Comparison of CAD Formulas, Method of Moments and Experiments for Rectangular Microstrip Antennas

Vladimír SCHEJBAL[1], *Zbyněk RAIDA*[2], *Zdeněk NOVÁČEK*[2]

[1] University of Pardubice, Studentská 95, 532 10 Pardubice, Czech Republic
[2] Dept. of Radio Electronics, Brno University of Technology, Purkyňova 118, 612 00 Brno, Czech Republic

vladimir.schejbal@upce.cz, raida@feec.vutbr.cz, novacek@feec.vutbr.cz

Abstract. *Calculations of several cases for rectangular microstrip patch antennas using more accurate cavity model have been compared with the conventional cavity calculations, expressions generated by curve fitting to full wave solutions and method of moments. Calculated as well as experimental values have been studied for different thickness, patch sizes and substrate materials with different permittivities and losses.*

Keywords

CAD formulas, rectangular microstrip antennas, microwave antennas.

1. Introduction

The widespread use of printed circuits led to the idea of constructing radiating elements using the same technology. During the past twenty years, microstrip patch antennas experienced a great gain in popularity and have become a major research topic in both theoretical and applied electromagnetic fields. They are well known for their highly desirable physical characteristics such as low profile, lightweight, low cost, ruggedness, and conformability. Numerous researchers have investigated their basic characteristics and extensive efforts have also been devoted to the design of "frequency agile," "polarization agile," or dual-band patch antennas.

Although patch antennas appear simple and are easy to fabricate, obtaining electromagnetic fields, which satisfy all the boundary conditions, is a complicated task. For this reason, simplified approaches such as the transmission line model and the cavity model have been developed. The cavity model is particularly popular [1] - [3]. The basic idea of the cavity model is to treat the region between the patch and ground plane as a resonant leaky cavity. The simplified approaches allow the analysis as well as the design of rectangular microstrip patch antennas but the accuracy of those formulas is rather low.

On the other hand, the more accurate full-wave analysis [3] cannot be used for design because it is very time consuming. Therefore, new simple computer-aided design formulas for the rectangular microstrip patch antennas have been developed (MSANCAD code [4]), which use the cavity model but the more accurate models for open-end effect of microstrip lines and effective permittivity are used.

One of the common methods of feeding a patch antenna is by means of a coaxial probe. The basic configuration is shown in Fig. 1, where a single metallic rectangular patch is printed on a grounded substrate. The patch is of length *B,* width *A* and substrate thickness *h*. The dielectric substrate has a relative permittivity ε_r. The feed-point coordinates of coaxial probe are $x_0 = A/2$ and $y_0 = L$. In this case, the linear polarization is radiated and the dominant mode is TM_{10}.

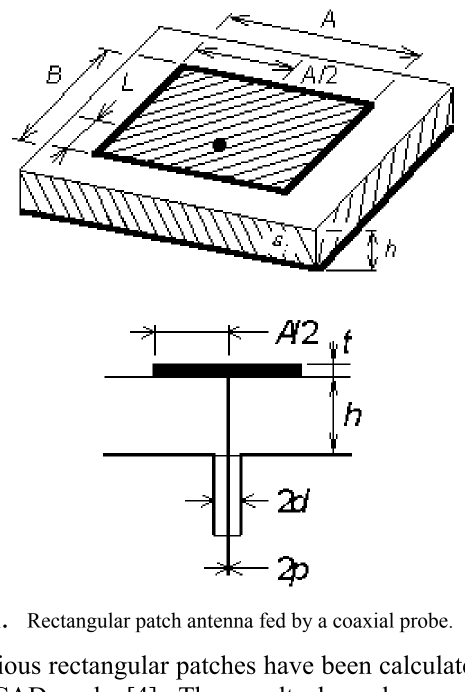

Fig. 1. Rectangular patch antenna fed by a coaxial probe.

The various rectangular patches have been calculated using MSANCAD code [4]. The results have been compared with the conventional cavity calculations using MSANT code [5], expressions generated by curve fitting to full wave solution (PATCHD code [6]) and method of moments (MoM) as well as experimental values. The basis for the PATCHD code is a series of closed form expressions, which were generated by curve fitting to full wave solutions. As such the PATCHD code results include surface wave effects and are rigorous except for the fact that no feed model is included. However, there are limitations on certain parameters ($0 \leq \sqrt{(\varepsilon_r - 1)}\, h/\lambda_0 \leq 0.2$, $1 \leq \varepsilon_r \leq 10$ and for rectangular patches $0.9 \leq A/B \leq 2$ and $0 \leq h/B \leq 0.2$).

