WIDEBAND MONOPOLE ANTENNA POR HF AND VHF

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ABSTRACT

The objective of this thesis is centered in the synthesis of a method of design of broadband monopole antennas for the range of HF and VHF. The antenna must have a practical size to be installed in a mobile station (automobile) and the power must radiate omnidirectionally for transmission of interference in the frequency band of interest (20-100MHz).
There are several antenna topologies that can be used, each with a variety of options of loaded sections and of them the antenna selected was the traditional monopole antenna of whip type, due to its practical size to be installed in a mobile station and the stability of its structure.
With the help of CST Studio Site 2015 software, the simulation and optimization processes of the proposed antenna were carried out. This antenna was numerically optimized taking into account the load elements and considering the return losses (S11), the voltage standing wave ratio (VSWR) and the gain value, among other parameters. The results of the optimal load solution for the monopole antenna are compared to each other to arrive at the best design. The best result obtained is the monopole antenna with four load sections distributed along its length. The simulation results should show that the proposed antenna to meet the specifications of the voltage standing wave ratio below 3 (VSWR<3:1) over the entire frequency band specified.

KEYWORDS : *Antenna, monopole, wideband,VHF.*

I. INTRODUCTION

Antennas of the dipole, monopole, loop type and their associated arrays are the most common in the VHF frequency band. These can be used in communication systems, broadcasting, measurement of electric and magnetic fields in the radio frequency bands up to 2GHz and others. The monopole is an antenna derived from the dipole, it is formed by a rectilinear arm that radiates the electromagnetic waves, with an orientation of the electric field in the same direction of its axial axis [1] and [2]

Antennas of the monopole type are generally antennas that have a high mobility, for certain dimensions can be located in automobiles as part of radio systems and other services, some of them have high demands for the parameters that determine the bandwidth of work, in the order of 80 to 100 MHz of bandwidth.

II. PROPOSED DESIGN METHOD FOR BROADBAND MONOPOLE ANTENNAS IN THE VHF FREQUENCY RANGE

This document describes the design method applied to a broadband monopole antenna in the frequency range from 20 to 100MHz, with efficiency. In correspondence with [3] and [4], a way to accomplish the task, is inserting with suitability in the structure of the monopole passive loads to concentrated parameters, such as parallel circuits R, L and C. In the investigation was used the computer program for the design and simulation of passive and active circuits of RF and Microwave CST Microwave Studio of the company CST (Computer Simulation Technology) [5]. This is a specialized tool that includes the simulation of the electromagnetic field in 3 dimensions, based on the use of the mathematical method of calculating finite differences in the time domain (FDTD).

During the optimization process, the algorithm of the aforementioned program, called the Trust Region Framework, was used, which evaluates the parameters of the antenna design and allows modifying them depending on the design goals proposed in order to obtain an optimal adaptation in the width of interest band. As a reference parameter during the design, the standing wave ratio (SWR) was established in the antenna input load plane, for a value less than 3 within the specified band, with a good coupling to the input impedance of the transmission line.

In response to the experiences acquired during the design, simulation and assembly of the antenna, the following steps are proposed to shape the method: [6]

1. Selection of an initial tuning frequency value of the antenna near the lower limit of the band of interest.
2. Selection of the initial length of the unloaded monopole (Linicial), which is determined by its value corresponding to
   λ / 4 of the selected initial frequency.
3. The initial radius (Rinic) of the monopole equal to Linicial / 100 is calculated.
4. The number of loads (n) chip RL that are going to be located in the antenna is defined, taking into account that the increase in the number of loads increases the bandwidth, but it may affect the efficiency of the antenna. It is recommended that the value of n be the minimum and sufficient amount to achieve the required bandwidth.
5. The initial values of the elements R and L that will be used in each load are established, adjusted to the commercial values of the series. An initial value of R = 100Ω that is defined in the commercial series is recommended for this frequency range. For the inductance value, inductance elements can be used, which together reach values between 1 μH and 2 μH. Because the inductance values of the elements must have been measured within the range of the frequency band of interest, the selected inductor has a value of 560 nH, capable of operating between 1 MHz and 900 MHz [6].
6. