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Determining an empirical formula for calculating characteristics of a rectangular microstrip antenna

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ABSTRACT

In this work, we have developed an empirical expression for the input impedance of a rectangular microstrip antenna by applying the curve fitting the experimental results. We can also determine from this formula the variations of the input impedance as a function of frequency and dielectric permittivity, respectively. The results obtained were compared with those published, and we are very satisfied with this comparison.

Keywords: Input Impedance, Rectangular Microstrip Antenna.

1. INTRODUCTION

Great technological innovations have marked the development of telecommunications.

Digitizing the signalsand the introductionof fiber opticshave beenkey stagesof this evolution.If these technologies are associated with concepts such as high-speed information and support for multimedia, recent years have shown a particular interest of users for concepts such as ease of access and mobility especially.

To meet these expectations, it is natural that the radio transmission techniques have been utilized to connect business users and individuals. The challenge now is to increase the capacity of cellular systems to meet the ever growing market [1]. The development of wireless systems, and broadband multimedia applications, can support strategy for different telecom operators.

Investment in technology microstrip antennas gives these telecom operators a competitive advantage [2], [3], which all the telecommunications industry can benefit from.

The rectangular patch is by far the most widely used microstrip antenna configuration. It is very easy to analyze by using both the transmission line and cavity models, which are most accurate for thin substrates [4].

In this work, we have developed an empirical expression for the input impedance of a rectangular microstrip antenna by applying the curve fitting from the experimental results.

It has also been determined from this formula changes in the input impedance depending on the width of the patch and the dielectric permittivity, respectively.

Outcomes were compared with those published.

2. THEORY

Figure 1 shows a rectangular microstrip antenna size (a×b) deposited on a dielectric support relative electrical permittivity ε_r and thickness h. The antenna is fed by a coaxial probe connected to the center of the antenna to maintain symmetry and minimize the excitation of surface waves. [5].

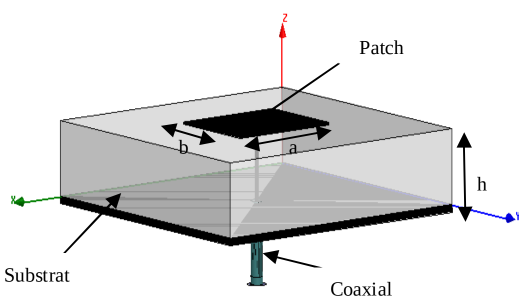

Figure 1: Schematic of a rectangular patch microstrip antenna.

In the theory of linear circuits the input impedance of a microstrip antenna is given by [4-6]:

$$Z_e(f)=R_e(f) + jX_e(f) \quad (1)$$

Or:
*Re(f)*is the resistance of the antenna,
Xe(f) is the reactance ,
f is the frequency of work.

The purpose of this study is to determine an empirical expression for the input impedance of the microstrip antenna patch to rectangular function of the frequency making an adjustment by the method sine experimental results.

3. RESULTS AND DISCUSSION

1. Adjusting the experimental results:

Figure 2 illustrates the approach obtained using an adjustment sinusoidal (performed under Matlab7.1.0.246) and the results published by [7]. This type of adjustment is chosen because it gives a very good result compared to other types of adjustment (Gaussian or polynomial),In addition it generates a more appropriate equation(sinusoidal).

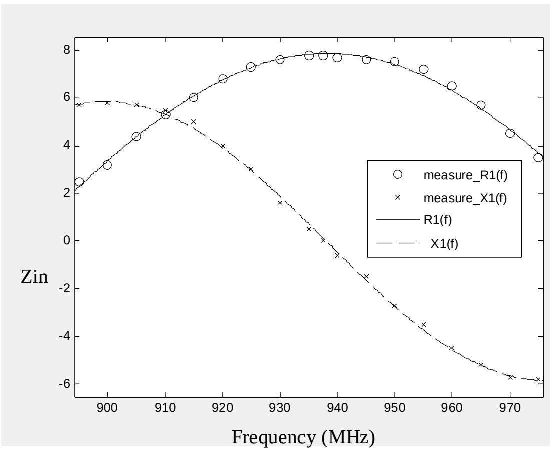

Figure 2: sinusoidal adjustment of the experimental results modeling the change in impedance depending on the frequency for f_r=937.5 MHz, a/h=12, and ε_r=10.

This figure shows the variation of both the real and imaginary parts of the input impedance versus frequency. The resonance frequency of the microstrip antenna is obtained when the real part is the maximum and the imaginary part is zero, and this is in accordance with what's in the literature [8].

This curve shows the results of the adjustment approach using a sine wave.

The comparison shows a perfect relationship between the experimental results and those found by the proposed method.

