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Dual Band Microstrip Antenna

Antena Microstrip de Doble Banda

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Abstract

The amount of data in today's communication systems is increasing considerably, which in turn increases the bandwidth needed to deploy a given service. This requires antennas that are capable of operating simultaneously in more than one band. In this work we present the modeling and development of a rectangular patch type dual band antenna operating at 900 and 1800 MHz. To achieve this, the antenna is modeled as a resonant cavity with electric walls on the upper and lower faces and magnetic walls on the sides. To achieve dual band operation shorting pins are used which allow the fundamental resonant frequency of the antenna to be adjusted to the desired value. The design is analyzed by simulation with the electromagnetic computational tool CST. Measurements carried out on a prototype show a return loss of less than -23 dB, a bandwidth of 22 MHz in the lower band and 60 MHz in the upper band for a SWR less than or equal to 2 and a directivity greater than 7 dBi. We can argue that the antenna presents good characteristics for its operation in current systems.

Keywords: antenna, microstrip, dual band

Resumen

El volumen y cantidad de datos, en los sistemas de comunicaciones, está sufriendo un incremento considerable, de modo que cada vez se necesita un mayor ancho de banda para desplegar un determinado servicio, requiriendo en consecuencia, que las antenas sean capaces de operar simultáneamente en más de una banda. En el presente trabajo, se presenta el modelado y desarrollo de una antena rectangular tipo patch dual band, en 900 y 1800 MHz. Para lograr esto se modela la antena como una cavidad resonante con paredes eléctricas en las caras superior e inferior y magnéticas en las laterales. Para alcanzar un funcionamiento dual band se utilizan pines en cortocircuito (shorting pins, SP), lo que permite ajustar la frecuencia de resonancia fundamental de la antena al valor deseado. Se analiza el diseño mediante simulación con la herramienta computacional electromagnética CST. Las mediciones realizadas sobre el prototipo muestran una pérdida de retorno inferior a -23 dB, un ancho de banda es de 22 MHz en la banda inferior y 60 MHz en la superior para un ROE menor o igual a 2 y una directividad mayor a 7 dBi. Podríamos decir que la antena diseñada y desarrollada presenta buenas características para su operación en sistemas actuales.

Palabras claves: antena, microcinta, doble banda.

Introduction

Communication systems are part of a constantly evolving process, where the volume of data to be transmitted is ever increasing. To fulfill these needs new frequency bands are enabled for certain services, which implies that antennas used in these systems need to operate in more than one band (multiband antennas) or increase the receiving bandwidth (broadband antenna). Microstrip patch antennas are an increasingly used option, with characteristics such as low volume, weight and adaptable format. Besides, it is possible to modify them for operating in more than one band. Their disadvantages, however, must be taken into account: low efficiency and their natural narrowband operation (Balanis, 2005). To make the antenna operate in two bands several techniques such as stacked, slots or shorting pins (Kumar et al., 2003) can be used. The use of shorting pins (SP) has been widely used

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in cavities and antennas because it allows modifying the electromagnetic fields in a selective way for improving the device response. Fong et al., (2004) conducted a review of the use of shorting pins in antennas include frequency tuning, control of frequency separation, size reduction and bandwidth enhancement. In Zhang et al., (2016a) the use of SP is employed to achieve an improvement of 3 dBi in the directivity at the fundamental frequency of an antenna with microstrip technique, in Xu et al., (2018) the technique based on SP is used to reduce the input impedance, increasing the operating bandwidth or to vary its value without affecting the response of the antenna (Zhang et al., 2015). It is also possible to use a combination of slots and SP to achieve dual band operation, in the 402-405 MHz and 1570-1580 MHz bands (Ray et al., 2018). A microstrip type antenna operates in circular polarization without the need for an external polarizer by adding SP, as detailed in Zhang et al., (2016b) and the effect of the SP position on the main beam direction is studied in Sabapathy et al. , (2014). In Wong, (2004) the use of SP is analyzed to decrease the resonance frequency of the fundamental mode, without varying the dimensions of the antenna, resulting in a reduction of the dimensions with respect to the conventional design.