A variety of different substrate thickness and patch sizes with various widths to length ratios and permittivities have been considered. Some of the comparison results have been already published [4], [7] – [9], and therefore, they are not repeated here.

2. Comparison of CAD Formulas and Experiments

In order to perform the detailed comparison, several samples of patch antennas with various substrates have been completed [10]. In Figures 2 to 7, the input impedance characteristics of three antennas are given.

The antenna 1 uses the AR 600 substrate (the producer declares values of $\varepsilon_r = 6.0 \pm 0.5$ and $\tan\delta = 35 \cdot 10^{-4}$) with measured $\varepsilon_r = 6.45$ and $\tan\delta = 64 \cdot 10^{-4}$ (the discrepancy can be given by the radiation of the measured microstrip and errors due to the system with low losses). The substrate dimensions are 90×90 mm. The patch dimensions are $A = B = 68$ mm. The 50 Ω connector is placed at $L = 25$ mm. The probe radius equals to $p = 0.6$ mm.

The antenna 2 uses the rather loss substrate with measured $\varepsilon_r = 4.24$ and $\tan\delta = 266 \cdot 10^{-4}$. The substrate dimensions are 200×140 mm. The patch dimensions are $A = 100$ millimeters and $B = 80$ mm. The 50 Ω connector is placed at $L = 5$ mm. The probe radius equals to $p = 0.6$ mm.

Dimensions of the antenna 3 are identical to the antenna 2 except for $L = 10$ mm.

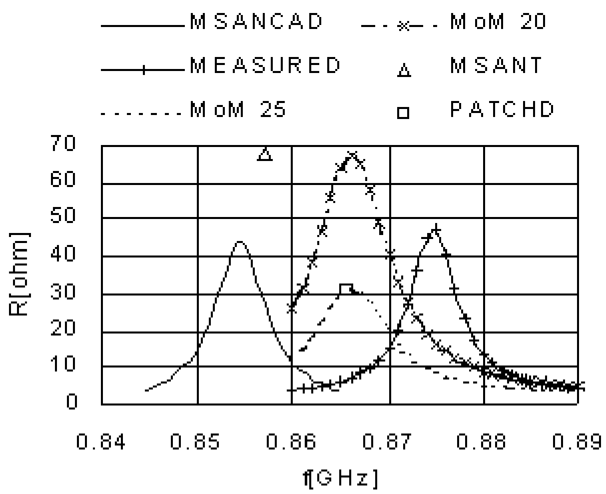

Fig. 2. Input resistance of the probe-fed rectangular patch (the antenna 1)

The input impedance has been measured using vector analyzer. The measured values have been corrected by means of directional coupler parameters. The MoM with two-dimensional model of coaxial probe feeding is employed. The input impedance is calculated using surface currents.

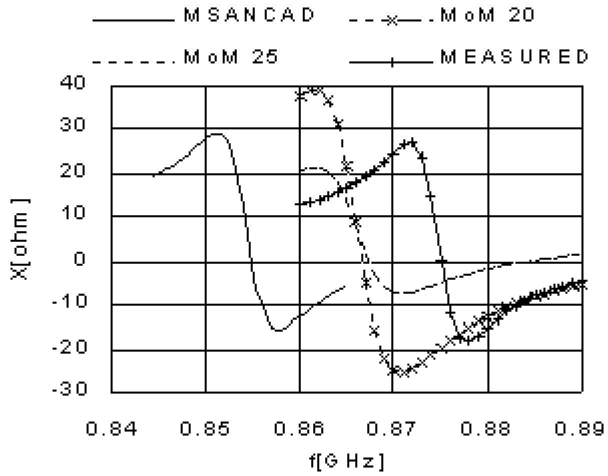

Fig. 3. Input reactance of the probe-fed rectangular patch (the antenna 1)

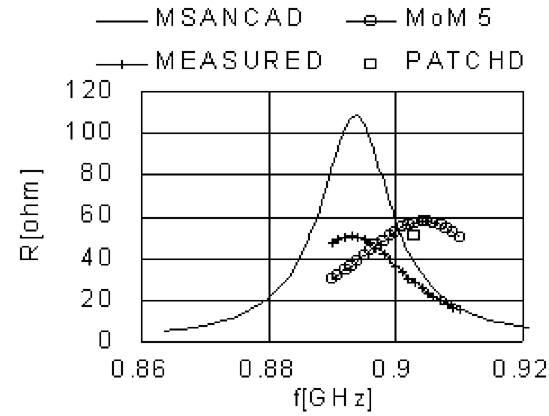

Fig. 4. Input resistance of the probe-fed rectangular patch (the antenna 2)

