Half-wave stacked patch antenna with dielectric feed

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Abstract

A half-wave stacked patch antenna was developed for sufficient bandwidth and cross-polarization separation for the wideband radio channel sounding. To further reduce the cross-polar level, a concept of dielectric feed was developed, which electromagnetically resembles the aperture feed. The increase of the cross-polar discrimination was 2.6 dB in the prototype.

1. Introduction

When a good separation of the two polarizations is required in a patch antenna element, as is the case in mobile basestations utilizing polarization diversity and in radio channel sounding, it is necessary to use a half-wave patch antenna [1]. A probe feed was chosen because of the simplicity of construction. When using probe feed, the probe should be as short as possible. However, to have a wide bandwidth, a thick patch antenna has to be used [2], which typically leads to a long probe. A way to increase the bandwidth without extending the probe is to add resonators, for example by adding another patch on top of the main patch, to form a stacked patch antenna.

The goal of this study was to maximize the *XPD* of the dual polarized stacked patch antenna with probe feed. The research was carried out by making FDTD simulations and building prototypes. The voxel size in the simulations was $\lambda/140$ at the center frequency of 2.15 GHz in order to achieve accurate impedance estimations. The measurements of the prototypes were performed in the IRC/Radio Laboratory of Helsinki University of Technology.

2. Antenna structure

The antenna is made of two half-wave patches on top of each other above the ground plate, Figure 1. The patches are made of 0.5 mm thick copper plate. The ground plate dimensions are 100x100 mm^2.

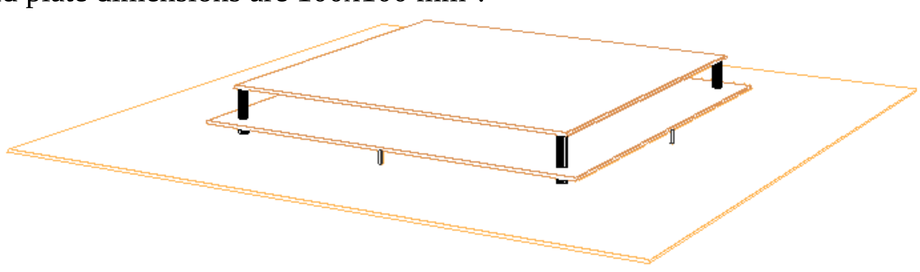

Figure 1. Antenna structure: chip capacitors in the middle of the patch edge, supports in the corners.

3. Dielectric feed

The antenna probe feed is essentially the center conductor of the coaxial cable where the outer conductor is cut at the level of the ground. The capacitor between the center conductor tip and the lower patch of the stacked patch antenna is mainly used as a matching capacitor [3]. Furthermore, in our design the capacitor is physically so large that it reduces the length of the probe, thus reducing the cross-polarization. In other words, the idea of the matching capacitor was developed to a dielectric coupling system, electrically resembling the aperture coupled feed [4].

4. Half-wave stacked patch antenna with dielectric feed

The dimensions of the antenna are shown in Figure 2 and a close-up of the feed is shown in Figure 3. The basic structure is the stacked patch antenna, and the feed connector is same, but the probe is as short as possible, and a substrate with metal on top and bottom surfaces forms the feeder dielectric feed, or feeder capacitor.