In this work we propose the use of SP to modify the response of the antenna, changing the fundamental mode frequency without affecting the frequency of the following modes. Advantages of using this method include simplicity, cost effectiveness and size reduction compared to antenna stacking. However, when higher bandwidths are required or better polarization control, other methods will be more suitable.

Rectangular Microstrip Antennas

The design of microstrip patch antennas, or microstrip antenna as they are known, is widely used in the literature (Balanis, 2005), the basic design parameters being those shown in equations 1 to 4. Figure 1 shows the dimensions of a microstrip antenna. For an efficient radiator, the width W that allows obtaining good radiation efficiency is given by eq. 1, the patch length should be L=λ/2, eq. 2:

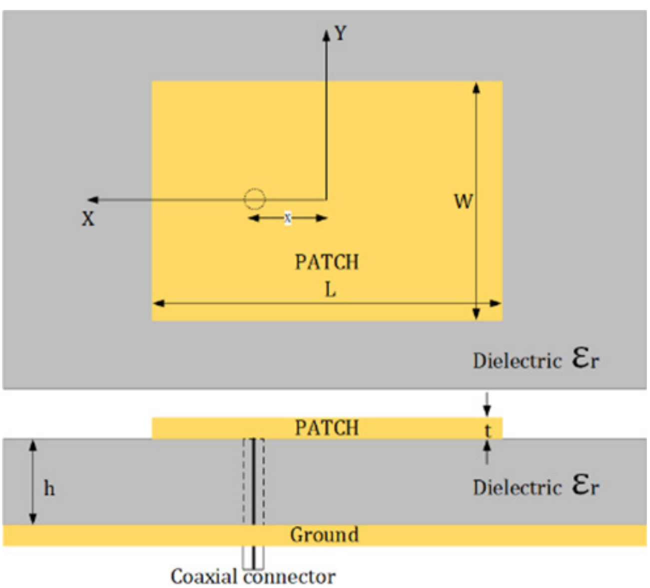

Figure 1. Schematic diagram of a microstrip antenna

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$$W = \frac{c}{2.f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad \textit{Patch wide} \tag{1}$$

$$L = \frac{c}{2.f_r.\sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad \textit{Patch length} \tag{2}$$

Due to the edge effect (fringing), the antenna appears electrically larger than it really is, such that the electrical dimensions of the antenna extend at each end by a distance ΔL, as given by Eq. 3:

$$\frac{\Delta L}{h} = 0.412\frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \qquad \textit{Normalized extension } \Delta L \tag{3}$$

Since the field lines pass through two different media, air and substrate, the antenna is assumed to be immersed in a homogeneous medium with a constant permittivity ε_{reff}, which can be estimated as described in Eq. 4.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}.\left(1 + \frac{12h}{W}\right)^{-\frac{1}{2}} \qquad \textit{Effective dielectric constant} \tag{4}$$

Considering the structure as a waveguide, it can be stated that the length L of the rectangular patch for the fundamental excitation mode TM10 is a little less than λ/2, where λ is the wavelength in the dielectric, (Balanis, 2005). By increasing the width W it is possible to improve the edge fields of the patch, which affects the radiation pattern. This parameter can also be improved by decreasing the relative permittivity ε_r, changing the dielectric material or increasing the thickness of the substrate. The antenna designed here is fed by a coaxial probe, the geometry is shown in Fig. 1.

Antenna Design

The proposed dual band antenna is based on the design of a rectangular patch antenna on a FR4 substrate (https://laminatedplastics.com/fr-4.pdf) . Generally, to obtain antennas with good performance, high substrates (h) with low dielectric constants are preferred, since they provide better efficiency and greater bandwidth, at the expense of a larger element size (Kumar et al., 2003). In the present work, to improve the efficiency and bandwidth of the proposed antenna, two superimposed FR4 substrates are used. This type of low cost material is made up of fiberglass and epoxy laminates and is widely used in the design of printed circuits. Table 1 shows the dimensions and characteristics of the board used.

