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# A Note on the Impedance Variation with Feed Position of a Rectangular Microstrip-Patch Antenna

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## Abstract

The variation with feed position of the input impedance of a rectangular patch antenna is investigated theoretically. Two different feed types are examined: an inset microstrip line, and a coaxial probe. The Finite-Difference Time-Domain (FDTD) technique is used for the calculations. Numerical results are compared with published measurements and other theoretical models.

Keywords: Impedance; microstrip antennas; antenna feeds; coaxial coupler

## 1. Introduction

Microstrip-patch antennas have been widely used in applications where low-profile antennas are needed. The input impedance of a microstrip antenna depends on its geometrical shape and dimensions, the physical properties of the materials involved, and the feed type. The transmission-line model [1] predicts that the input resistance of a probe-fed rectangular patch antenna is proportional to the cosine-squared ($\cos^2$) of the normalized feed-point distance from the patch edge. This dependence can also be seen in [2], where measured values of resistance were compared with calculations based on modal analysis for different positions of the probe feed. Using the Method of Moments (MoM), similar results were obtained in [3] for three width/aspect ratios of the rectangular patch. However, recent work [4] has shown that when the patch is fed with an inset microstrip line, the resistance dependence becomes proportional to the fourth power of the cosine ($\cos^4$), although no theoretical justification was given there for this result. This short note presents numerical calculations that confirm the different behaviors of the two feed types, as shown in [4].

## 2. Method

The results were obtained with *SEMCAD* (Schmid and Partner Engineering AG, Zeughausstrasse 43, 8004 Zurich, Switzerland), which implements the Finite-Difference Time-Domain (FDTD) technique [5]. The antenna modeled was the one measured in [4]; the dimensions are shown in Figure 1. The distance $s$ was chosen to be equal to the width of the microstrip feed (3.8 mm). In both configurations, the impedance was calculated as a function of

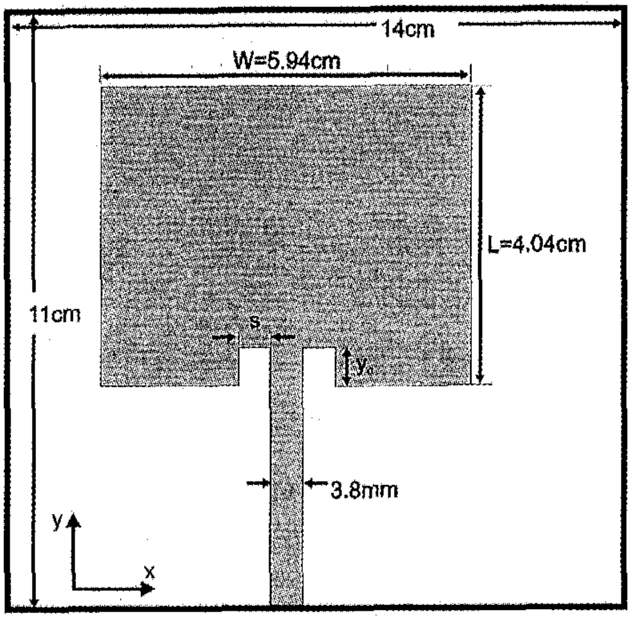


**Figure 1a. The dimensions of the antennas examined: microstrip inset feed.**

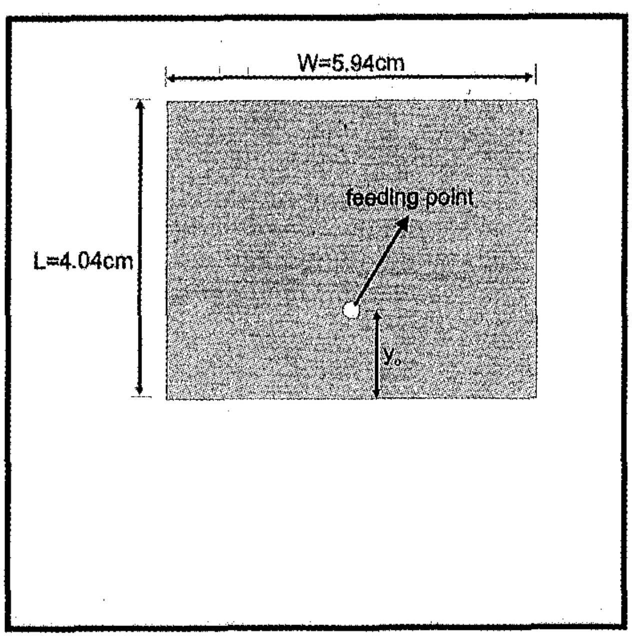


**Figure 1b. The dimensions of the antennas examined: probe feed.**

$y_0$, where $y_0$ varied from zero (at the edge of the patch) to $L/2 = 20.2$ mm (at the center of the patch). The substrate was 1.27 mm thick, and had dielectric properties of $\tan\delta = 0.0019$ and $\varepsilon_r = 2.42$. The antenna was designed to work at 2.3 GHz.

