European Conference on Antennas and Propagation 2010, 12-16 April 2010, Barcelona

A HIGH GAIN PLANAR ANTENNA WITH IMPROVED BANDWIDTH USING A FABRY-PÉROT RESONATOR

M. Mirbach[1] and W. Menzel[1]
[1]Institute of Microwave Techniques, University of Ulm, PO Box, D-89069 Ulm, Germany,
michael.mirbach@uni-ulm.de, wolgang.menzel@uni-ulm.de

Introduction: A Fabry-Pérot cavity (FPC) antenna consists of a radiating element placed between a metal ground plane and a partially reflective surface (PRS), which serves as a radiating aperture [1,2,3]. Multiple reflections of electromagnetic waves between the two surfaces lead to resonances and therefore to a high gain, however at the expense of bandwidth.

Recently, different ways for improving the operational bandwidth have been examined. For instance, thinned arrays of microstrip patches have been used to feed a FPC antenna [4]. This allows the application of a PRS with reduced reflectivity, leading to larger bandwidths while still preserving a high gain performance due to the antenna's array characteristics.

Another method for bandwidth enlargement focuses on the design of the PRS. By adjusting the phase of the PRS reflection coefficient, the resonance condition of the cavity can be satisfied in a wider range of frequencies [5]. Such an optimized reflection response can be realized by a double layer PRS design [6].

In this work, a broadband FPC antenna structure featuring both previously mentioned approaches – the array antenna feed and the double layer PRS – has been designed, fabricated, and measured. Furthermore, a new design of an optimized PRS consisting of only one substrate layer has been examined.

Antenna Design: Fig. 1 illustrates the structure of the proposed antenna. It is fed by a 2x2 array of microstrip patches attached to the circular metal ground plane with a diameter of 133 mm. The distance between the PRS substrate and the ground plane is about 12 mm, which corresponds roughly to the free space wavelength of the chosen design frequency of 24 GHz. The spacing between the patch antennas is 33 mm, i.e. 2.64 λ_0.

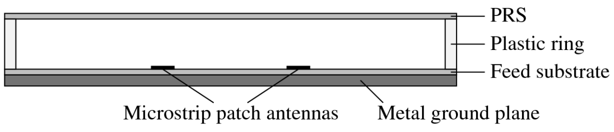

Fig. 1: Structure of the proposed antenna.

Double layer PRS. In analogy to [6], the PRS is formed by two substrate layers of distance h, both metalized with different periodic structures of square patches. In Fig. 2 the unit cells of the periodic structures as well as a cross section of the PRS are illustrated. For stability reasons the two substrates are glued on the top and bottom face of a round slice of acrylic glass. Fig. 3 shows the simulated values of the PRS reflection coefficient in magnitude and phase. In the range between 23.5 GHz and 24.5 GHz the phase is increasing with frequency. Thereby, when using this PRS as a boundary of the resonant cavity, the phase difference caused by a slight frequency shift can be compensated. The desired resonance can hence occur in a wider range of frequencies, leading to an enlargement of the FPC antenna bandwidth.

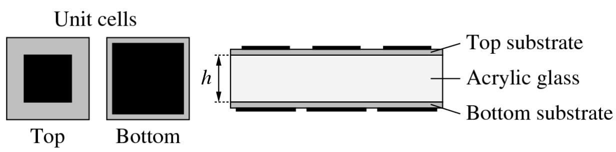

Fig. 2: Unit cells and cross section of the double layer PRS structure.

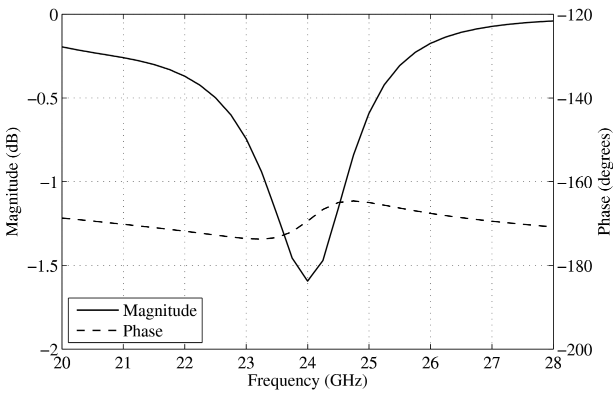

Fig. 3: Simulated reflection coefficient (magnitude and phase) of the double layer PRS.

New single layer PRS. Since the desired slope in the reflection phase of the double layer PRS is a result of two different resonances, it should be possible to obtain a similar reflection response by placing two resonant elements on a single layer substrate. The advantage of such a structure would be a less complex fabrication and a reduction of the antenna height.

Full-wave simulations were performed in order to find an adequate metalization pattern. The best results could be achieved with a substrate metalized with resonant slots on the top and with resonant strips on the bottom of the substrate as depicted in Fig. 4. The simulation results of the new structure's reflection coefficient are presented in Fig. 5 showing a similar behavior as the corresponding curves of the double layer PRS. Therefore a broadband performance of a FPC antenna using the new substrate can be expected.

Fig. 4: Unit cells and cross section of the new single layer PRS structure.

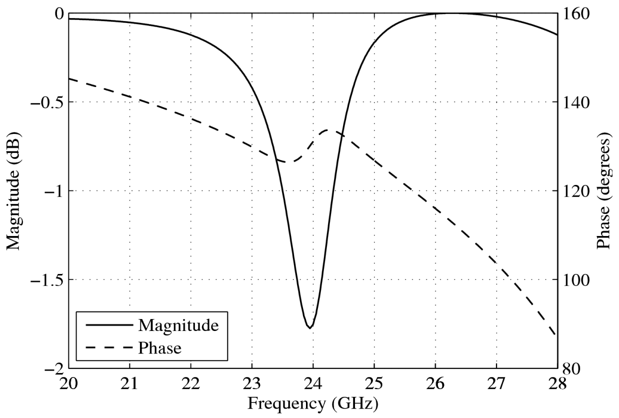

Fig. 5: Simulated reflection coefficient (magnitude and phase) of the new single layer PRS.