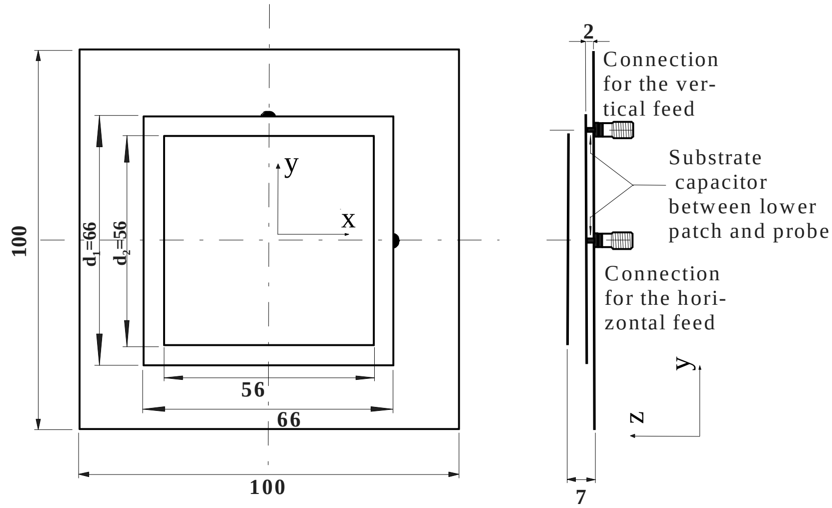

Figure 2. Half-wave stacked antenna with dielectric feed. Dimensions in mm. The active feed is in y-axis in the radiation pattern plots. Therefore the E-plane is in yz-plane, and the H-plane is in xz-plane. The angle is the deviation from the z-axis, and the angle is positive towards the positive y-direction in E-plane and towards the positive x-direction in H-plane.

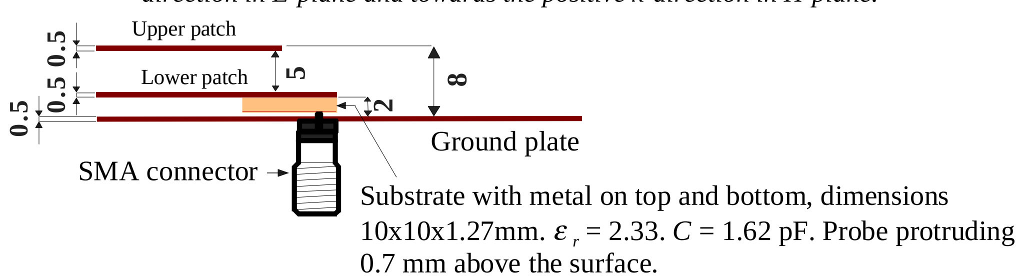

Figure 3. Enlargement of Figure 2 at the feed point showing the structure of dielectric feed

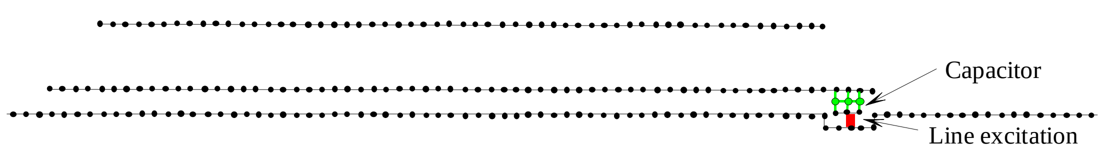

Figure 4. The FDTD grid pattern. The figure is a cross-section cut along the central y-line, the ground plate only partially shown. The black lines represent y-directional PEC lines and the dots represent the x-directional PEC lines. The green lines and dots represent the insulator in the capacitor in z- and x-axis, ε_r = 100, length of capacitor edge 2 mm. C = 1.77 pF. The grid is 1 mm.

The dielectric feed was implemented by dielectric plate placed between the lower plate of the antenna and the top of the center of the coaxial cable. The dimensions of the plate are 10x10x1.27mm $\varepsilon_r = 2.33$. In the simulation the size of the plate was 2x2x2mm, and $\varepsilon_r = 100$. The high permittivity is possible in the simulations. The low permittivity in the prototype was determined by the available material.

The dimensions of the lower patch were 64x64 mm^2 in the simulation, because that produced the same impedance match as the 66x66 mm^2 patch in the prototype. This is within the step size in the simulations using 1 mm voxel cube because due to the symmetrical structure the step size in the horizontal dimensions is 2 mm.