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PARAMETER	VALUE
Board dimensions	200 x 200 mm
W Patch width	80 mm
L Patch length	118 mm
Probe feed position in X	23,6 mm
FR4 substrate height	1.6 mm
h substrate antenna height	3.2 mm
Copper thickness	t=0.035 mm
Dielectric constant	ε_r=4.3
Losses constant	tanδ=0.02

Table 1 – Dimensions and characteristics of the design

Simulation

For the simulation of the designed antenna, the electromagnetic analysis tool CST was used, which allows to analyze the frequency response of the S11 reflection coefficient, estimate the design directivity, the radiation pattern and surface current distribution, among other things. The simulation results are shown in Figure 2. It can be observed that the calculated antenna effectively presents a dual-band operation, the resonance frequency for the TM30 mode is at 1.8 GHz and the frequency of the TM10 fundamental mode at 0.6 GHz, but the lower frequency is below the desired frequency of 0.9 GHz. The ratio of both frequencies is approximately 3.

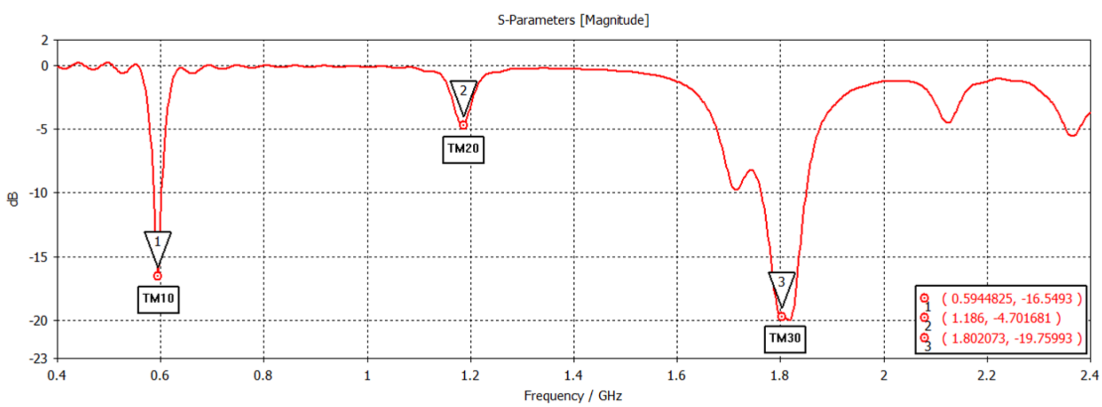

Figure 2 – S11 reflection coefficient of the microstrip antenna

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To modify the resonance frequency f_{r10}, short-circuited pins (SP) are added at position x=L/3 where the TM30 mode is null, in such a way that it does not affect the corresponding resonance frequency, but will have a strong effect on the resonance frequency of the TM10 mode.

Based on this technique, it is possible to add several SPs until achieving the desired resonance frequency. This effect is shown in Table 2 and Figure 4, where it can be seen how the fundamental frequency of 0.6 Ghz is shifted to higher values as SPs are added. In addition, it can be seen that there is little influence on the upper frequency.

