A MILLIMETER WAVE DUAL-POLARIZED, COPLANAR-WAVEGUIDE COUPLED PATCH ARRAY ANTENNAS FOR NEW GENERATION WIRELESS

Matteo Albani[1], Stefano Maci[2]

1 Dip. Fisica della Materia e Tecnologie Fisiche Avanzate, Univ. di Messina, salita Sperone 31, 98100 Messina

2 Dip. Ingegneria dell'Informazione, Univ. di Siena, via Roma 56, 53100 Siena

ABSTRACT

In this paper a dual-polarized coplanar waveguide coupled (slot fed) patch antenna printed on a single layer is presented, which is useful for millimeter-wave applications. The antenna is a good candidate for front-end receivers in indoor or local-loop short link wireless applications, particularly for broadband access to fixed networks, in the framework of 4th-generation mobile wireless communication systems. In particular, a prototype has been fabricated in an extremely reduced space (22 mm of diameter) with frequency range and bandwidth usable for Local Multiport Distribution Service (LMDS) systems.

INTRODUCTION.

The past decade has seen explosive innovation by the telecommunications industry as it strives to satisfy a worldwide appetite for greater bandwidth. Several developments are fueling this growth, the proliferation of the Internet, increased dependence on data and a global trend toward deregulation of the industry. Nowhere is the phenomenon more evident than in the quest to alleviate the local-loop bottleneck. This constriction occurs where local-area networks, which link devices within a building or a campus, join to wide-area networks, which cross countries and hold the Internet together. In this broadband millimeter wave wireless contest, the antenna front-end, assumes a fundamental role; nevertheless, low cost technology at this frequency is not well settled yet, thus requiring investigations and innovative solutions. Among the best antenna candidates for receivers, unless frequency do not increase too much, is still patch antenna, properly arranged to avoid low efficiency problems and strong coupling effects due to surface wave excitation.

PATCH ANTENNA TECHNOLOGY AT MILLIMETER WAVE FREQUENCY.

When increasing frequency, every possible cause of perturbation with respect to the ideal case can be fatal for polarization purity and spurious side-lobes enhancement. Consequently, the direct feed of a patch by a microstrip should be avoided. Alternative solutions as slot-coupling can be used to obtain separation between the feeding-network/circuitry plane and the radiating plane. This is commonly obtained using a two layers stack, where the two substrate are faced at opposite sides of a common ground plane. A coupling slot allows the feeding microstrip to excite a patch on the other side of the ground plane. At millimeter-wave frequency the use of multi-stratification should be preferably avoided for the difficulty and relevant cost to stick the substrates together without introducing losses.

A second, important aspect in the millimeter-wave contest is that the substrates used and the substrate thickness available on the market, can produce strong surface-wave excitation, with relevant problems of low efficiency and strong coupling. A certain number of paper has been

recently published on the use of bandgap-materials to reduce this latter. However, the bandgap technology, although promising, seems to be not still mature for low cost antenna market.
The aspects discussed before, together with the broad bandwidth requirement, are taken into account in the solution described next.

COPLANAR WAVEGUIDE FEED CAVITY-BACKED FOUR PATCH ARRAY.

The solution shown in Fig. 1 and 2 offers benefits in terms of separation between circuitry and radiation planes and SW suppression. Two four-element patch arrays are printed on the same substrate to realize orthogonal polarisations (Fig. 1). Each four-element array is surrounded by a perfectly conducting metallization which leaves thin radiating gaps around the patches (denoted by level “T”). The square metallization acts as a ground plane for the microstrip feeding network.

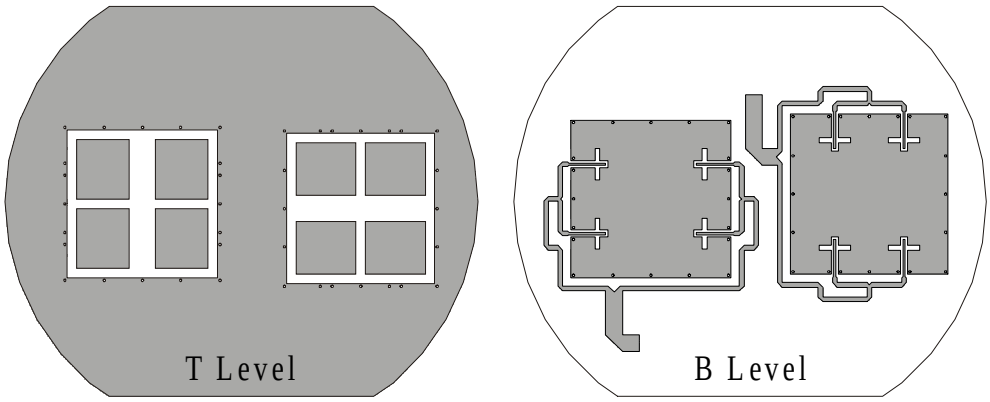


Fig. 1 T level (left) and B (right) level layout. In the T level two windows are opened in the microstrip ground plane to accommodate two 2x2 array of patches inside. In the B level the patches ground planes are connected to the T level ground plane by means of via holes. Each slot feeds the respective patch and is connected by a coplanar waveguide to the microstrip network.

