ETMSA and ITMSA Antenna for Wideband Wireless Radiocommunication Systems

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Abstract: - In this paper the triangular antenna is widely analyzed, calculated and simulated. The ETMSA and ITMSA variations of the triangular variations were carried out in order compare their features. The proximity fed of the antenna was used with the aim to improve the frequency response of the antenna in a air layer between the ground plane and the triangular element. The computation and simulation are shown in detail and the results of the electromagnetic field is presented using the antenna pattern and the S_{11} parameter, where the wideband feature of the antennas is plotted. The design and optimization by computer demonstrate that the use of low-cost of the PCB and the other materials can be used in the implementation of the proximity fed triangular antenna and using an inexpensive manufacturing process.

Key-Words: - Microstrip antenna, mobile radiocommunication, higher modes, broadband antenna, antenna bandwidth, equilateral triangular antenna, return losses.

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1 Introduction

Due to their main features plane or microstrip antennas has been employed in mobile radio communication, because a thin geometry is more compatible with handset terminals [1]-[10]. The main limitation of these sort of antennas is their bandwidth inherent limitation [8]-[12]. Nevertheless, that set of antennas are quite simple and do not require expensive or complex manufacturing process [11]-[18].

A lot of structures have been probed with the aim to obtain a wideband planar antenna, examples of these are: defected rectangular or circular microstrip patch antennas, [19]-[25]

Symmetric triangular antennas are related to higher bandwidths than rectangular patches, because this structure can be improved adding slots in their triangular main element [9], [10].

The isosceles triangular structure is widely analyzed in this work. Some variations of the triangular structures like ETMSA (Equilateral Triangular Microstrip Antenna) or ITMSA (Isosceles Triangular Microstrip Antenna) are calculated and simulated. Besides, the structures are improved using linear and U slots increasing the frequency response and employing a proximity feeder, in order to increase their matching interval.

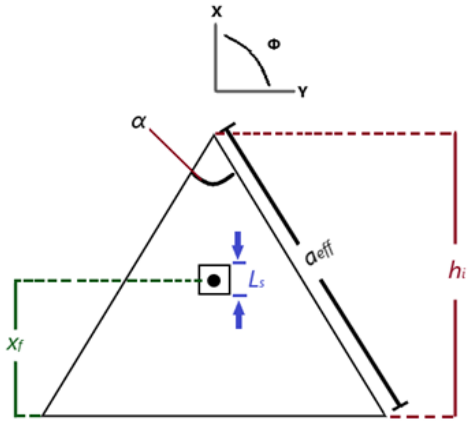
Another contribution in this paper, is the presentation of design and simulation of the ETMSA and ITMSA antennas for L-band applications with a low-cost PCB (Printed Circuit Board). Finally, the analysis in temperature and the effect of a plastic enclosure are included for the implementation of the antenna.

The simulations of this article were carried out using Ansys HFSS (High Frequency Structure Simulator), which employs a FEM (Finite Element Method) algorithm to solve the Maxwell equations.

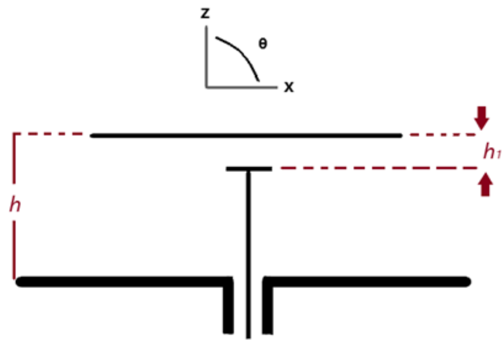
2 Design Procedure of the Equilateral Triangular Antenna

In this section, the mathematical model of the triangular antennas and its computation are presented in detail [1], [2], [4].

The Figure 1 shows the triangular geometry of the ETMSA and ITMSA antennas, where the second one involves a isosceles triangle.



(a)



(b)

Fig.1 Geometry of Triangular Antennas with proximity feeder (a) Top view, (b) Side view.

