Bandwidth Enhancement of an Ultra Wide Band Planar Inverted F-Antenna

Pedro Paulo F. do Nascimento, Glauco Fontgalland, Raymundo de Amorim Júnior, Tagleorge M. Silveira and Rodrigo C. F. da Silva

***Abstract*—This paper presents the bandwidth enhancement of a Planar Inverted F-Antenna (PIFA) up to 1.55 GHz as results of adding slots in the radiator element of the structure. The S-Parameters, gain, and radiation pattern after analyzed were used for comparison purpose with a published PIFA model. The simulations were made using the commercial software *CST Design Studio.* As result, a bandwidth enhancement of approximately 53% was achieved.**

Keywords— Planar Inverted F-Antenna, PIFA, Simulation, Enhancement, Bandwidth

I. Introduction

The PIFA (Planar Inverted-F Antenna) is largely utilized in various applications, especially in the mobile phones**,** as it has low cost, reduced size, and easy fabrication and implementation. Typically, the PIFA consists of: (i) ground plane; (ii) planar element; (iii) short-circuit plate or pin; (iv) feeding mechanism.

The first publication of PIFA appeared in the IEEE literature in 1987 [1]. Historically, its name comes from the evolution of Inverted-F Antenna. With similar design, the PIFA has its developing more closely related to the Patch Antenna [2]. On the other hand, the Inverted-F Antenna is based on monopole antenna of a quarter of wavelength. The PIFA is an evolution of the Inverted-F Antenna with the substitution of the wire for a plate in order to enhance the bandwidth [3]. Despite that, the bandwidth is still somewhat small and many techniques and parametric analysis have been done [3-4]. These studies include the insertion of slots in the radiator [5] or in the ground plane [6], in order to enhance the bandwidth.

Motivated by the large application of PIFA in portable devices and by the limited results obtained by previous works to increase the broadband characteristics of the antenna, in this paper it is proposed the insertion of new slots in the design to enhance the bandwidth of an already published PIFA model.

II. Geometry Design

Using the published model proposed in [3], the slot insertion technique was used with the objective of improving the bandwidth of the model. In order to do that, firstly simulations were made in the commercial software CST Design Studio to recover the initial design and model parameters, as it can be observed in the Fig. 1. The FR4 was used as substrate on the ground plane. The parameters and dimensions used were the same as in [3] with the exception of Ws = 0.008λ and dr_x = 0.055λ, which were defined after optimization and have presented the best overall results in the 1.25 GHz – 3 GHz band. In [3] the wavelength was defined as λ = 100 mm (central frequency f_c = 3 GHz), but in this study it was adopted λ = 162.05 mm and, therefore, a central frequency of f_c = 1.85 GHz. The reason for this choice was the enhancement of the lower frequencies response. It must be observed that one of the parasitic element proposed in [3] was not add to the proposed structure, since it was not observed a significant contribution to the antenna.

Once the initial model was validated, the antenna's design by insertion of slots in the planar element and the ground plane was initiated. A careful parametric study and optimizations were made and it was possible to obtain a reasonable model, which can be seen in the Fig. 2, whose enhancements in the bandwidth are considerable.

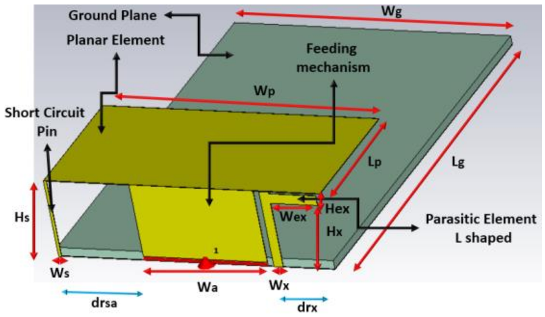

Fig. 1. Original Model as proposed in [3].

The modifications that presented the best results are: (i) Insertion of slots in the planar element and (ii) Removal of the FR4 Substrate. The inserted slots, A, B, and C, can be observed in the Fig. 2. Lastly, the FR4 substrate was removed and the simulations has showed a substantial improvement. The final dimensions were organized in Table II.

III. Results

For the original model, with λ = 162.05 mm, the operation frequency band observed was from 1.28 GHz to 2.29GHz. In the new model, the enhancement in the upper frequency to 2.83GHz was obtained, which represents an improvement of about 540 MHz in the bandwidth, i.e. a bandwidth enhancement of 53%, considering VSWR < 2.

The first slot inserted, Slot A, has the effect of reducing the reflection coefficient and slightly enhancing the bandwidth at higher frequencies. The addition of the second slot, Slot B, creates a resonance frequency at various frequencies according to the values chosen, and it greatly increases the bandwidth. The addition of the third slot, Slot C, shifts the resonance frequency and further expand the operation intervals to higher frequencies. The removal of the FR4 substrate and the insertion of the slots greatly enhances the reflection coefficient. All the curves for the reflection coefficient's results of the original model and the proposed model with insertion of slots, and FR4 substrate removal were presented in the Fig 3.