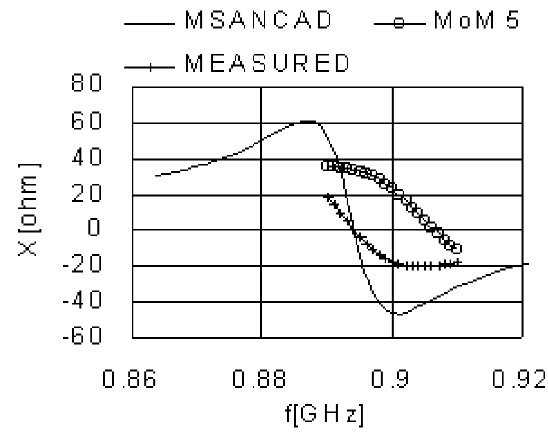

Fig. 5. Input reactance of the probe-fed rectangular patch (the antenna 2)

The MSANCAD [4] calculations have been compared with MSANT [5] and PATCHD [6] (resonant resistances are calculated only), the input impedance measurements and

MoM computations (MoM 5, MoM 10, MoM 20 and MoM 25 use L = 5, 10, 20 and 25 mm, respectively). The differences between measurement and MSANCAD, PATCHD, MSAMT and MoM resonant frequencies are about 1 to 2 per cent. Considering the input impedance characteristics, more significant differences can be observed. The MSANT resonant resistances are 218 Ω and 194 Ω for antennas 2 and 3, respectively, and they are not shown in Fig. 4 and 6.

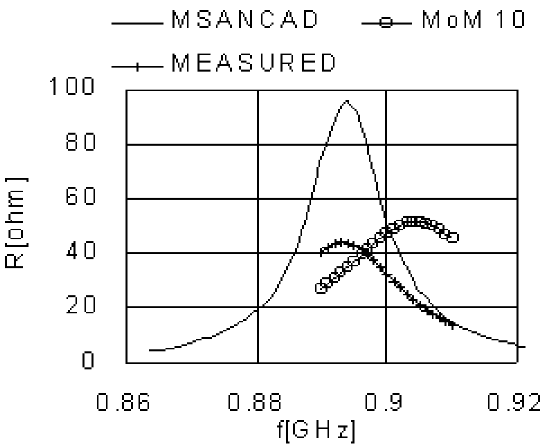

Fig. 6. Input resistance of the probe-fed rectangular patch (the antenna 3)

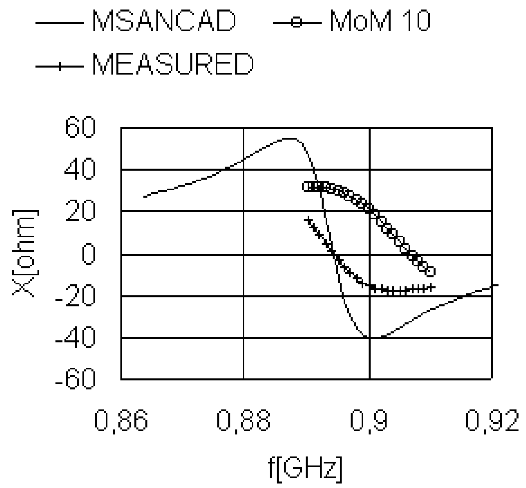

Fig. 7. Input reactance of the probe-fed rectangular patch (the antenna 3).

3. Conclusions

Various simple CAD formulas for a rectangular patch antenna have been presented (see [1] to [4]). The method [4] (MSANCAD code) uses the cavity model with the more accurate models for open-end effect of microstrip lines and the effective permittivity. That allows increasing accuracy and reliability. Because of the relative simplicity of the model [4], the analysis as well as the design of rectangular microstrip patch antennas can be performed. Published comparisons [4], [7] to [9] are not repeated here.

In order to perform the detailed comparison, several samples of patch antennas with various substrates and dimensions have been completed. The MSANCAD [4] calculations have been compared with MSANT [5] and PATCHD [6] (resonant resistances are only calculated), the input impedance measurements and MoM computations in Figures 2 to 7. The differences between measurement and MSANCAD, PATCHD, MSAMT and MoM resonant frequencies are about 1 to 2 %. Considering the impedance input characteristics bigger differences can be observed.

Considering the measured values, we cannot conclude that the MoM values are more reliable than MSANCAD. The calculation of resonant frequencies is better for MoM than for MSANCAD but MSANCAD impedance computations are more realistic than MoM impedance computations for the antenna 1. Considering the antennas 2 and 3, the calculation of resonant frequencies is better for MSANCAD than for MoM but MoM impedance computations are more realistic than MSANCAD impedance computations.

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