A Novel Planar Four-Quad Antenna

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***Abstract*— So-called bi-quad antennas fabricated from a simple piece of wire have found their use in applications for terrestrial digital TV (DVB-T) and wireless LANs (WLAN). A realization of such antennas in planar form and the extension to a novel four-quad antenna are described in this contribution. A bandwidth of more than 40% and a gain of around 8 dB of this antenna are demonstrated; narrower beamwidths and a further increase of gain can be achieved using a reflector.**

Keywords- antennas, quad antenna, planar antena, DVB-T, WLAN

I. INTRODUCTION

Loop antennas including square or polynomial shapes are known since longtime [1 - 4]; the combination of two edge-fed square loops (quads) has found great interest in amateur internet forums for an easy design of wire antennas, partly with a metal reflector. Such “bi-quad” or “double-quad” antennas show a reasonable gain and can easily be built from some piece of wire for (digital) terrestrial TV (DVB-T) or WLAN applications, e.g. [5 - 8]; such antennas are even proposed for wireless networking in developing countries [9].

Presently, however, no realization of such type of antennas on planar substrates is known to the authors, so some general investigations have been done in that respect. To further improve gain and to reduce beamwidth in the E-plane, a modification was done combining four quads to an overall antenna with square shape.

II. ANTENNA PARAMETERS

A typical layout of a planar bi-quad antenna is shown in Fig. 1. The two arm lengths L1 ≈ L2 are approximately a quarter wavelength long; slight differences are due to the feeding area. Feeding this antenna is done symmetrically at the points A and B. The electric field for this orientation of the antenna therefore is oriented vertically (in the y-direction, Fig. 1). Simulation of the antenna was done using the ADS module MOMENTUM [10].

As long as the operating frequency of such antennas is reasonably low (e.g. 500 MHz, 2.45 GHz or 5.8 GHz), substrate thickness does not play a major role, at least for reasonably low values of the dielectric constant. The most interesting parameter for the planar realization of such antennas is the *width* w of the antenna arms. To evaluate its influence, an antenna for the frequency range of around 560 MHz (DVB-T) was simulated for different values of w; the results of the input reflection coefficient are plotted in Fig. 2 as a function of frequency and width w. Both center frequency and bandwidth of the antenna increase with increasing width. As a major portion of the antenna current is flowing at the inner edges of the metallization, the slight increase in center frequency is due to a reduced inner cross section with increasing w. The interesting point is the increase of bandwidth which results from a reduction in the Q factor of the square loop resonators. According to the wider lateral antenna dimension (y-direction), the E-plane radiation diagram with a 3dB beamwidth of 85° is wider than the H-plane diagram (70°, Fig. 3). Only a range of 180° is shown in Fig. 3; basically the same radiation diagram is seen in the backside direction.

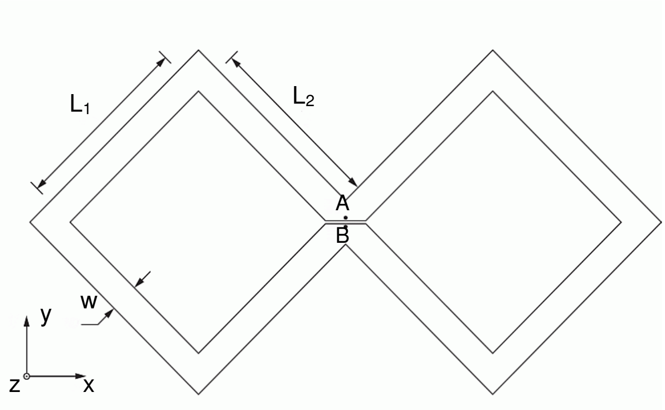

Figure 1. Principle layout of a planar bi-quad antenna.

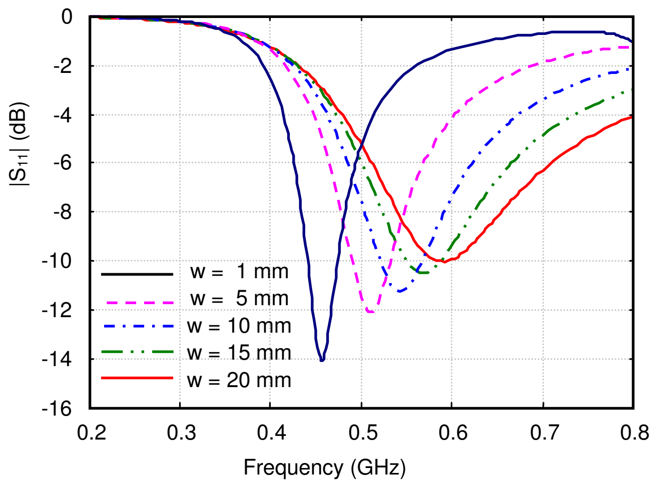

Figure 2. Simulated reflection coefficient of a planar bi-quad antenna as a function of frequency and strip width w. (Substrate material FR4, $\varepsilon_r = 4.75$, thickness h = 1.55 mm, see also Fig. 1).

