POLARIZATION AGILE MICROSTRIP PATCH PLANAR ARRAY ANTENNA

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Abstract: A polarization agile microstrip subarray is described herein. The subarray is composed of five square patches with a central aperture-coupled element feeding the outer patches through a straightforward network of resonant microstrip lines. By properly exciting the subarray, any kind of polarization of the radiated field can be accomplished. Preliminary numerical results obtained by the Method of Moments (MoM) are presented.

INTRODUCTION
As wireless communication systems evolve, service quality and capacity are of primary importance. To ensure reliable communication over a mobile radio channel, a system must overcome multipath fading, polarization mismatch, and interference. The trend towards low power hand held transceivers increases all of these challenges. Antenna arrays can improve the reliability and capacity of the systems through the use of diversity and adaptive beamforming techniques. Particularly, multi-polarized adaptive arrays can match the polarization of a desired signal or null an interferer having the same direction of arrival as the desired signal, if the two signals have different polarization states, thus increasing the quality of the link. Polarization agility can be obtained by aperture-coupled microstrip patch antennas, which have many desirable characteristics well described in the literature such as in Pozar[1]. However, one of the drawbacks of microstrip antennas at high frequencies is their significant losses dissipated in the feed network, especially for large arrays. In this respect, series-fed arrays, where the length of feed line runs is substantially reduced, have an advantage over corporate-fed arrays and experience lower losses in their feed network. Two-dimensional arrays are usually implemented by a series or parallel feeding of several linear arrays. Notwithstanding, planar subarrays with a central patch could be very advantageous since they can provide pencil beam radiation patterns with low side lobes as demonstrated in Legay et al.[2] and Duffy et al.[3], where two similar single-polarization microstrip patch planar subarrays with probe and slot feed, respectively, are described.

In this contribution, a multi-polarized aperture coupled microstrip patch subarray is proposed to be used as the basic element of large polarization agile array antennas with simple feeding networks. Indeed, the proposed antenna element shows quite good performance in terms of gain and cross-polarization level which make it suitable to be employed also in a stand-alone configuration.

ANTENNA CONFIGURATION AND DESIGN
The antenna substrate structure consists of two layers of low-loss dielectric material with $\varepsilon_r = 2.2$. The geometry of the antenna is shown in Fig. 1. The radiating part includes five microstrip square patches etched on the upper substrate, whose thickness is 2.286 mm. The central patch is coupled to a pair of 50 Ohm microstrip lines, running on the bottom 1.143 mm thick layer, through two centred crossed slots etched on the middle ground plane and fed offset. This solution has proved to yield a more symmetrical excitation of the subarray and, thus, improved radiation characteristics with respect to two off-centre separated orthogonal slots. Microstrip T line sections are used to propagate a resonant standing wave to feed the surrounding patches. Specifically, these latter elements are connected to the central patch by the pair of their outer corners so as to realize a dual feeding arrangement. A dual corner feed has been adopted for the patches since it provides higher isolation than the standard dual edge feed as shown in Zhong et al.[4]. Each connecting microstrip line is one wavelength long on the whole to deliver an excitation signal to the external patches with phase equal to that of the central patch. The narrow width of the connecting microstrip lines, corresponding to a 100 Ohm impedance, minimizes the discontinuity effects at bends and at the corners of the central patch.

The excitation amplitude for the outlying patches is controlled by the impedance levels of these elements and the central patch. The input impedance of the outlying corner-fed patches can be estimated through the closed form expression derived in Lim et al.[5]. As a result, the loading effect of the outer patches can be included in the design and impedance matching of the central patch by using a full-wave approach in conjunction with basic circuit theory as in Duffy et al.[3]. It is noted that the central patch turns to be smaller than the external ones due to the loading of the surrounding elements which tend to increase its resonance frequency. Impedance matching of the antenna is performed by tuning the length of the feed line ending stubs and the size of the...
cross-shaped coupling slot. The above antenna geometry allows to obtain any kind of linear or circular polarization of the radiated field by appropriately driving the two input ports. Particularly, quadrature excitation of the feed lines results in circularly polarized radiation whose sense is determined by the lead-lag phase relationship between the aperture excitations.

![Fig. 1. Bottom view of the antenna showing the patches, the cross-shaped slot and the two feed lines.](image)

**PRELIMINARY NUMERICAL RESULTS**

The element has been modelled by a full-wave MoM approach capable of completely accounting for the dielectric layers and the ground plane and its performances have been analysed around the design frequency which is 3 GHz. The return loss and the isolation at the inputs of the antenna are shown in Fig. 2 and indicate an operational range between 2.965 and 3.03 GHz corresponding to a 2.2 % bandwidth (VSWR ≤ 2). It is noted that isolation is a little poor due to the close proximity of the two feed lines, the discontinuity associated with the bends and the unbalanced feed of the slots.

![Fig. 2. Return loss and isolation at the input ports of the antenna calculated by the MoM around the design frequency.](image)

However, by virtue of the antenna substantially symmetrical arrangement, quite low cross-polarization levels are observed. The principal plane radiation patterns calculated for the horizontal polarization at the design frequency are plotted in Fig. 3 with the cross-polar components. The maximum cross-polarization level is −22.8 dB at the design frequency. This result slightly worsens at the upper bound of the impedance bandwidth (−18.7 dB) while it improves at the decreasing of the frequency. The calculated gain of the antenna is about 13
dB whereas the back radiation lobe is –22 dB. Similar results are obtained for the vertical polarization. Furthermore, even for the circular polarization the same cross-polarization level and gain are found. It is noticed that better cross-polarization performances can be obtained by feeding the slots in a balanced configuration with two symmetric feed lines, which requires the adoption of a more complicated multilayered structure for the feed similar to those proposed in Edimo et al.[6] and Yamazaki et al.[7] for a single patch.

CONCLUDING REMARKS
A new compact array antenna with a central aperture-coupled patch distributing the power to four surrounding dual corner-fed patches by a simple network of microstrip lines has been presented. The antenna can operate either in linear or circular polarization and exhibits good gain and enough low cross-polarization level which make it suitable for being used both in a stand-alone configuration and as the basic component of large planar arrays with the advantage of reduced complexity feeding networks. The demonstration of the use of this subarray in larger array antenna is presently being considered.

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REFERENCES