TABLE I. DIMENSIONS FOR THE FINAL MODEL

Dimension	Value (mm)	Dimension	Value (mm)
Wsl_A	0.031 λ	Lsl_A	0.136 λ
Wsl_B	0.112 λ	Lsl_B	0.019 λ
Wsl_C	0.031 λ	Lsl_C	0.098 λ
Ws	0.008 λ	dr_{SA}	0.055 λ
dr_{BC}	0.038 λ		

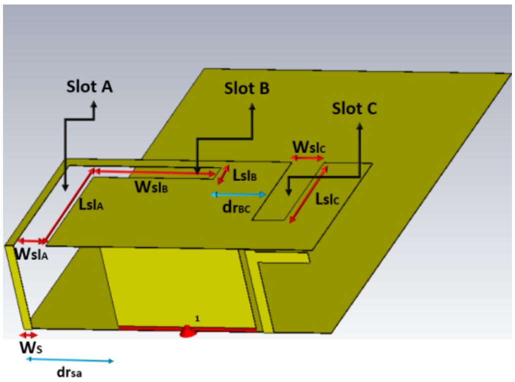

Fig. 2. Final model with the details of the slots and the FR4 substrate removal

The maximum simulated gain over frequency band was analyzed in the models and it is presented in Fig. 4. The new model has a great gain improvement in the frequencies up to about 1.8 GHz and a slight gain reduction above 2.2 GHz. Therefore, an equalized gain response was achieved. Looking at the S_{11} parameters these changes show that the slight gain reduction is accompanied with a greater reduction of the reflection coefficient value in the affected frequencies, i.e., a much better matching characteristic. These results are due to the many slots inserted, and consequentially, the reduction of conductive material, i.e., the radiation parts.

The radiation pattern simulated is presented in Fig. 5, a directional pattern was obtained in the azimuth plane whose Front to Back Ratio was 6.3 dB. And an omnidirectional pattern on the elevation plane, which is the expected result for the PIFA and therefore the changes did not impact on the radiation pattern of the antenna.

IV. CONCLUSIONS

A good enhancement of the bandwidth, approximately 53% in comparison with the original model, and a great gain improvement in the frequencies up to 1.8 GHz and a slight reduction in the frequencies above 2.2 GHz was observed.

One possible application of this antenna is in GPS systems, as the bands L1, L3 and L4 are all within the range obtained for the PIFA with the reduction of its weight by substrate removal.

With these results, the objective is to keep expanding the bandwidth in order to obtain smaller operation frequencies and to keep the miniaturization of the antenna. The next step is to build a prototype made with copper plates sustained with an electromagnetic invisible material, such as Styrofoam, for structural support and measure the antenna's parameters.

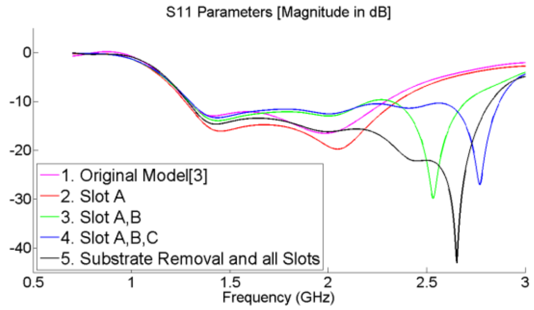

Fig. 3. Curves for simulated S11 Parameters

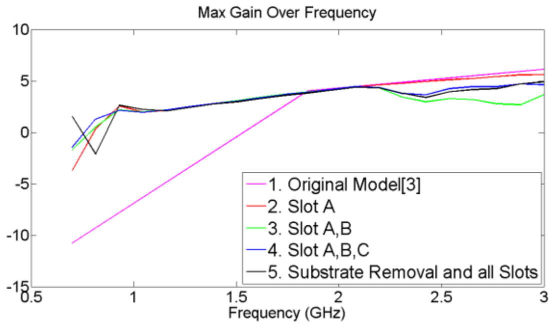

Fig. 4. Maximum simulated gain over frequency; for the analyzed models

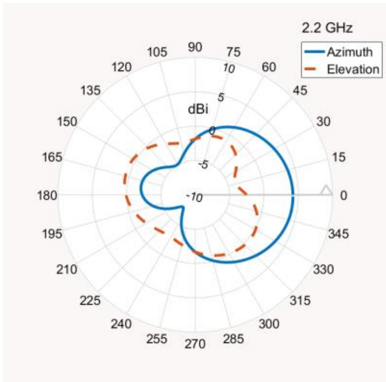

Fig. 5. Radiation pattern for the 2.2 GHz frequency for both the azimuth and the elevation plane

REFERENCES

[1] Tokio Taga, *Performance analysis of a built-in planar inverted F antenna*, IEEE Journal on Selected Areas in Communications, Vol. 5, No. 5, pp. 921-929, June 1987.

[2] J. A. Ray and S. R. B. Chaudhuri, *A review of PIFA technology 2011 Indian Antenna Week (IAW)*, Kolkata, 2011, pp. 1-4. doi: 10.1109/IndianAW.2011.6264946

[3] H. T. Chattha, Y. Huang, M. K. Ishfaq and S. J. Boyes, *Bandwidth enhancement techniques for planar inverted-F antenna* in IET Microwaves, Antennas & Propagation, vol. 5, no. 15, pp. 1872-1879, December 9 2011.

[4] H. Chattha, Y. Huang, M. Ishfaq and S. Boyes, *A Comprehensive Parametric Study of Planar Inverted-F Antenna*. Wireless Engineering and Technology, Vol. 3 No. 1, 2012, pp. 1-11.

[5] L. K. Sahu and R. Jyoti, *Design and development of triple band U Slot PIFA antenna*, 2014 IEEE International Microwave and RF Conference (IMaRC), Bangalore, 2014, pp. 144-147.

[6] C. Picher, J. Anguera, A. Andújar, C. Puente and S. Kahng, *Analysis of the Human Head Interaction in Handset Antennas with Slotted Ground Planes* in IEEE Antennas and Propagation Magazine, vol. 54, no. 2, pp. 36-56, April 2012.

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