# Double-fed Wideband Printed Monopole Antenna

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***Abstract*—A double-fed printed monopole antenna having a wideband characteristic is presented. The monopole is rectangular in shape and is fed by a 50 ohms two-branch microstrip line. The antenna is designed and prototyped on a FR4 substrate. Both the simulated and measured results for impedance bandwidth are presented together with measured radiation patterns. The impedance bandwidth of the antenna is 2.2 GHz to 7.5 GHz covering all WLAN bands and frequencies in between. The antenna possesses approximately omni-directional radiation properties throughout this bandwidth. It is easily fabricated using low-cost printed circuit technology. In addition this antenna is mechanically stable and readily Integratable with various mobile and portable devices.**

***Keywords-monopole antennas; microstrip antennas; wideband antennas***

## I. Introduction

The expansion of wireless communication systems within the consumer market demands cheaper and more flexible antenna designs that cover a wider spectrum of the frequency band. The cellular systems and wireless LANs are already operating in multi band environment. These systems are beginning to integrate with each other and other existing wireless systems such as satellite navigational systems and ITS (Intelligent Transport Systems). During such integration, due to space and aesthetic constrains, multipurpose antenna design with wideband coverage is inevitably preferred. Moreover, emerging technologies like software radio and reconfigurable radio networks, both of which are intended for more flexible communications, need the access to wider bandwidth. In this paper, a printed rectangular monopole is presented as an antenna candidate for such all-in-one systems.

The simplest version of a monopole antenna, the quarter-wave monopole above a perfect ground plane, is unbalanced, has an omni directional coverage with good polarization properties and is easy to match. But it has a limited bandwidth. Thus in the past this basic version of monopole has gone through various transformations to make it more wideband while keeping its radiation properties intact. It has been suggested planar monopoles with different shapes such as rectangular, square, elliptical and circular. The square monopole is either fed directly at one, two or three feed points [1] or fed by microstrip lines [2] or is electromagnetically fed [3]. In this paper we introduce a rectangular monopole double-fed by a microstrip line.

This work is an integral part of the on going project CVIS (Cooperative Vehicle–Infrastructure Systems, http://www.cvisproject.org/ ) at SINTEF Information and Communication Technology (http://www.sintef.no/ ).

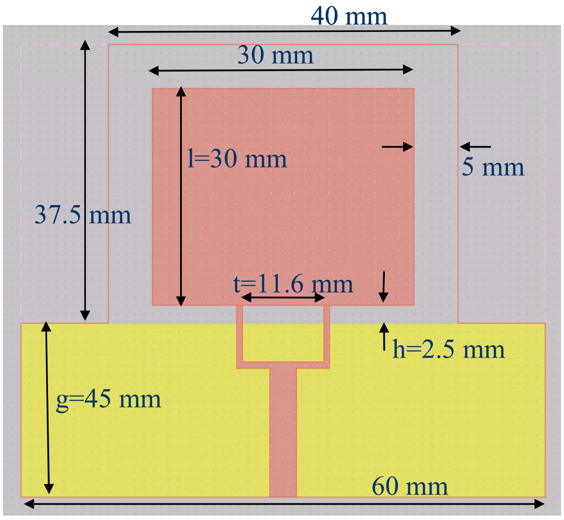


Figure 1. Double-fed printed rectangular monopole antenna: simulation model

The original design specifications for the antenna are:

- Wideband 2.4 GHz to 6.0 GHz
- Vertically polarization preferred
- Omni directional
- Planar, low-profile and easy to manufacture.
- The height of the antenna is limited (at most 10 cm) and to be mounted on a large ground plane.

## II. Antenna Design

### A. *Antenna geometry*

Fig. 1 illustrates the printed planar rectangular antenna double fed by microstrip lines and its optimized dimensions. The FR4 substrate with a relative permittivity of 4.4 and loss tangent of 0.02 is used. The thickness of the substrate and the copper layers are 1.55 mm and 35 µm respectively. The microstrip feed line is initially 3 mm wide and is later branched into two feed lines having a width of 0.7 mm. This results in a port impedance of 50 Ω. The height of the ground plane associated with the microstrip lines is 45 mm. As shown in Fig. 1, just underneath the monopole the substrate is 40 mm wide. However, underneath the ground plane it has a width of 60 mm due to practical reasons. The parameters *h*, *l* and *t* denote the distance between the upper edge of the ground and the lower edge of the monopole, the length of the monopole and the distance between the feed points, respectively. The antenna is expected to be mounted on a large ground plane normal to the plane of the monopole antenna as illustrated in Fig. 2.

