# Simple broadband dual-polarized aperture-coupled microstrip antenna

*Sami Hienonen, Arto Lehto, Antti V. Räisänen
Radio Laboratory, Helsinki University of Technology,
P.O.Box 3000, FIN-02015 HUT, Finland.

## I INTRODUCTION

Aperture-coupling has proven to be a reliable and a robust feeding technique of microstrip antennas [1, 2]. The lack of galvanic contacts makes it a preferable way to realize the feeding of large printed antenna arrays. Moreover, it is suitable for wide-bandwidth dual-polarization designs [3]. These designs, however, utilize two stacked microstrip patches and thus, are more expensive to produce than single-patch designs. In addition, most designs are not suitable for integration of active circuits.

This paper presents a simple broadband dual-polarized microstrip antenna with only three layers. The input impedance bandwidth (VSWR < 2) of 25 % is achieved with double resonance technique, in which the resonant frequencies of the patch and the coupling slot are tuned near to each other [1]. Proper positioning of the coupling slots and the use of a thin, medium permittivity substrate results high isolation (> 40 dB) between the ports and thus acceptable cross polarization (better than –20 dB).

The geometry, return loss, and the isolation of a single antenna element and the radiation pattern of a four-element linear array are presented. These antennas were designed for the European DBS-band 10.70–12.75 GHz.

## II DESIGN OF THE ANTENNAS

One coupling slot is placed at the middle of the patch and the other slot at the edge of the patch [4]. This configuration results high isolation between the ports because the center slot couples via magnetic field and the edge slot via electric field. The antenna has low cross polarization and as a trade-off with the simple structure somewhat asymmetrical radiation pattern and high feeding losses. This kind of antenna element is intended to be integrated with active circuits so that the feeding losses do not degrade the antenna array performance dramatically.

0-7803-5639-X/99/$10.00 (c)1999 IEEE

The antenna is composed of three layers: the feeding line substrate (Rogers RO4003, $\varepsilon_r$ = 3.38, $h$ = 0.20 mm), a spacer foam (Rohacell HF51, $\varepsilon_r$ = 1.07, $h$ = 1.9 mm) and a patch supporting substrate (FR4, $\varepsilon_r$ = 4.3, $h$ = 0.16 mm), see Fig. 1. In addition, a thick back plane of metal was used to support the antenna structure. The geometry and the most important dimensions of the antenna are shown in Fig. 2.

In order to attain the desired bandwidth, a thick foam layer has to be used which in turn requires strong coupling from the feeding lines to the patch. This is achieved with large coupling slots. The length of the slots is reduced by using a thin, medium permittivity ($h$ = 0.20 mm, $\varepsilon_r$ = 3.38) substrate and by shaping the slots. The shifting of the center slot creates cross polarization at the angles of ±40° from broadside direction, but has a minor effect on the input impedance.

A four-element linear array was constructed using these elements. The elements are placed so that the center slots are parallel and the edge slots perpendicular to the array. The element spacing is 21 mm (0.82λ @ 11.725 GHz) and they are fed with a corporate-series network. Power dividers are simple T-junctions with quarter-wave transformers.

## III SIMULATIONS AND MEASUREMENTS

The antennas were designed using HP EEsof's Momentum method of moments software. Input impedances of the single antenna element are shown in Fig. 4 and Fig. 5. Dashed circle corresponds to VSWR = 2. The phase shift and the loss due to the feed line are extracted from the results. Time domain filtering was used in the input impedance measurements because the quality of the coaxial-to-microstrip transition was poor. The transition itself had return loss in the order of 7 dB. However, it is strongly believed that the filtered results show the actual input impedance since there was a long microstrip line feeding the patch and the simulations conform with the measured results. In addition, a similar antenna was constructed with a different feeding substrate and those measurements show close correspondence with the simulations.

The input impedance bandwidths (VSWR = 2) of ports 1 and 2 are 24 % and 25 %. Measured values show weaker coupling than predicted, which is due to mechanical tolerances. Also, center frequency is shifted +0.6 GHz. Isolation between the ports is better than 40 dB over the whole frequency band 10.70–12.75 GHz, see Fig. 3.

Radiation patterns were measured on two planes, which are here called array and element plane. The array plane designates E-plane for port 1 and H-plane for port 2. Element plane is perpendicular to the array plane. Array plane radiation patterns of the four-element array are shown in Fig. 6 and Fig. 7 ($f$ = 11.725 GHz). The cross-polarization level within 3 dB beamwidth is at least

24 dB below the main lobe level. Radiation patterns at 10.70 GHz and 12.75 GHz were also measured and they show somewhat more asymmetric copolar patterns due to the corporate-series feed. Cross-polarization level is better than –23 dB at all frequencies in the array plane. In the element plane the cross polarization remains better than –20 dB at all frequencies, except at one frequency in the direction of –44°. In an array configuration this cross-polarization level of –16 dB is likely to improve to –20 dB.

## IV CONCLUSIONS

A simple and broadband dual-polarized antenna element is designed by combining previous designs [1,4]. The structure of the antenna is suitable for low-cost active antenna arrays and shows acceptable radiation characteristics especially for commercial applications.

## REFERENCES


[1] Zürcher, J.-F., Gardiol, F.E. *Broadband Patch Antennas*. Norwood 1995, Artech House, Inc., 209 p.

[2] Croq, F., Pozar, D.M. Millimeter-wave design of wide-band aperture-coupled stacked microstrip antennas. *IEEE Transactions on Antennas and Propagation*. 39(1991)12, pp. 1770–1776.

[3] Brachat, P., Baracco. J.M. Printed radiating element with two highly decoupled input ports. *Electronics Letters*, 31(1995)4, pp. 245–246.