The electric field distribution is calculated using the equations (1) and (2), where A is a constant; and, m,n,l determine the mode of the field.

$$E_z = A_{m,n.l}T(x,y) \tag{1}$$

$$\begin{aligned} T(x,y) &= cos\left[\left(\frac{2\pi x}{\sqrt{3a}} + \frac{2\pi}{3}\right) l\right] cos\left[\frac{2\pi(m-n)y}{3a}\right] \\ &+ cos\left[\left(\frac{2\pi x}{\sqrt{3a}} + \frac{2\pi}{3}\right) m\right] cos\left[\frac{2\pi(n-l)y}{3a}\right] \\ &+ cos\left[\left(\frac{2\pi x}{\sqrt{3a}} + \frac{2\pi}{3}\right) n\right] cos\left[\frac{2\pi(l-m)y}{3a}\right] \end{aligned} \tag{2}$$

The corresponding magnetic field distribution is obtained using the equation (3), where μ is the permeability, H/m; ε is the permittivity, F/m; and, ω is the angular frequency, rad/s.

$$H_x = \frac{j}{\omega\mu\varepsilon}\frac{\delta E_z}{\delta y} \tag{3}$$

The solution of the electromagnetic field involves the resonance frequency of the triangular element in the m,n,l mode in the x,y,z axes in the cartesian coordinated system. This frequency can be determined using the equation (4), where a is the size of the triangular antenna, m; c is the phase velocity, m/s; and, ε_r is the dielectric constant.

$$f_{m,n} = \frac{2c}{3a\sqrt{\varepsilon_r}}\sqrt{m^2 + mn + n^2} \tag{4}$$

It is necessary to consider the computation of the effective length of the triangular element because the radiation in a two different media. It is very well known the main approximation of the effective length, as is shown in the equation (5).

$$f_r = \frac{2c}{3a_{eff}\sqrt{\varepsilon_r}} \Rightarrow a_{eff} = \frac{2c}{3f_r\sqrt{\varepsilon_r}} \tag{5}$$

The effective dielectric constant of the PCB is determined by equation (6) where ε_{eff} is the effective dielectric constant; h is the thickness of the dielectric layer of the PCB, m; and, a is the size of the triangular antenna, m.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{4\sqrt{1 + \frac{12h}{a}}} \tag{6}$$

The design procedure of the triangular antenna was calculated using a PCB with a standard thickness equal to 1.588 mm and a FR-4 substrate with a dielectric constant approximately equal to 4.4.

The use of the dominant mode TM_{01} of the ETMSA an ITMSA antennas was taken in consideration in the 1.17 GHz frequency band. The variation of the α angle (that is shown in Figure 1) can be optimized for ITMSA antenna in comparison with an equilateral geometry of the ETMSA. The size of the antenna is illustrated in the Table 1 where the proximity fed is included.

Parameter	Value
f_r	1.17 GHz
h	3 cm
h_l	0.2 cm
α	60°
a_{eff}	8.33 cm
L_S	0.9 cm
h_i	7.2139 cm
x_f	36.0699 cm

Table 1. Dimensions of the ETMSA antenna after the design procedure.

The design of the ITMSA antenna is illustrated in the Table 2, where the angle of the triangle is changed in comparison with the ETMSA antenna.

Parámetro	Valor
f_r	1.13 GHz
h	3 cm
h_l	0.2 cm
α	110°
a_{eff}	8.33 cm
b	13.64707 cm
L_S	0.9 cm
h_i	4.77789 cm
x_f	2.3889 cm

Table 2. Dimensions of the ITMSA antenna after the design procedure.

3 Results

The main results of this work are presented in this section where the Figure 1, shows the equilateral variation of the triangular antenna ETMSA. In the side part of this figure the proximity fed is under the triangular radiator [32]-[40].

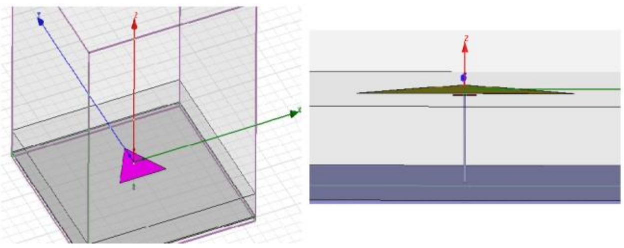


Fig.2 Model of the ETMSA antenna in HFSS.