### *B. Optimisation of antenna geometry*

The antenna is modelled and simulated on *Ansoft HFSS* version 10. The ground plane height and the width of the monopole are set to 45 mm and 30 mm respectively due to practical reasons. In order to achieve the best characteristics in terms of impedance matching over the required bandwidth, the length of the monopole *l*, the distance between two feed points *t* and the distance *h* between the upper edge of the ground plane and the lower edge of the monopole are varied.

In order to understand the response of the current monopole antenna to the change in dimensions, the design optimization was performed systematically changing one parameter at a time and denoting its effect on the return loss over the operating bandwidth (i.e. 2.4 GHz - 6.0GHz). Based on these analyses, an optimized design that meets our requirement is found. Nevertheless, we did not perform any automatic optimization procedures integrated into *Ansoft HFSS* since the set up of an automatic optimization procedure in this case is complicated and time consuming. The optimized dimensions of the antenna are already given in Fig. 1.

## III. SIMULATED AND MEASURED RESULTS

In addition to the optimized design, a few more designs which are identical to the optimized design apart from one particular parameter (for example either *h*, *l* or *t*), are prototyped. These designs enable us to compare the simulated parameter sensitivity analysis with measured response. Fig. 3 shows the measured return loss when the parameter *t* is modified while keeping *h* and *l* at their optimal values of 2.5 mm and 30 mm respectively. Likewise Fig. 4 and Fig. 5 summarise results for parameters *h* and *l*, respectively. It should be noted that the height of the ground plane of all the prototyped antennas are equal to 20 mm. When the antennas are mounted on the antenna base (Fig. 2) which is 25 mm high, the monopole effectively will be 45 mm above the horizontal ground plane. This is equal to the height of the ground plane applied in the simulation model (Fig. 1)

As shown in Fig. 2 the antenna is mounted on a base with a large circular ground plane. The return loss of the antenna is then measured using calibrated HP 8720C network analyzer. The simulated and measured return loss for the optimized antenna is given in Fig. 6. It is obvious that the designed antenna has a wider bandwidth than what it is specified for. The simulated return loss values agree well with the measured values. Both co polar and cross polar radiation patterns are measured on the azimuth and elevation planes in an anechoic chamber. A part of the measurement setup is shown in Fig. 2. A sample of the measured radiation patterns on azimuth plane are shown in Fig. 7-11 at different frequencies. Fig. 12-15 summarise the radiation patterns on the two major elevation planes. One of the elevation planes is normal to the antenna plane and the other coincides with the monopole antenna plane. It is noted that at higher frequencies the cross polarization is significant in certain directions. However, for mobile environments with considerable amount of multi path propagations, this would have less impact on the system performances. It should also be mentioned here that the current design is not explicitly optimised with respect to polarisation properties and more work is already in progress for improving cross polar discrimination (XPD).

## IV. CONCLUSIONS

A printed rectangular monopole antenna is designed and prototyped for wideband applications operating between 2.2 GHz to 7.5 GHz including all the WLAN frequency bands. It is shown that the simulated and measured impedance bandwidth agree very well. The measured radiation patterns are closely omni directional guaranteeing an almost equal radiation characteristics on the azimuth plane. However, in certain directions higher cross polarization values are noted on the azimuth plane for higher frequencies. Further work is already underway to improve the cross polar discrimination in the upper frequency bands. Early analysis has already shown that this is viable within the design constraints.

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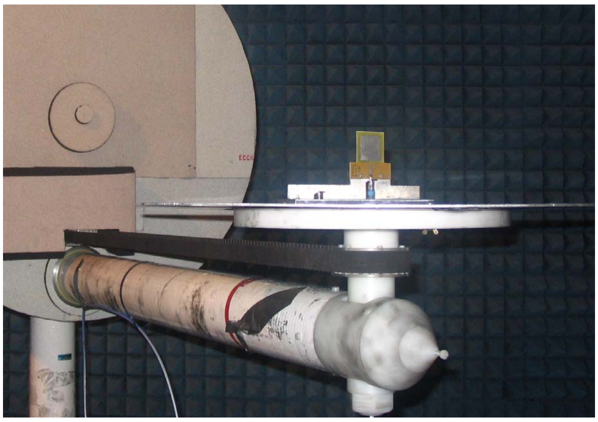

Figure 2. Monopole antenna is mounted on a circular ground plane and is made ready for measurements in an anechoic chamber.