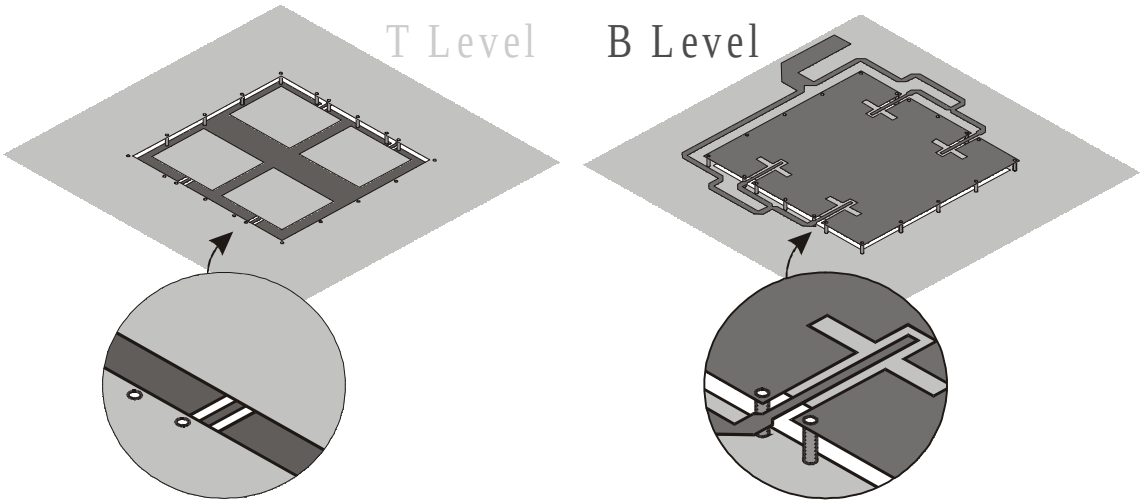
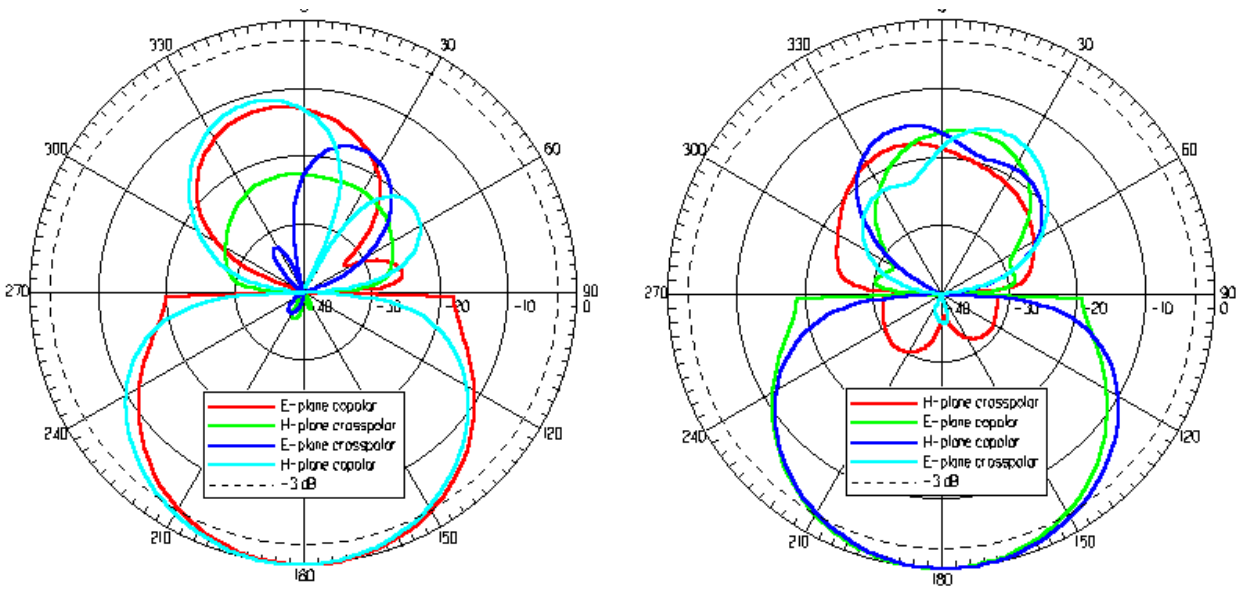


Fig. 2 3D view of the arrangement of a single antenna, the substrate is transparent, metallization on the T level (light gray) and on the B level (dark gray) is drawn. View from the T level (left) and view from the B level (right). Inside the circles the detail of the microstrip to coplanar wave guide transition is magnified.