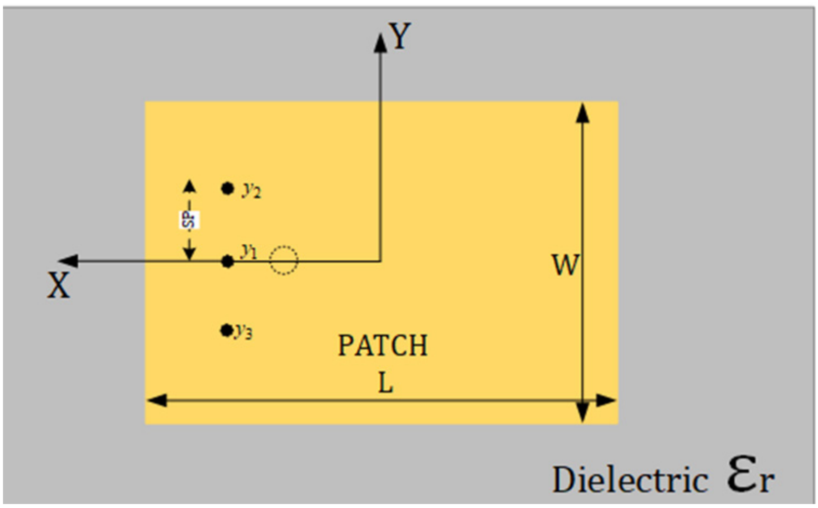

Figure 3 – Shorting pins position

#SP	SP position mm	f_1 MHz	f_2 MHz	$\frac{f_2}{f_1}$
0	-	592	1799	3.03
1	y_1=0	706	1790	2.53
2	y_3=-18 ; y_2=18	840	1792	2.13
3	y_1=0; y_2=18; y_3=-18	904	1794	1.98

Table 2. Lower frequency variation by adding shorted pins.

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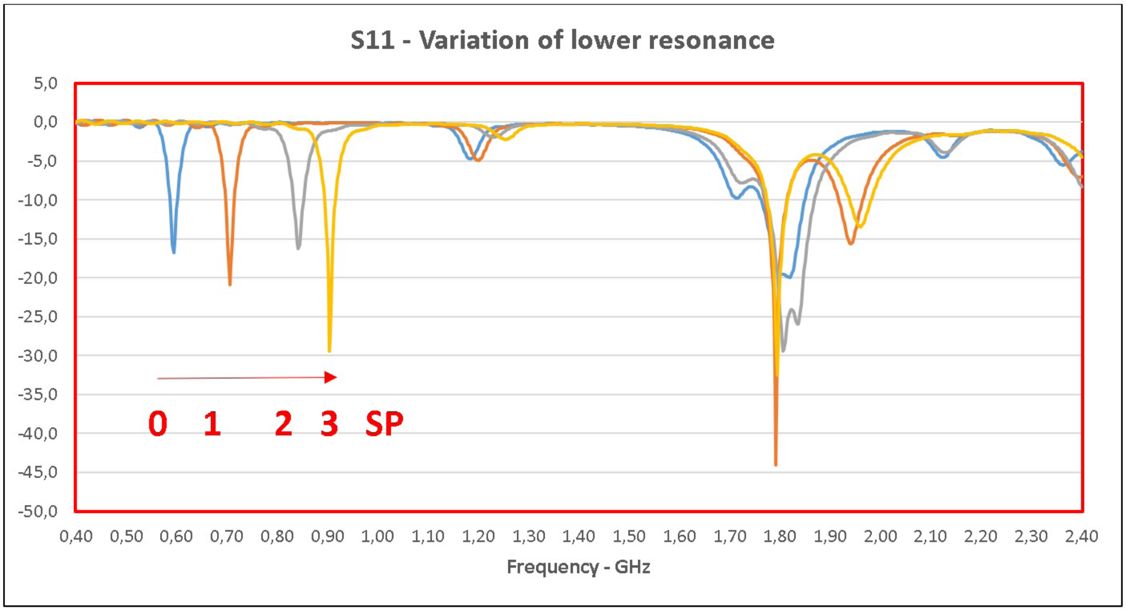

Figure 4. Variation of the lower resonance frequency when 1 and 2 SPs are added

It is then observed that with 3 short-circuited pins of radius r=0.5 mm in the aforementioned positions, the desired frequencies at 0.904 and 1.794 GHz are achieved. The feed position is modified to x=22 mm to improve the adaptation. Figure 5 shows the S11 reflection coefficient of the designed antenna, with 3 short-circuited pins inserted.