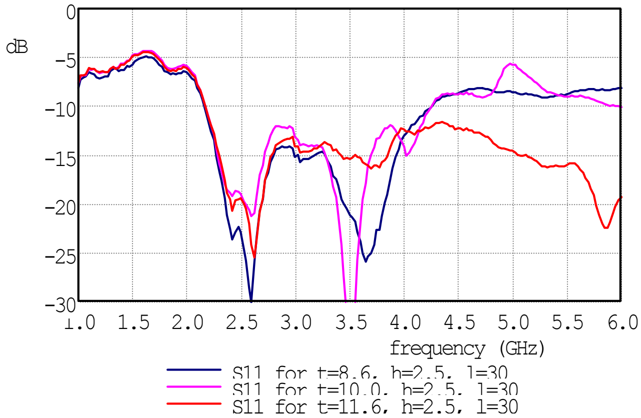


Figure 3. Measured return loss as a function of frequency for different values of *t* (the distance between two feed points) while keeping the other design parameters intact

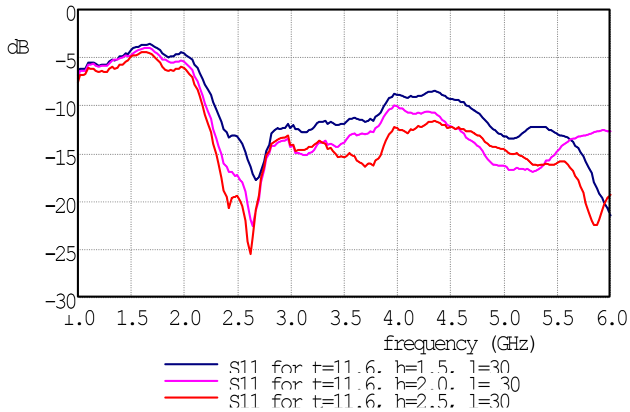


Figure 4. Measured return loss as a function of frequency for different values of *h* (the distance between the upper edge of the ground plane and the lower edge of the monopole) while keeping the other design parameters intact

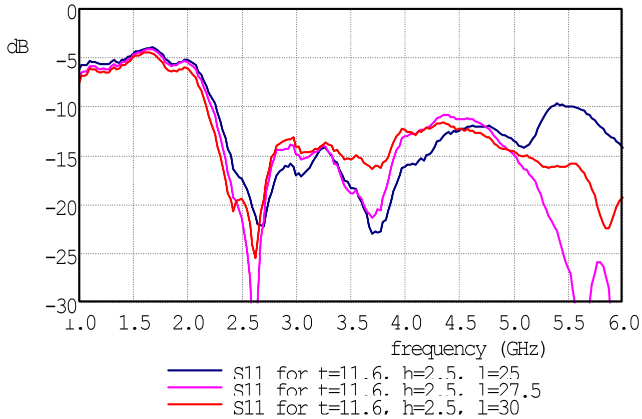


Figure 5. Measured return loss as a function of frequency for different values of *l* (the length of the monopole) while keeping the other design parameters intact.

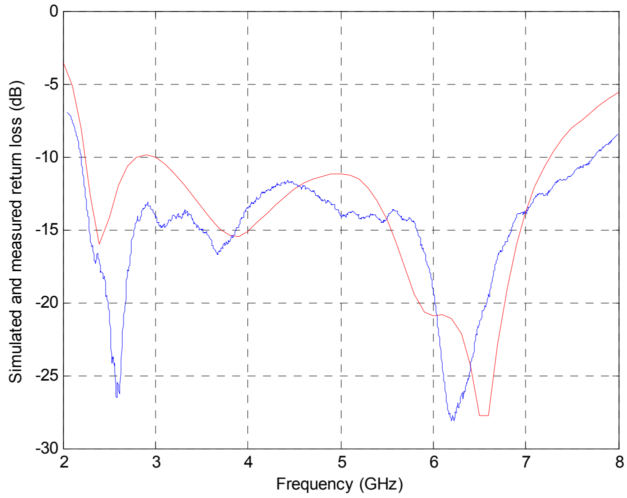


Figure 6. Simulated (red) and measured (blue) return loss (in dB) of the optimized antenna with h = 2.5 mm, l = 30 mm and t = 11.6 mm