The frequency response of the ETMSA antenna is shown in the Figure 3, where the resonance frequency is approximately equal to 1.17 GHz.

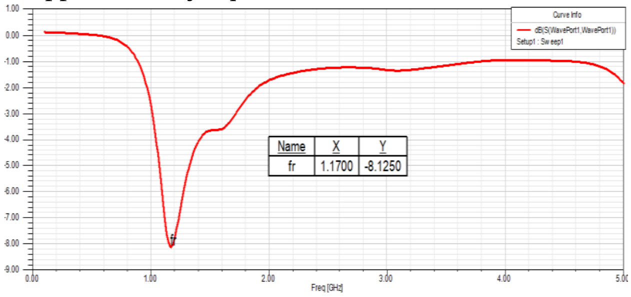


Fig.3 S_{11} of the ETMSA.

The antenna pattern of the ETMSA antenna is illustrated in the Figure 4, where the directivity of the antenna is approximately equal to 5.71 dB.

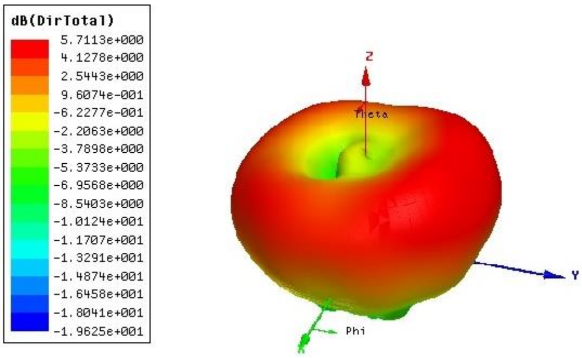


Fig. 4 Antenna pattern of the ETMSA.

The optimization of the ITMSA antenna improves the frequency response in comparison with the ETMSA variation where the angle of the triangle cannot be changed, see the Table 3.

Parámetro	Valor
f_r	2.35 GHz
h	3 cm
h_l	0.2 cm
α	110°
a_{eff}	8.33 cm
b	13.64707 cm
L_S	0.1 cm
h_i	4.77789 cm
x_f	1.3389 cm

Table 3. Dimensions of the ITMSA antenna after the optimization procedure.

The optimized results obtained with the changes illustrated in the Table 3, where focused in the antenna matching with the return losses (S_{11}) and the antenna pattern.

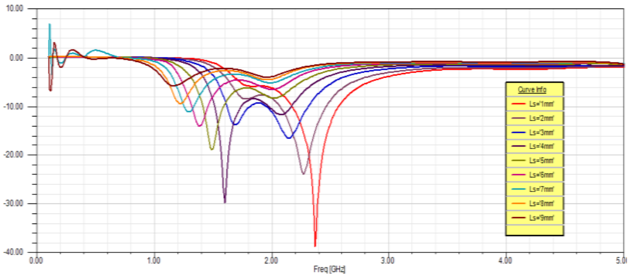


Fig. 5. Return losses (S_{11}) of the ITMSA antenna.

The best response of the antenna is obtained with a L_S equal to 0.1 cm where the return losses is approximately equal to -38.584 dB.

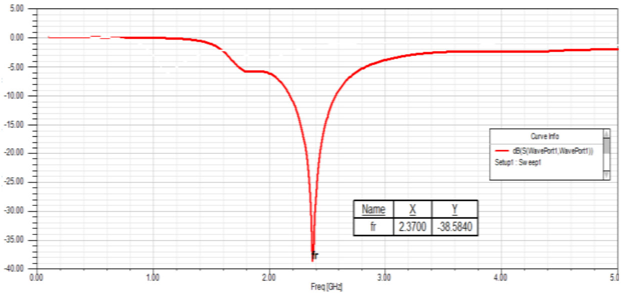


Fig. 6. Optimization of the S_{11} of the ITMSA antenna.