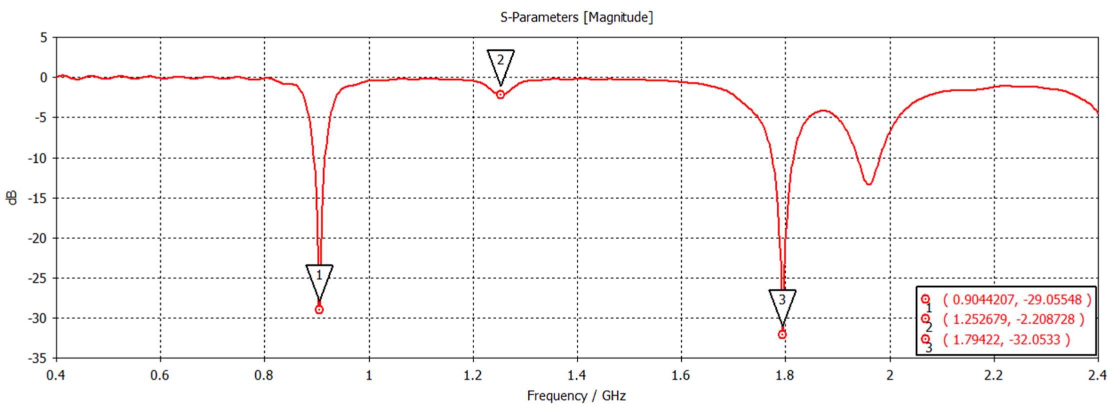

Figure 5. Patch Antenna with 3 shorting pins - S11 return loss.

Figures 6a y 6b show the results of the simulation done on CST of the radiation pattern in 900 MHz and 1800 MHz. The pattern in both bands is of broadside type, with the maximum in the same direction.

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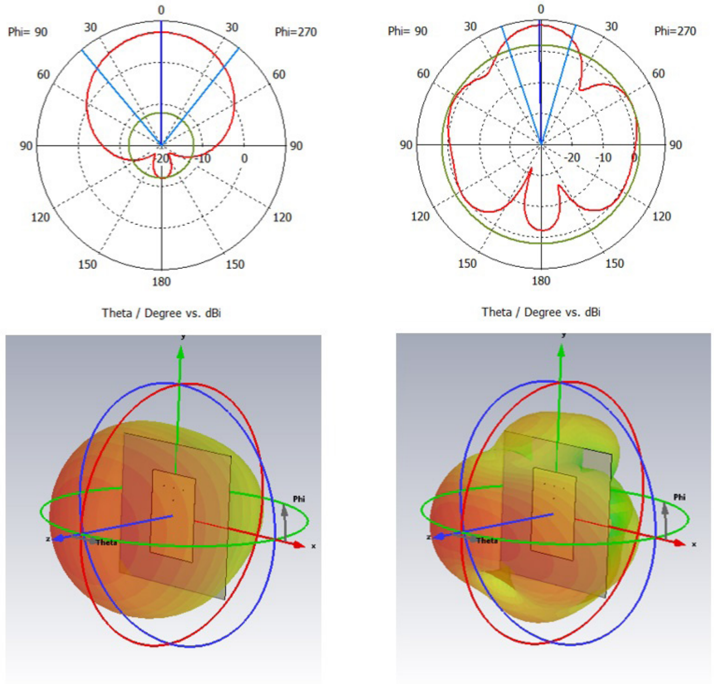
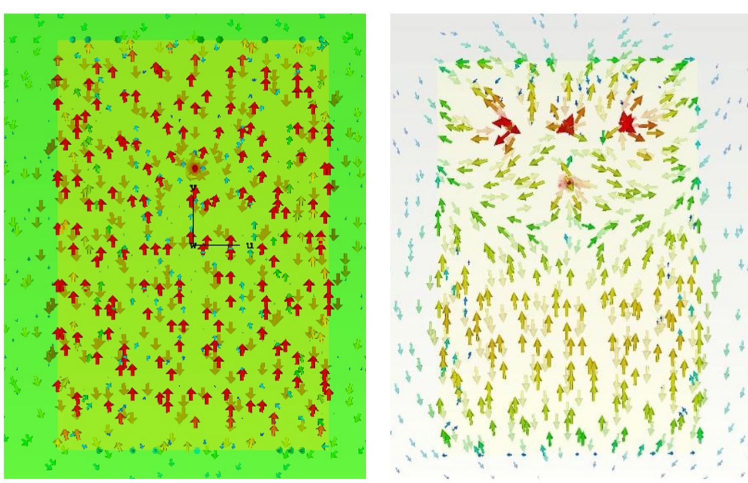
Radiation Pattern 900 and 1800 MHz