Table 1: Results of R_e and X_e given by Matlab

	results
R_e	*General model Sin1:* *f(x) = a1*sin(b1*x+c1)* *Coefficients (with 95% confidence bounds):* *a1 = 7.984 (7.846, 8.122)* *b1 = 0.1385 (0.1351, 0.1418)* *c1 = 0.1625 (0.1282, 0.1968)* *Goodness of fit:* *SSE: 0.4738* *R-square: 0.991* *Adjusted R-square: 0.9898, RMSE: 0.1777*
X_e	*General model Sin1:* *f(x) = a1*sin(b1*x+c1)* *Coefficients (with 95% confidence bounds):* *a1 = 5.972 (5.509, 6.436)* *b1 = 0.1717 (0.1486, 0.1948)* *c1 = 1.404 (1.167, 1.641)* *Goodness of fit:* *SSE: 1.424* *R-square: 0.9955* *Adjusted R-square: 0.9949, RMSE: 0.3081*

From the results obtained, we found an empirical formula for the input impedance of an antenna microruban:

$$R_1(f) = \alpha_1 \sin(\beta_1 f + \gamma_1)$$
$$X_1(f) = \alpha_2 \sin(\beta_2 f + \gamma_2) \quad (2)$$

Or are coefficients which depend on the experimental results; that is to say, settings of the antenna and its operating range.

For this case where the resonant frequency is between 895 MHz and 975 MHz, a/h=12, etε_r=10, obtained:

α_1 = 7,984	α_1 = 5,952
β_1 = 0,1385	β_2=0,1717
γ_1 = 0,1625	γ_2=1,404

Thus, the results obtained can be used to study the effect of some settings of the antenna on the real part of the input impedance.

2. *Effect of some parameters on the antenna resistance*

2.1.Width of the patch

The width of the patch plays a very important role in the characterization of microstrip antennas. In this work we use the formula published in the frequency reference [9], [10]:

$$f = \frac{c}{2b}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (3)$$

We replace the expression (3) in equation (2) we get the change in impedance as a function of the width of patch (Figure 3).

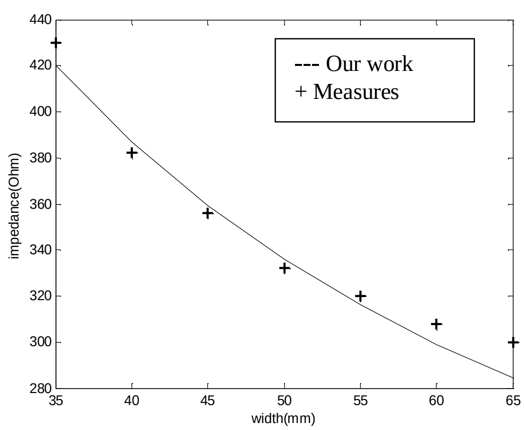

Figure 3: Variation of the real part of the impedance as a function of width b the patch for h=1.6mm and εr=4.4 and (a,b)=(50,40)mm.

Figure 3 illustrates the variation of the real part of the impedance of the antenna according to the width of the patch.

This study shows the real part of the input impedance of the antenna decreases with increasing width of the patch. Thus, to have an antenna which operates at high frequencies and its influence, the width of the patch should be smaller.

The relative error ΔRe/Re calculated is between 1% and 5%; this allows to conclude a coincidence between the results obtained by the formula (2) and those published by [10].

2.2. Electrical permittivity

Figure 4 shows the effect of the relative dielectric permittivity the substrate on the real part of the input impedance of the antenna using equations (2) and (3).

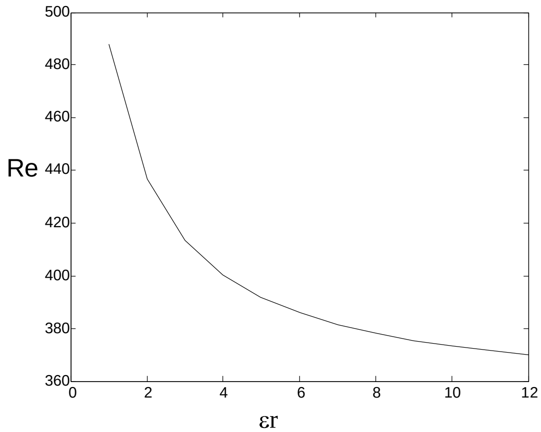

Figure 4: Variation of the input impedance as a function of the electrical permittivity of the substrate to b=40mm.

The real part of the input impedance decreases strongly when the value of the electrical permittivity of the substrate augment. The curve has the same shape as that given in the reference [11].

4. CONCLUSION

In this study we developed an empirical expression for the input impedance of a microstrip antenna, applying the principle of adjusting curves.

The results fulfill expectations since there is a direct relationship with the experimental results.

Moreover, we have observed changes in the input impedance depending on the width of the patch and the dielectric permittivity of the substrate of the antenna.

This method can be easily used to characterize other types of microstrip antennas, circular or triangular.

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