Similarly the antenna gain of the optimized model of the ITMSA is illustrated in the Figure 7, where the antenna gain is approximately equal to 5.79 dB.

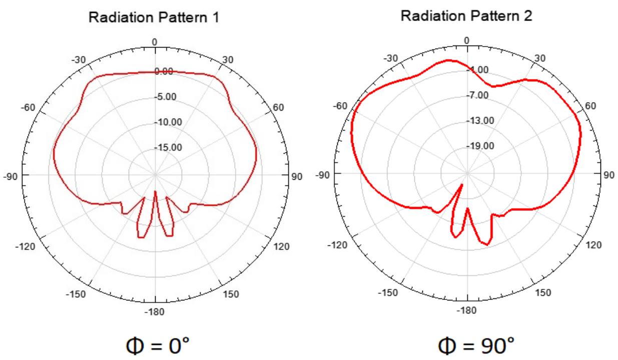


Fig. 7. Antenna pattern of the optimized ITMSA Antenna.

Building slot in the triangular element of the ITMSA antenna is possible to obtain a better frequency response. Using two parallel symmetric slots, two resonance frequency are obtained (2.49 GHz and 9.76 GHz, with corresponding bandwidths equal to 590 MHz and 1.16 GHz), see Figures 8 and 9.

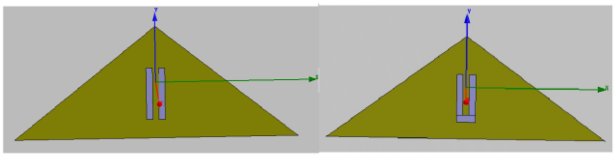


Fig. 8. ITMSA antennas with regular and U slots.

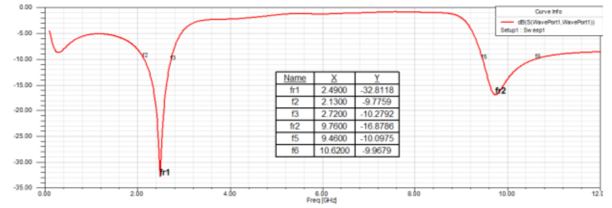


Fig. 9. Antenna pattern of the optimized ITMSA Antenna.

Finally, U-slot gives a large bandwidth to the ITMSA antenna as it is shown in the Figure 10, where the return losses are plotted. In this case, the resonance frequency is equal 2.38 GHz, and the bandwidth is approximately 1.51 GHz.

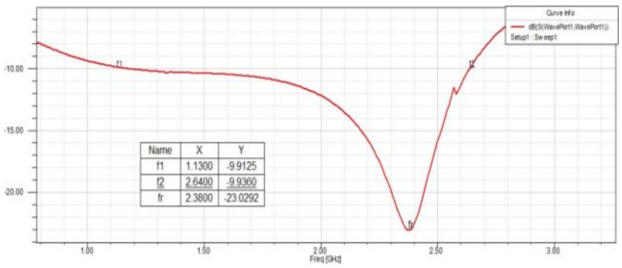


Fig. 10. Return losses of the ETMSA antenna with a U-Slot.

4 Conclusion

The analysis, calculation and simulation of the main two variations of the triangular antennas were carried out. This kind of structure has a more complex behavior in comparison with rectangular and circular microstrip antennas.

The use of the triangular antennas (ETMSA or ITMSA) can provide a higher bandwidth with the other mentioned structures in the previous paragraph.

One of the most important features of the proposed antenna is the use of a very common PCB with a non-expensive FR-4 substrate and a standard thickness (h = 1.588 mm). This kind of antennas can be built with inexpensive manufacturing process.

The ITMSA antenna is more flexible than ETMSA because the limitation of the angle in the triangle element. Besides, the use of slots in the antenna improves the bandwidth in two different ways: a U-slot can provide a bandwidth approximately equal to 50% (a feature of UWB antennas) and parallel slots gives two resonance frequencies, that can be used in multichannel systems [20]-[32].

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