6a) 6b)

Figure 6 - Antenna radiation pattern in 900 MHz a) and 1800 MHz b).

A closer look at the surface current distribution on the patch surface, obtained from the simulation process, allows us to see how the perturbation introduced by the SPs affect them in the low band, Figure 7 a) and b).



7a) 7b)

Figure 7 – Surface current MSA without SP for 0.6 GHz a) and with 3 SP for 0.9 GHz b)

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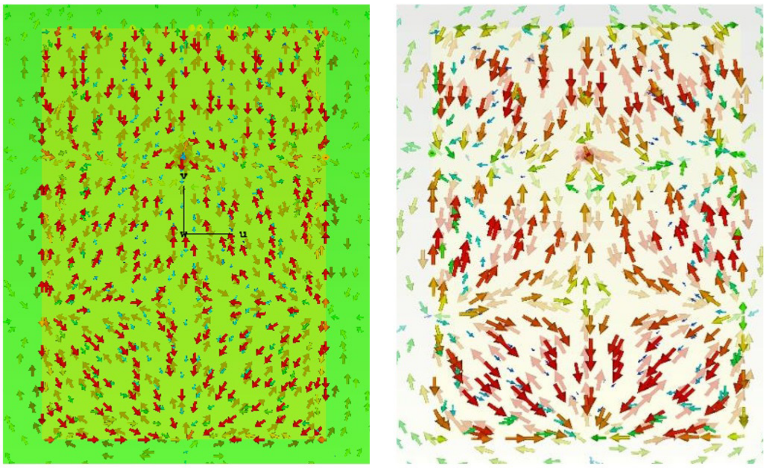
When analyzing the surface current distribution for the 1.8 GHz frequency, it can be seen how the introduction of the SPs, in the position indicated above, practically does not affect its surface current distribution, it can also be observed how the distribution adjusts to the TM30 mode, Figure 8 a) and b)



8a) 8b)

Figure 8 – Surface current MSA without SP for 1.8 GHz a) and with 3 SP for 1.8GHz b)

Measurements

The manufactured prototype is shown in Figure 9, and below are the results obtained, comparing the response of the simulated model and the measurements, S11 in Figure 10 and SWR in Figure 11. Table 3 summarizes the main parameters of the proposed antenna. To determine the bandwidth, VSWR < 3 was used.

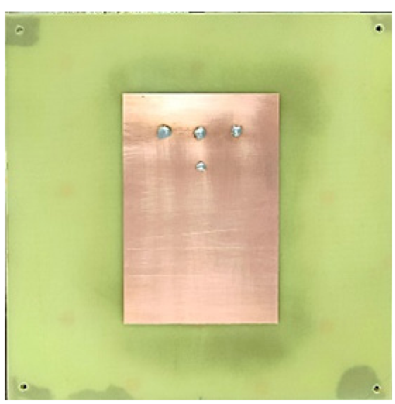


Figure 9. Prototype antenna

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FREQUENCY [MHz]	MEASUREMENT		SIMULATION		
	|S11| [dB]	BANDWIDTH [MHz]	VERTICAL PLANE [º]	DIRECTIVITY [dBi]	EFFICIENCY
890	-23.06	32	78.1º	7.19	0.14 (-8.3 dB)
1878	-22.87	76	34.7º	8.17	0.20 (-6.9 dB)