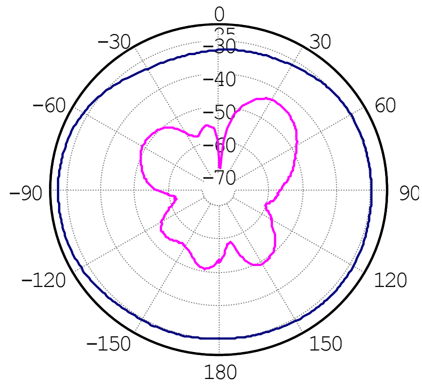


Figure 7. Measured co (blue) and cross (magenta) polar radiation patterns on the azimuth plane at 2.26 GHz (Amplitude is in dB)

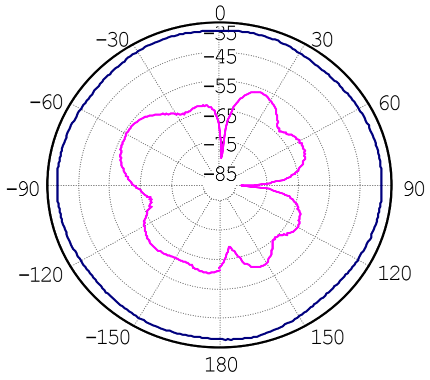


Figure 8. Measured co (blue) and cross (magenta) polar radiation patterns on the azimuth plane at 3.56 GHz (Amplitude is in dB)

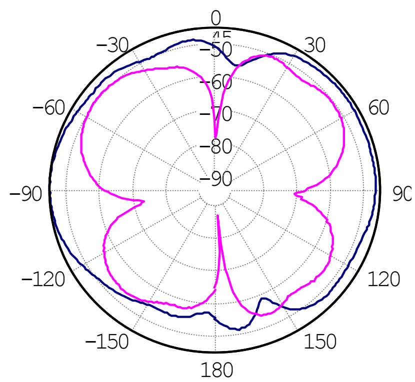


Figure 9. Measured co (blue) and cross (magenta) polar radiation patterns on the azimuth plane at 4.99 GHz (Amplitude is in dB)

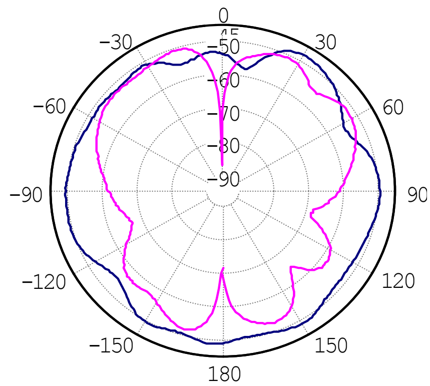


Figure 10. Measured co (blue) and cross (magenta) polar radiation patterns on the azimuth plane at 6.29 GHz (Amplitude is in dB)

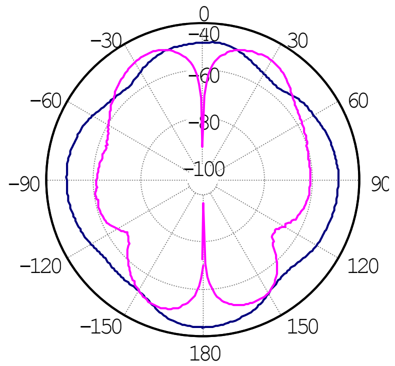


Figure 11. Measured co (blue) and cross (magenta) polar radiation patterns on the azimuth plane at 7.46 GHz (Amplitude is in dB)

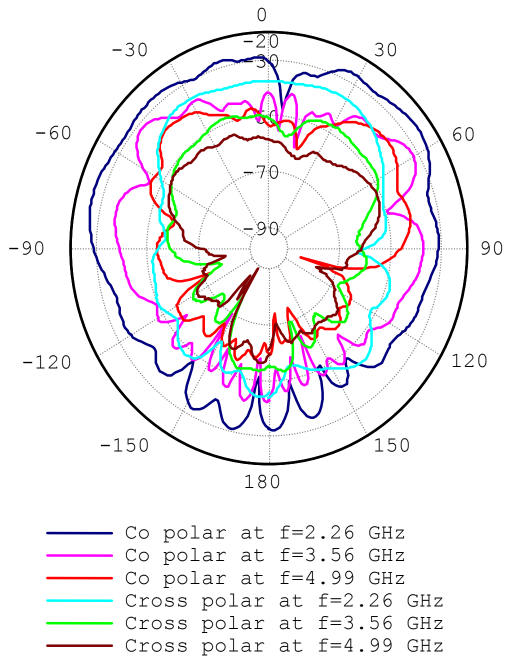


Figure 12. Measured co and cross polar radiation patterns on the elevation plane which is normal to monopole plane at 2.26 GHz, 3.56 GHz and 4.99 GHz (Amplitude is in dB)