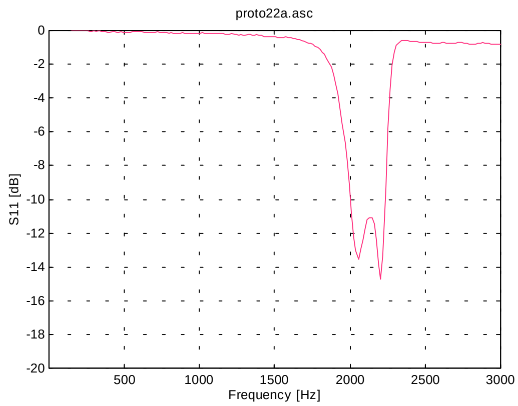

Figure 5. Measured reflection coefficient.

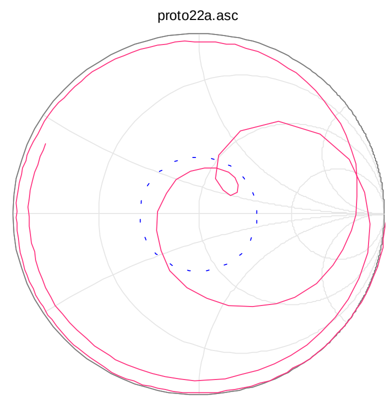

Figure 6. Measured impedance on Smith chart.

The bandwidth with L_{ret} = 10 dB is 11.2%, Figure 5. From Figure 6 one can conclude that the matching of the double resonance is not perfect, because the loop does not go around the center of the Smith chart, and bandwidth can be increased if necessary.

Figure 7 and Figure 8 show the radiation patterns of the antenna in E-plane and H-plane. In E-plane the *XPD* > 20 dB between -72°...+41° scanning angles. In H-plane *XPD* > 20 dB between -57°...+78° scanning angle. This exceeds the requirements of the the antenna (*XPD* > 20dB between ±30°). The gain is 6.6±1 dBi and the 3 dB beamwidth is 60° in E-plane and in 69° H-plane.

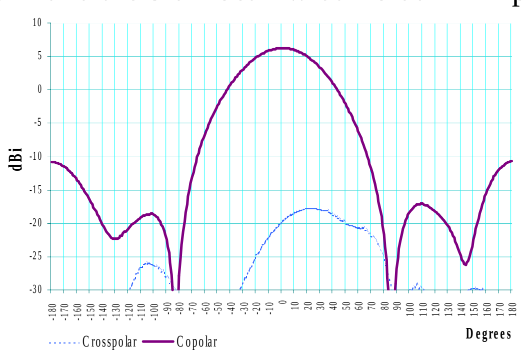

Figure 7. Measured radiation pattern in E-plane. The antenna has two dielectric feeds, and the feed for the other polarization is terminated with a 50Ω load The maximum cross-polarized level is -25.0 dB below copolar level in the z-direction. XPD>20 dB between -72°...+41° scanning angles.

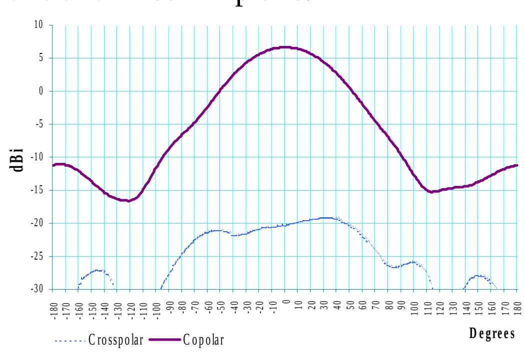

Figure 8. Measured radiation pattern in H-plane. Dielectric feeds, and the other feed is terminated with a 50Ω load The maximum cross-polarized level is –25.6 dB below copolar level of the z-direction. XPD>20 dB between -57°...+78° scanning angles

The dielectric feed decreases the maximum cross-polar level by 2.6 dB in the measured two similar antennas, Figure 8 and Figure 9. The prototype with dielectric feed in Figure 8 is 3.6 dB better than the simulated one in Figure 10. The probe-fed prototype in Figure 9 is 2 dB better than the simulated one in Figure 11. The dielectric feed decreases the maximum cross-polar level by 1 dB in the theoretical simulation for two otherwise similar antennas, Figure 10 and Figure 11.