Table 3 – Summary of proposed design parameters

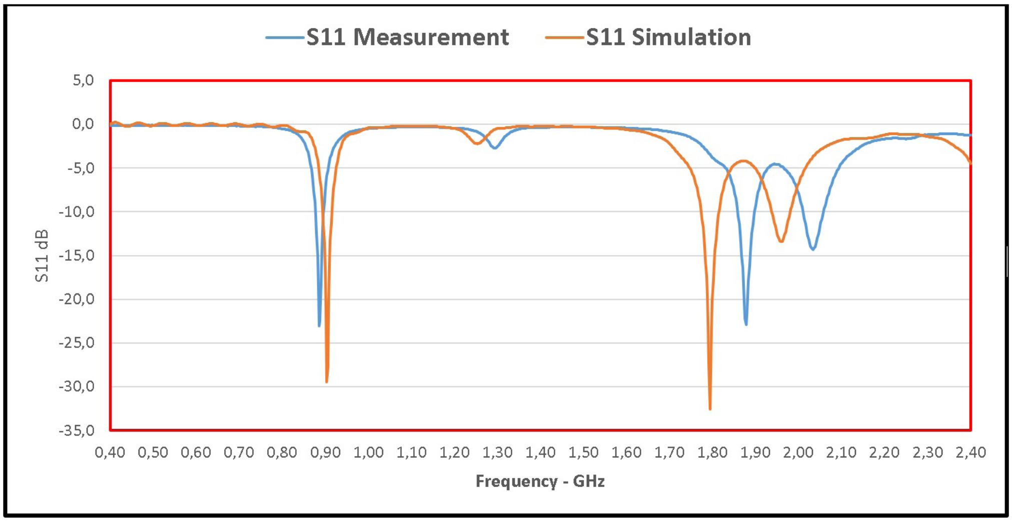

Figure 10 – Measured and simulated reflection coefficient S11 (dB)

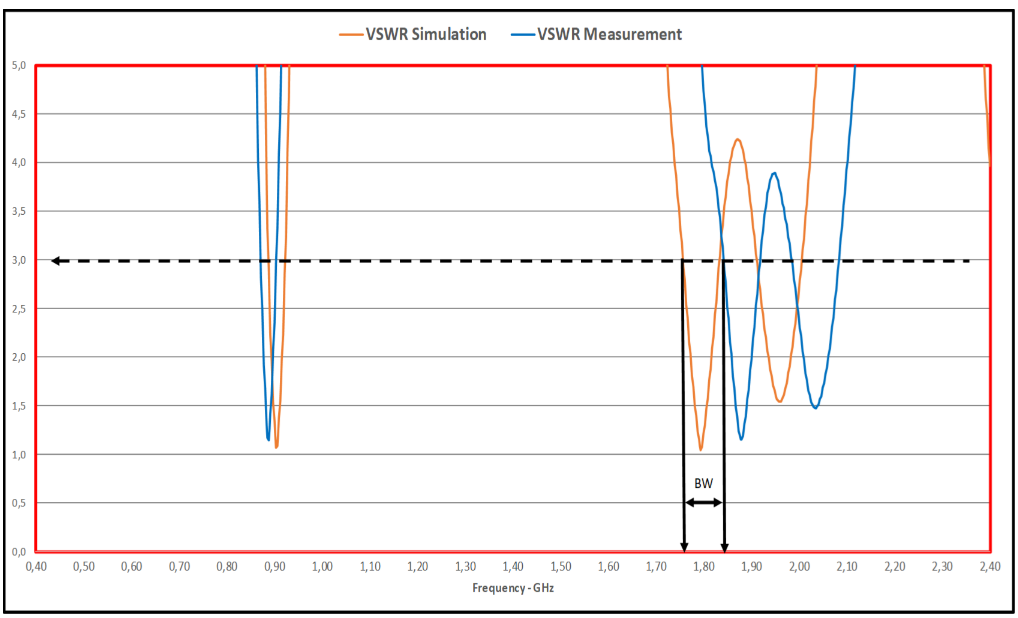

Figure 11 – Measured and simulated VSWR, vertical scale is in units.