[4] Valmu, H. L-band dual-polarized microstrip patch antennas for an airborne aperture synthesis radiometer. *URSI XXII Convention on Radio Science*, Oulu, Finland, Nov. 20–21, 1997, pp. 33–34.


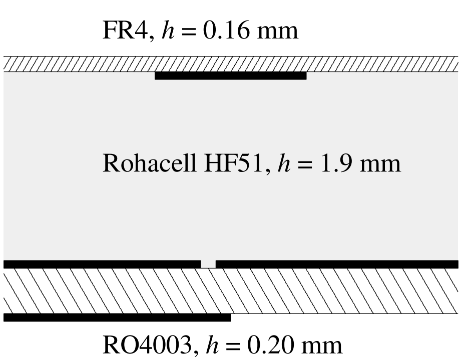


Fig.1. Layers of the antenna.

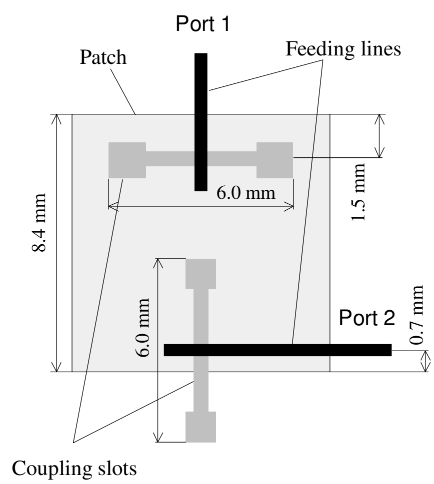


Fig. 2. Geometry of the antenna.

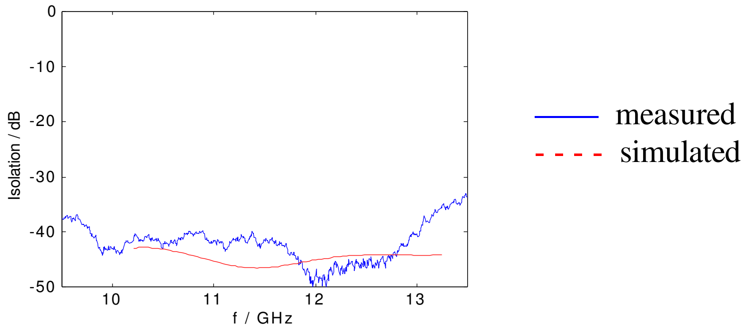


Fig. 3. Isolation between ports 1 and 2.

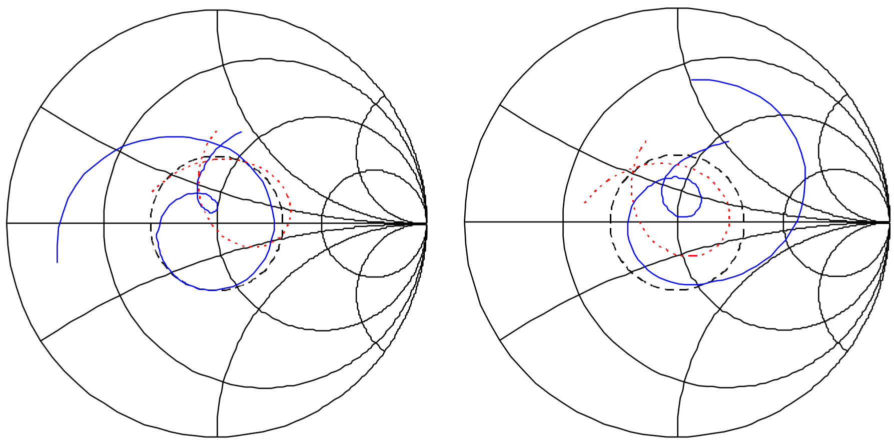

Fig. 4. Input impedance of port 1 (on the left) and port 2 (on the right). —— measured, $f$ = 9.5–13.5 GHz, ······ simulated, $f$ = 10.20–13.25 GHz. Dashed circle indicates VSWR = 2.

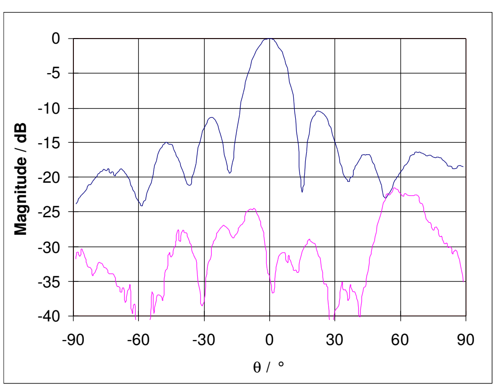


Fig. 6. Copolar and crosspolar E-plane radiation pattern of the 4×1 -array. Port 1. $f$ = 11.725 GHz.

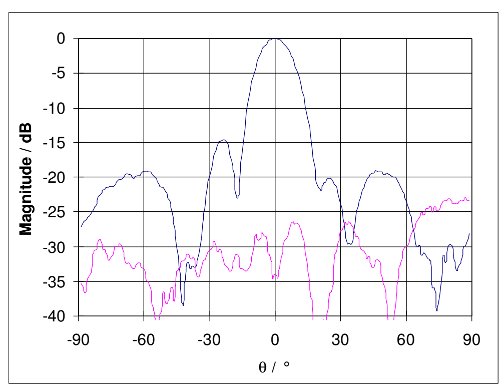


Fig. 7. Copolar and crosspolar H-plane radiation pattern of the 4×1 -array. Port 2. $f$ = 11.725 GHz.

0-7803-5639-X/99/$10.00 (c)1999 IEEE