A non-uniform grid was used in the model. The maximum cell size (near the boundaries of the computational domain) was 2 mm ($\lambda/65$). The Gaussian pulse that excited the antenna was centered at 2.3 GHz, but had harmonics up to 4 GHz. Therefore, the maximum cell size corresponded to about 1/26 of the minimum wavelength. The computational domain was truncated with a six-cells-thick perfectly matched layer (PML).

## 3. Results and Discussion

The variation of the input impedance with the feed position is shown in Figure 2 for the two feed types. The values of the resistance for the microstrip inset feed followed the $\cos^4$ variation, and those for the probe feed followed the $\cos^2$ variation [1], normalized at $2y_0/L = 0.25$. The results for the resistance compared well with the measurements of [4], especially for feed positions close to the center of the patch. The agreement of the reactance values was also good.

One would expect that symmetrical excitation of the patch ($y_0 = L/2$) should lead to zero resistance, since no mode can be excited. However, experimental [4] and numerical results (this letter) showed that the input still resistance takes some value in this case, since the symmetry of the patch is destroyed by the inset. Thus, a mode is produced that makes the patch radiate. The trans-

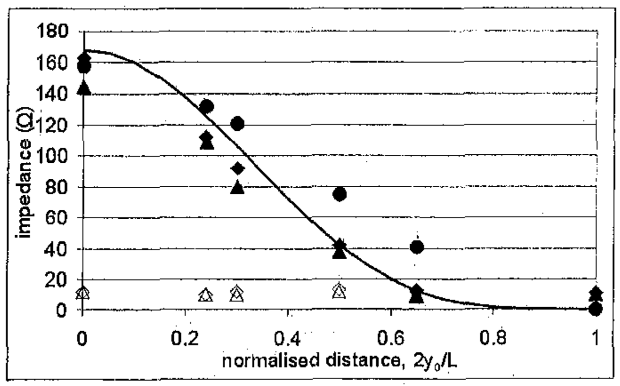


**Figure 2a. The variation of the input impedance with feed position for the antenna with a microstrip inset feed:**
—— $\cos^4(\pi y_0/L)$; - - - $\cos^2(\pi y_0/L)$; ◆ **FDTD,** $R(\Omega)$; ◇ **FDTD,** $X(\Omega)$; ▲ **Measured [4],** $R(\Omega)$; △ **Measured [4],** $X(\Omega)$; ● **Transmission-line model, [6]** $R(\Omega)$.

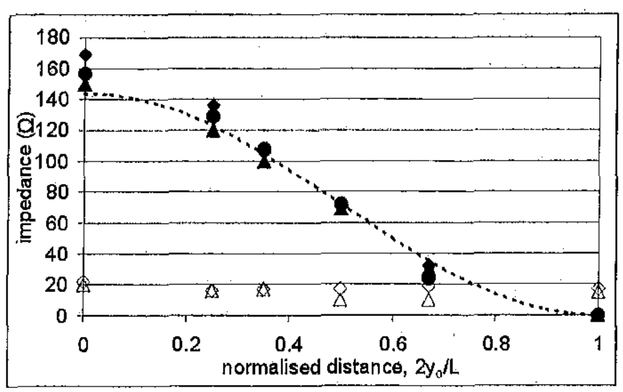


**Figure 2b. The variation of the input impedance with feed position for the antenna with a probe feed (legend as in Figure 2a).**

Table 1. Results for the microstrip-fed antenna.

| Normalized Distance $(2y_0/L)$ | $\cos^4(\pi y_0/L)$ | FDTD $R\ (\Omega)$ | Measured [4] $R\ (\Omega)$ | Transmission-Line Model [6] $R\ (\Omega)$ |
|---|---|---|---|---|
| 0.00 | 168 | 163 | 145 | 158 |
| 0.24 | 126 | 112 | 109 | 132 |
| 0.30 | 106 | 92 | 80 | 121 |
| 0.50 | 42 | 42 | 38 | 75 |
| 0.65 | 13 | 13 | 9 | 41 |
| 1.00 | 0 | 11 | 10 | 0 |

Table 2. Results for the probe-fed antenna.

| Normalized Distance $(2y_0/L)$ | $\cos^2(\pi y_0/L)$ | FDTD $R\ (\Omega)$ | Measured [4] $R\ (\Omega)$ | Transmission-Line Model [6] $R\ (\Omega)$ |
|---|---|---|---|---|
| 0.00 | 144 | 169 | 150 | 157 |
| 0.25 | 123 | 136 | 120 | 129 |
| 0.35 | 105 | 106 | 100 | 108 |
| 0.50 | 72 | 72 | 69 | 72 |
| 0.67 | 35 | 32 | 30 | 24 |
| 1.00 | 0 | 0 | 0 | 0 |

mission-line model [6] fails to predict this phenomenon (Table 1). Moreover, the values it gives follow the $\cos^2$ law (Figure 2). In the case of the probe feed at the center of the patch, the symmetry was respected and the input impedance was zero (Table 2).

The results confirmed that the variation of the input impedance with the feed position is different, depending on the feed type.

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