Results: The radiation patterns and the gain of the described antenna have been measured at different frequencies for both setups using either the double layer PRS or the single layer PRS. For comparison, also an antenna with a single metallization layer PRS similar to [4] has been built. Fig. 6 shows the gain over frequency of the two new antenna configurations measured in steps of 100 MHz. The 3 dB bandwidths of the antenna gain are 800 MHz and 1 GHz for the double layer setup and for the single dielectric layer setup, respectively. However, the maximum gain of the latter configuration is 22.1 dBi and is thus lower than the gain of the double layer structure with 23.8 dBi. This gain difference might be caused by losses occurring in the PRS substrate, which has to be further examined. Compared to the conventional setup with single metallization, the bandwidth could be improved by 60% and 100%, respectively.

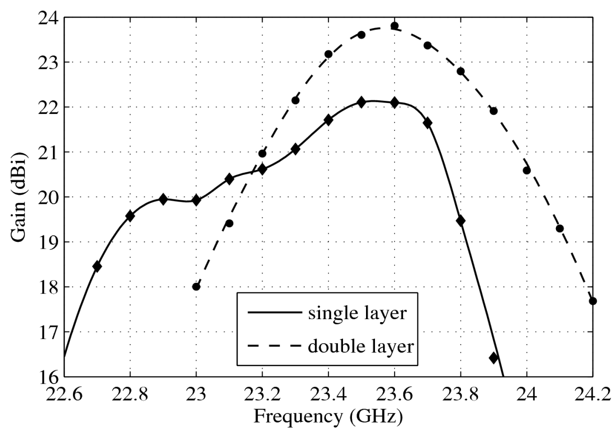

Fig. 6: Measured gain of the antenna with single layer PRS and double layer PRS.

Fig. 7 shows the radiation patterns measured with the antenna covered by the single layer PRS. The beam widths are 8.7° and 8.6° in the H-plane and in the E-plane, respectively, equivalent to an effective antenna aperture diameter of about 88 mm. The side lobe levels are -12 dB in the H-plane and -14 dB in the E-plane. The measurements of the antenna using the double-layer substrate result in similar radiation patterns.

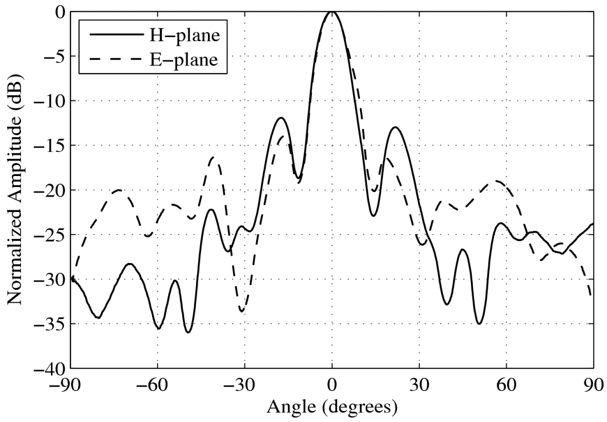

Fig. 7: H-plane and E-plane radiation patterns of the antenna with the new single layer PRS at *f*=23.5 GHz.

Conclusion: A compact Fabry-Pérot cavity antenna for 24 GHz, fed by a thinned array of microstrip patches has been examined. In order to increase the antenna bandwidth, a double layer and a single layer partially reflective surface have been designed using full-wave simulations and their measurement results have been compared. With the double layer substrate a maximum antenna gain of 23.8 dBi and a bandwidth of 800 MHz has been achieved. Using the single layer PRS the bandwidth could be enlarged to 1 GHz at the expense of a reduced gain of 22.1 dBi. Compared to a conventional single layer setup the bandwidth could be improved by 60% and 100%, respectively. Both antenna configurations showed a highly directive performance with reasonably good side lobe levels between -14 dB and -12 dB.

References

[1] D. R. Jackson, N. G. Alexopoulos; Gain enhancement methods for printed circuit antennas, *IEEE Trans. Antennas Propagat.*, vol. AP-33 (1985), pp. 976 – 987.

[2] H. Ostner, J. Detlefsen, and D. R. Jackson, "Radiation from one-dimensional dielectric leaky-wave antennas," *IEEE Trans. Antennas Propagat.*, Vol. AP-43, pp. 331 – 339.

[3] Thevenot, Marc, Cyril Cheype, Alain Reineix, and Bernard Jecko: Directive photonic-bandgap antennas. *IEEE Transactions on Microwave Theory and Techniques*, 47(11):2115–2122, 1999.

[4] R. Gardelli, G. Donzelli, M. Albani, and F. Capolino: Design of patch antennas and thinned array of patches in a fabry-perot cavity covered by a partially reflective surface. In *EuCAP 2006*, Nice, France, 2006.

[5] A. P. Feresidis and J. C. Vardaxoglou: High gain planar antenna using optimised partially reflective surfaces. *IEE Proceedings - Microwaves Antennas Propagation*, 148(6):345-350, 2001

[6] A. P. Feresidis and J. C. Vardaxoglou: A broadband high-gain resonant cavity antenna with single feed. In *EuCAP 2006*, Nice, France, 2006.