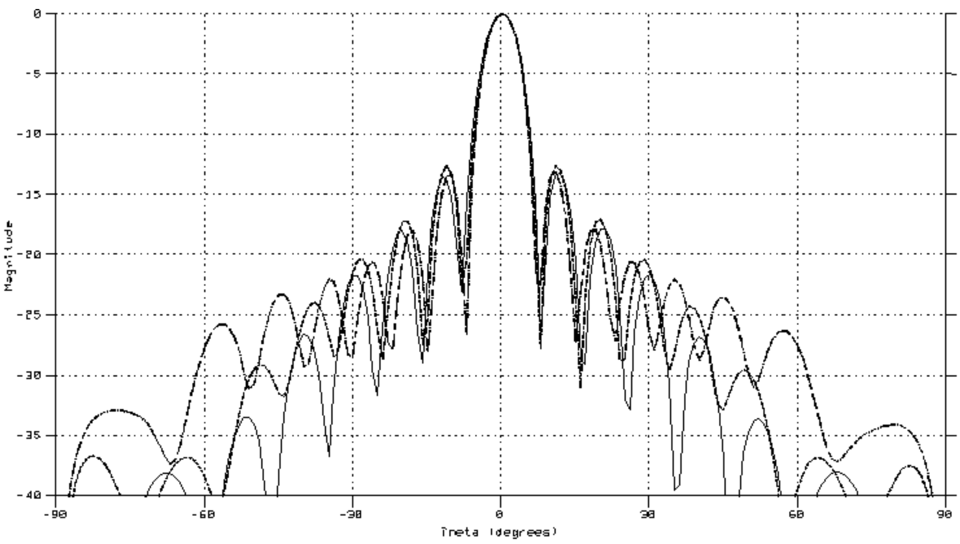

Fig. 5a: E-plane pattern of a 8 elements linear horizontal array. Continous line: 25.5GHz, dashed line 26.5 GHz, dashed-dotted line 27.5 GHz.

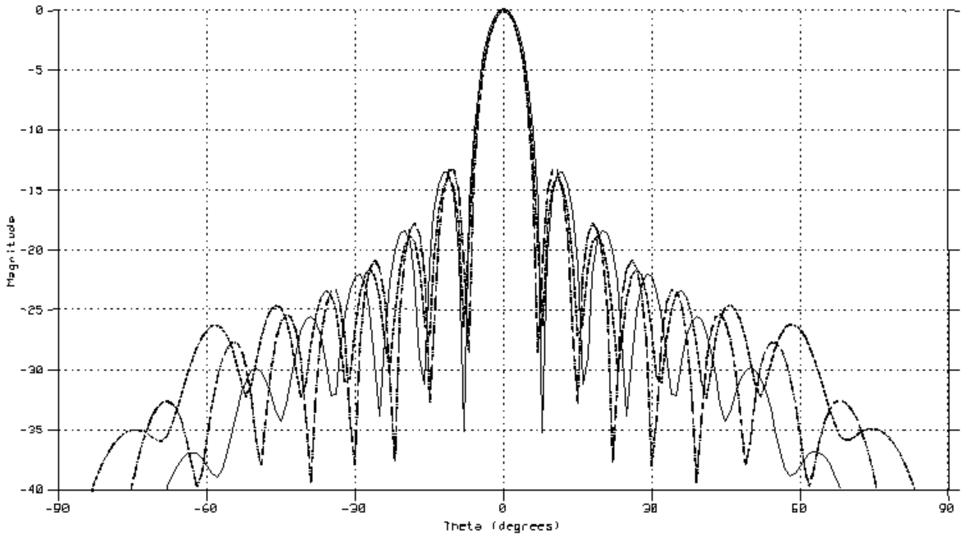

Fig. 5b: H-plane pattern of a 8 elements linear vertical array. Continous line: 25.5GHz, dashed line 26.5 GHz, dashed-dotted line 27.5 GHz

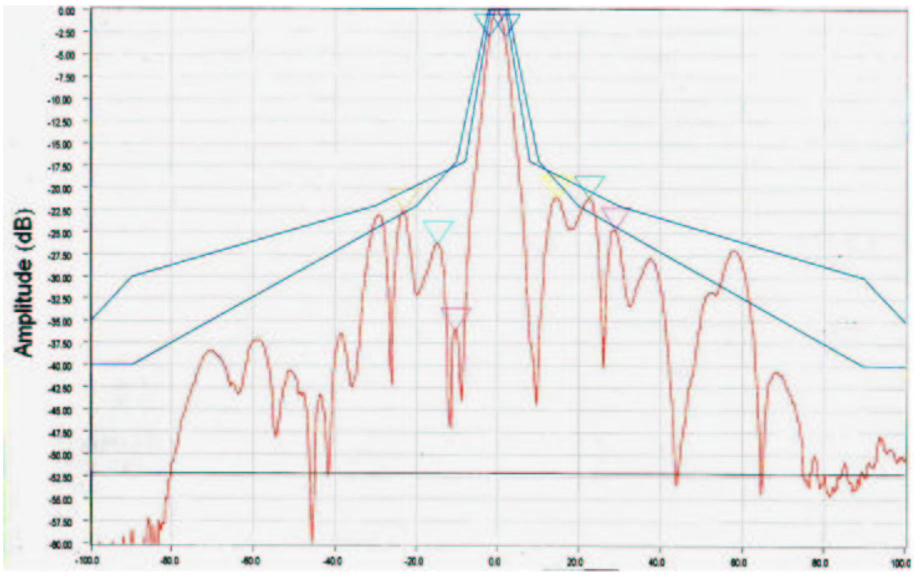

Fig. 6: Measured E-plane pattern of a 16x16 diamond array prototype at 24.5 GHz frequency