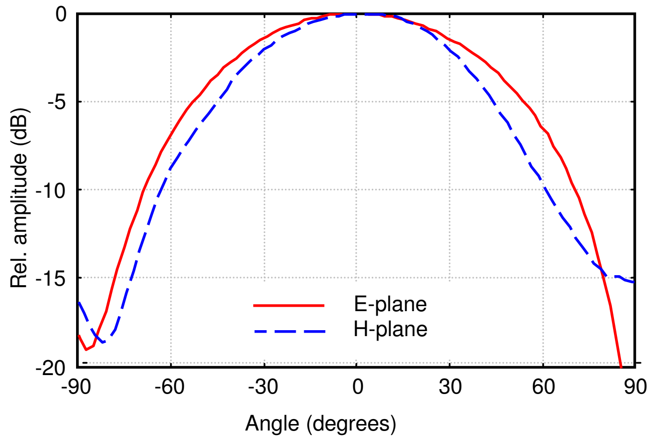

Figure 3. Measured radiation diagram of a planar bi-quad antenna at 560 MHz. (Substrate material FR4, $\varepsilon_r = 4.75$, thickness h = 1.55 mm, conductor width w = 20 mm).

III. Four-Quad Antenna

To increase the size of the antenna structure (higher gain) and to equalize the radiation diagrams in the two planes, a modified antenna design was developed which basically consists of a series connection of two bi-quad antennas as shown in Fig. 4; the overall structure shows some similarity to [11], although details are quite different. In the center of the arrangement, sections of parallel strips were added to optimize both the return loss and the radiation performance. Feeding is done again symmetrically via the two contact point shown as white holes in the antenna center.

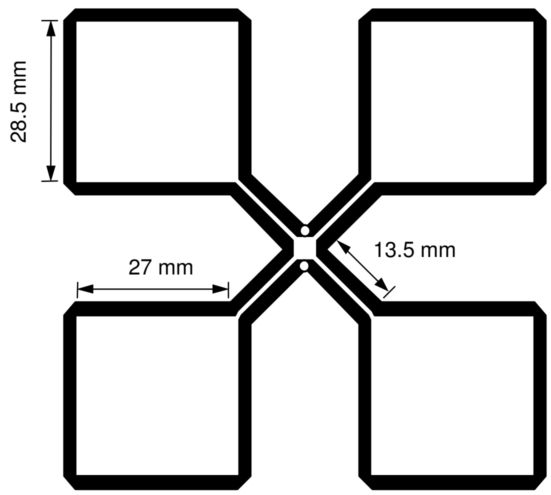

Figure 4. Principle layout of the novel planar four-quad antenna.

A test design was done for the IMS/WLAN band around 2.5 GHz on a RT-Duroid 5880 substrate ($\varepsilon_r = 2.22$, h = 0.508 mm, w = 2 mm); line lengths are given in Fig. 4. The fabricated antenna is shown on the photograph in Fig. 5. For simplicity, no balun was used; just center conductor and outer shielding of a thin coaxial cable were soldered to the antenna feed points. Fig. 6 shows simulated and measured reflection coefficient of this antenna. Minimum simulated reflection can be observed around 2.4 GHz, but it is better than -5 dB above 2.2 GHz (at least up to 4 GHz) for the simulated reflection coefficient and between 2 GHz and 3.75 GHz in experiment. Some problem occurred during measurement of the return loss due to power re-reflected from the surroundings. Apart from this, a reasonable agreement can be stated between theory and experiment.

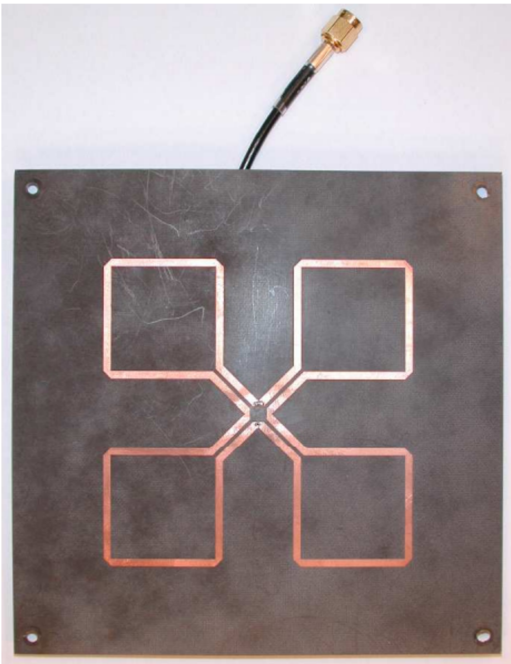

Figure 5. Photograph of the fabricated four-quad antenna.