This ground plane is short circuited to another square metallization (denoted by level “B”) on the other face of the dielectric slab by using λ/8 spaced via holes distributed all along the square perimeter, thus providing a sort of cavity behind the patches. To permit the pin connections the two ground planes at opposite sides are partially overlapped. A corporate microstrip beam forming network (BFN) printed at level B ensure an in-phase feeding for the four element. Each microstrip enter into the B ground plane with four transitions into coplanar waveguides (CPW). Each CPW termination incorporate a matched slot which is coupled to one of four T-level patch of the 2X2 array. Four patches in place of one are used to provide a circular symmetry to the antenna pattern, besides to increase the directivity.

A CAD at 30 Ghz have been performed with ENSAMBLE. For qualitative illustration, the computed radiation pattern for the left and rigth arrays are presented in Fig. 3. The 3dB beam width is 60° in both E and H plane at the center frequency; the simulations revealed a quite stable behaviour of the radiation pattern in all the input impedance bandwidth (12%).



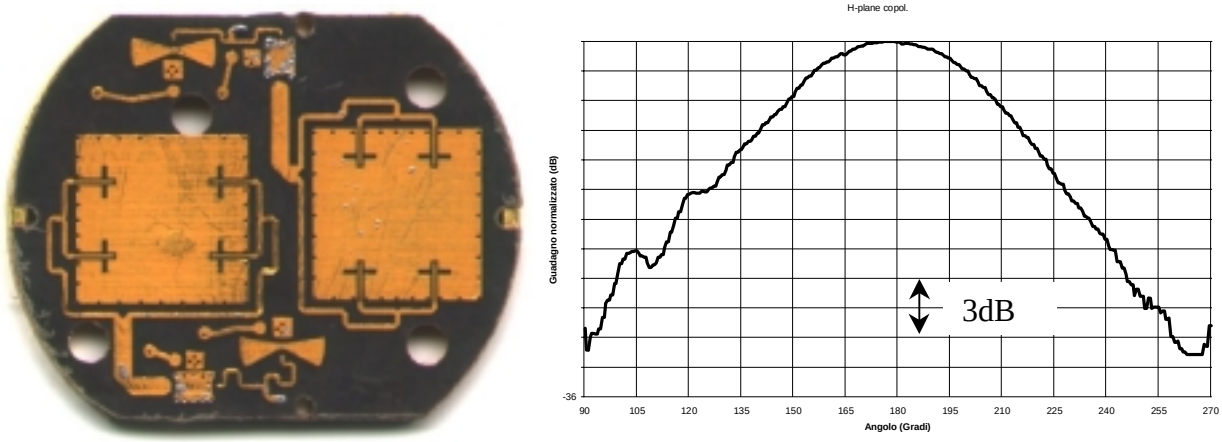
(a) **(b)**

Fig. 3 Simulated curves for the normalized radiation pattern at the center frequency **(a)** array at left in fig. 1, **(b)** array at right in Fig. 1

PROTOTYPE.

A prototype is realized at the operative frequency of 30 GHz with 12% bandwidth. The orthogonal linearly polarised 4-element sub-arrays has been arranged on a 22 mm board. A good de-coupling between the two polarization channels is obtained (about 30 dB). Each channel is provided by a PCM receiver constituted by cascading a Low Noise Amplifier (LNA) and a diode envelope-detector to provide a direct base band conversion. Other configuration have been designed, which incorporate IF conversion. Fig. 2 shows a photo of the prototype. The antenna gain is around 8 dB and the pattern exhibit an excellent circular symmetry around the boresight direction with a half-power beamwidth of 60°. The backlobe level, mainly due to the microstrip BFN radiation is less than –10dB.

All the struture has been simulated by a full-wave analysis by using ENSAMBLE. A photo of the prototype is shown in Fig. 4a, while Fig. 4b presents measurement of radiation pattern in the H-plane



(a) (b)

Fig. 4 Photo of the B level of the prototype. The diameter of the board is 22 mm. (b) Measured radiation pattern at 30 Ghz for the H-plane co-polar component (subarray at left).

CONCLUSIONS

A dual-polarized coplanar waveguide coupled (slot fed) patch antenna has been presented, which is useful for front-end receivers in indoor or local-loop short link wireless applications. A prototype has been fabricated in an extremely reduced space (22 mm of diameter). The particularity of the feed system allows the use of a single layer, while mainteining a physical separation between BFN an radiating plane. As a consequence the prototype exhibits attractive features of reduced cross-pol levels and cross-coupling between the two polarization channels, accompanied by low technological cost.