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It was observed that the upper frequency of the prototype is shifted upwards by approximately 80 MHz compared to the simulation. To investigate this discrepancy, we began with the hypothesis that the substrate's permittivity might be lower than the default value specified in the simulator's Materials Library.

Based on this assumption, new simulations were conducted using a relative permittivity of ε=4 and varying the positions of the two external SPs, to adjust the lower band. By fitting the simulated response, it was determined that a relative permittivity of ε=4 and SP positions of y_2=12 mm, and y_3=12 mm better describe the prototype, as shown in Figure 12.

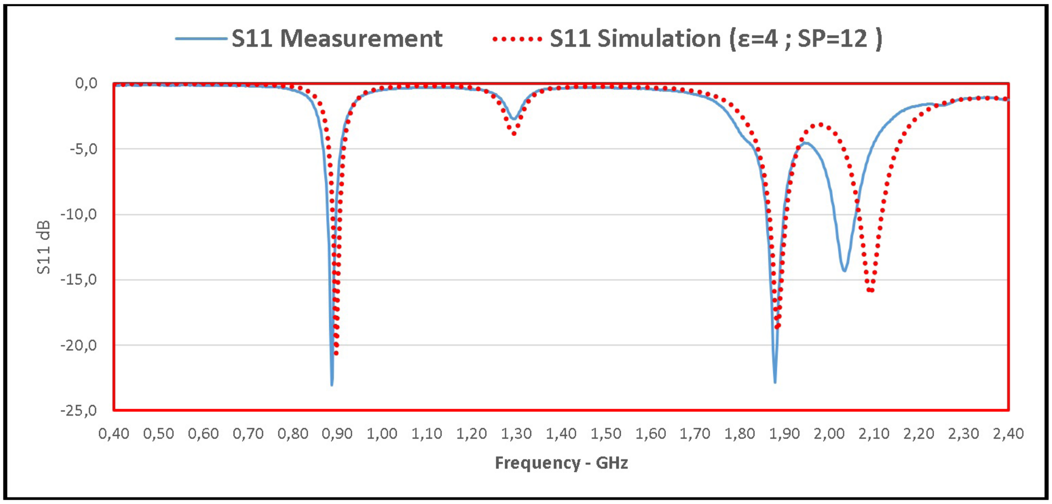

Figure 12 – Measured and simulated reflection coefficient S11 for ε = 4 and SP position +/- 12 mm

Discussion

The antenna of this work is characterized by its simple, compact design and good frequency response, therefore we consider it important to compare the results obtained with other relevant research in the same line of work.

Comparing the results obtained in this work with those of other authors, it is possible to observe in Table 4 an improvement in the bandwidth and return loss with respect to the development of Nunes et al (2000), but still without being able to reach the bandwidth achieved by Sriča et al (2012).

Research	Antenna	Technic	Bandwidth [MHz]	S11 [dB]	Directivity [dBi]
Nunes Moleiro	MSA dual band 900/1800 MHz	8 SP	3 / 9	-8.7 / 14.8	NA
Sriča Bonefačić	MSA dual band 900/1800 MHz	Slot	80/70	-22 / -32	3.8 / 9
This work	MSA dual band 900/1800 MHz	3 SP	32/76	-23.06/-22,87	7.19 / 8.17

Table 4 – Comparison with similar research

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Conclusions

A dual band patch antenna was developed for operation at 900 and 1800 MHz. The design was carried out using the microstrip antenna technique, simulating the calculation results and then validating them through measurements. Dual band operation has been achieved by modifying the lower frequency of the antenna's natural resonance by introducing 3 SPs in the position where the TM30 mode is null; the reflection coefficient in each band is less than -20 dB, considering a lower VSWR ≤ 2; the measured bandwidth is 32 MHz in the lower band and 76 MHz in the upper band, although a frequency shift of the constructed antenna with respect to the simulation is observed, something that should be evaluated in the future in order to reduce the observed differences. It would also be of interest to study other available materials besides FR 4 to evaluate their performance.

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