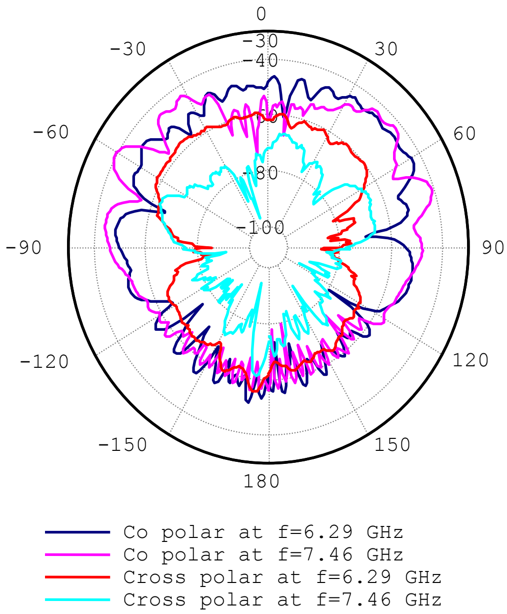


Figure 13. Measured co and cross polar radiation patterns on the elevation plane which is normal to the monopole plane at 6.29 GHz and 7.46 GHz (Amplitude is in dB)

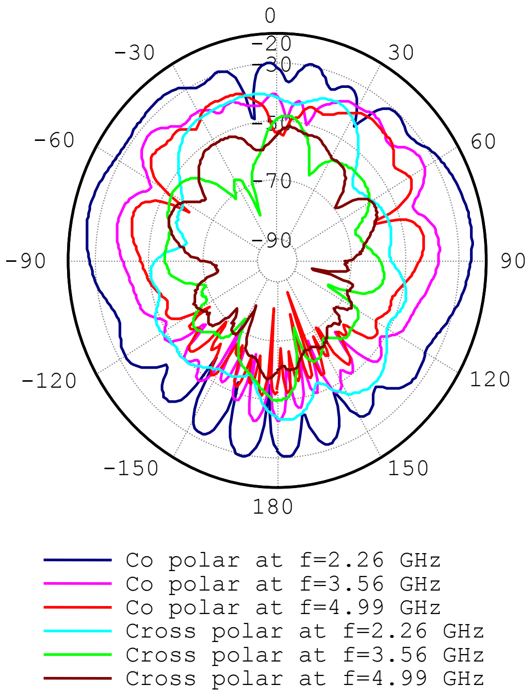


Figure 14. Measured co and cross polar radiation patterns on the elevation plane which coincides with the monopole plane at 2.26 GHz, 3.56 GHz and 4.99 GHz (Amplitude is in dB)

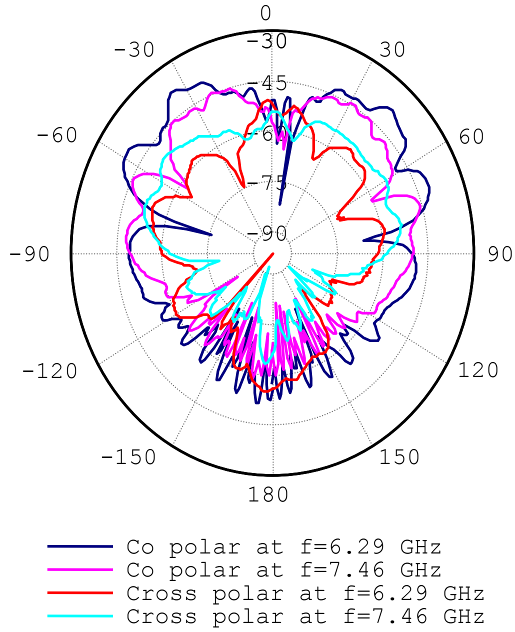


Figure 15. Measured co and cross polar radiation patterns on the elevation plane which coincides with the monopole plane at 6.29 GHz and 7.46 GHz (Amplitude is in dB)