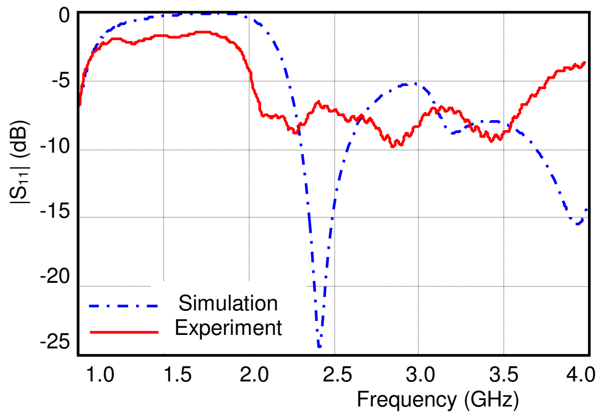

Figure 6. Reflection coefficient of the planar four-quad antenna.

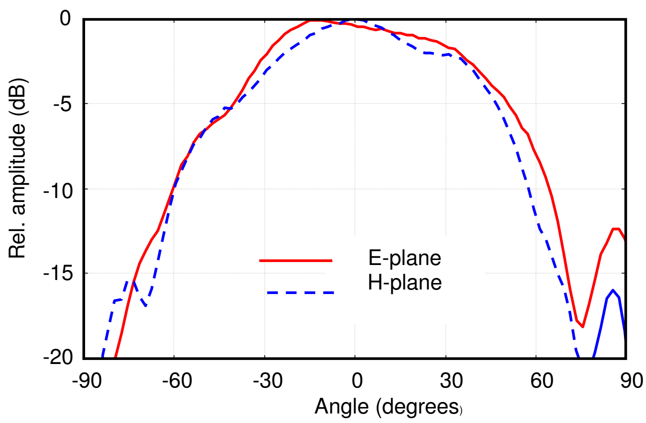

Figure 7. Measured radiation diagrams of the novel planar four-quad antenna for 2.5 GHz (without reflector).

Fig. 7 displays E- and H-plane radiation diagrams at 2.5 GHz. Once again, only the radiation from -90° to 90° (towards the metallization side of the antenna) is shown, nearly the same diagram exists towards the back side. Beamwidth in both planes is quite similar and close to 70°; some ripple and some asymmetry in the diagrams is due to interaction with the cable and a plastic frame used for mounting the antenna during measurement. Apart from this, the measured diagrams also are very close to the simulated ones (not shown here).

Fig. 8 finally shows E-plane radiation diagrams from 2 GHz to 3 GHz. Beamwidth varies to some extent, but the general form of the diagrams keeps the same. In this frequency range, no standard gain horn is available in the authors' lab, so only simulated gain is available, showing values increasing from about 7 dB at 2 GHz to 9 dB at 3 GHz (Fig. 9). In comparison, a simple planar bi-quad antenna of this type resulted in a simulated gain of about 5 … 6 dB. Experiences show, however, that losses of such antennas are relatively low, so the real gain should be close to the simulated one.

Measurements of the radiation diagrams also have been done between 3 GHz and 4 GHz shown in Fig. 10. The antenna still shows a suitable main lobe, only some shoulders start rising, resulting in a drop of gain of about 2 dB.

A further increase in gain can be expected using a backside reflector for the four-quad antenna. The antenna as shown in Fig. 5 was combined with a metal reflector of the same size as the dielectric substrate (135 mm x 135 mm), positioned at a distance of 30 mm. Although this limited size reflector will not give the full benefit in gain, the antenna is kept at a reasonable size. The E- and H-plane radiation diagrams of this combination at 2.5 GHz are plotted in Fig. 11, together with the E-plane diagram of the antenna without reflector (dotted line). Due to the different influence of the *finite* reflector as a function of polarization as well as some asymmetries related to a plastic frame for mounting and the coaxial cable, E- and H-plane exhibit different beamwidths of 48° and 58°, respectively, compared to about 70° without reflector. From 2 GHz to 2.75 GHz, very similar diagrams result. At 3 GHz and 3.25 GHz, broader diagrams result, while above (measured up to 4 GHz), good and more narrow diagrams can be stated.