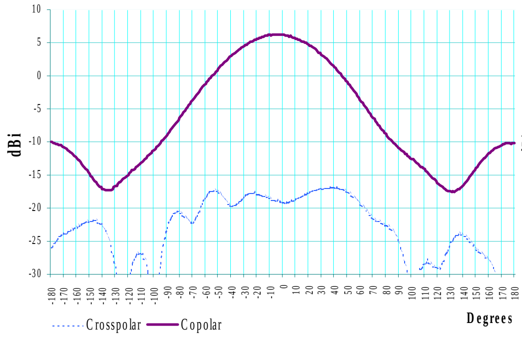

Figure 9. Measured radiation pattern in H-plane, ordinary probe feed. The other feed is terminated with a 50Ω load. The maximum cross-polarized level is –23 dB below copolar level of the boresight direction. XPD>20 dB between –48°...+33° scanning angles.

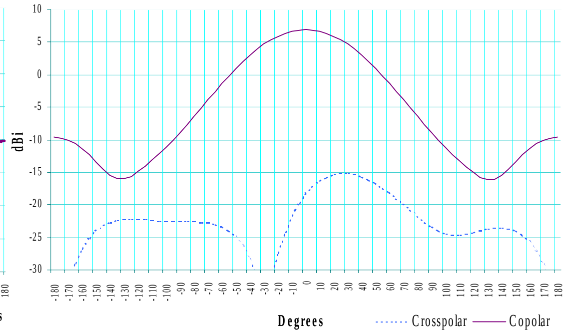

Figure 10. Simulated radiation pattern in H-plane. Dielectric feed, and the other feed is terminated with a 50Ω load The maximum cross-polarized level is –22 dB below copolar level of the boresight direction. XPD>20 dB between –65°...+30° scanning angles.

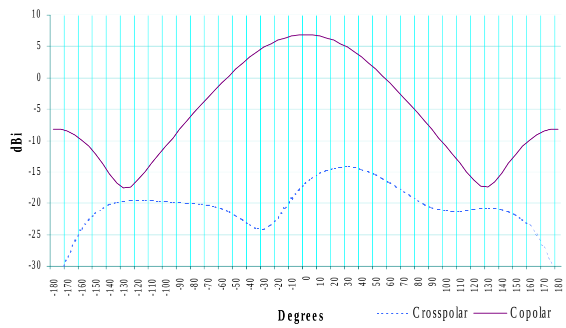

Figure 11. Simulated radiation pattern in H-plane, ordinary probe feed. The other feed is terminated with a 50Ω load The maximum cross-polarized level is –21 dB below copolar level of the boresight direction. XPD>20 dB between –60°...+25° scanning angles.

5. Conclusion

A probe-fed half-wave patch antenna was modified by using a dielectric feed replacing part of the probe. That results in improved cross-polarization separation, was *XPD*>20 dB between -57°...+78° scanning angles. Using the stacked patch structure 11.2% bandwidth with 10dB return loss was acquired. The dielectric feed increases the cross-polar discrimination 2.6 dB in the measured case and 1 dB in the simulation. The simulation predicts the behavior of the antenna reasonably well.

6. References

[1] J. Kivinen, T. Korhonen, P. Aikio, R. Gruber, P. Vainikainen, S.-G. Häggman, "Wideband Radio Channel Measurement System at 2 GHz," *IEEE Trans. Instrum. Meas.*, (accepted for publication 1999).

[2] K. Hirasawa, M. Haneishi *Analysis, design, and measurement of small and low-profile antennas*, Norwood, Massachusetts: Artech House, 1992, 253 p.

[3] G.A.E. Vandenbosch, "Capacitive Matching of Microstrip Antennas", *Electronics letters*, Vol. 31, no. 18, 31st August 1995, pp. 1535-1536

[4] V. Voipio, *"Wideband Patch Antenna Array Techniques for Mobile Communications,"* Licentiate thesis, Helsinki University of Technology, 23rd November 1998, 109 pp.