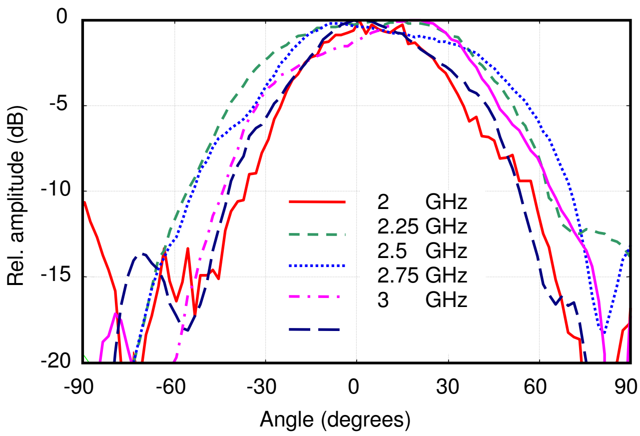

Figure 8. Measured E-plane radiation diagrams of the novel planar four-quad antenna from 2.0 GHz to 3 GHz (without reflector).

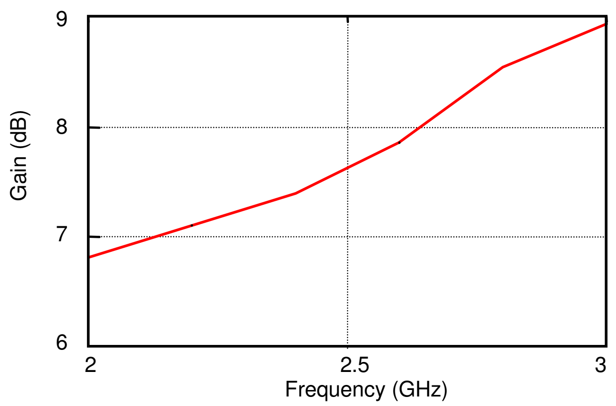

Figure 9. Simulated gain of the novel planar four-quad antenna (without reflector).

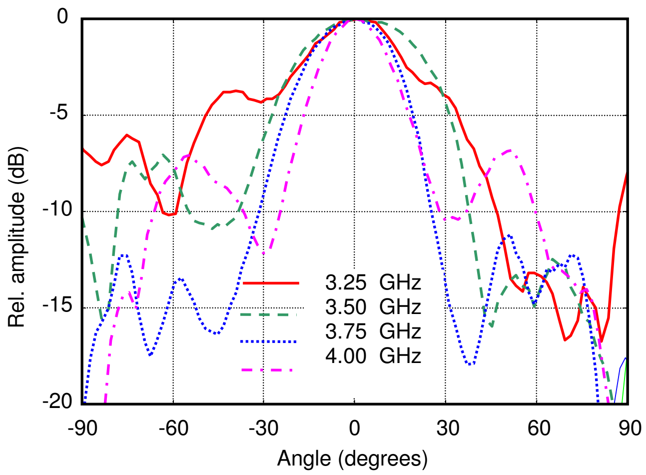

Figure 10. Measured E-plane radiation diagrams of the novel planar four-quad antenna from 3.25 GHz to 4 GHz (without reflector).

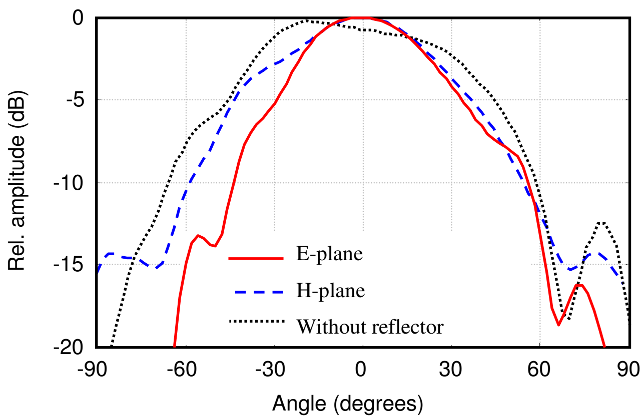

Fig. 11. Measured E- and H-plane radiation diagrams of the novel planar four-quad antenna with reflector at 2.5 GHz compared to the E-plane diagram without reflector (dotted line).

I. Conclusion

Some general investigations on planar integrated bi-quad antennas have been reported, and a novel four quad antenna has been presented showing a wide bandwidth with a quite constant radiation diagram. Gain without a backside reflector amounts to 8±1 dB, 10 dB or more should be achieved with a reflector. First tests of such antennas both for terrestrial television (DVB-T) as well for WLAN applications have shown promising results, exceeding by far the performance of simple monopole antennas delivered with respective USB receivers.

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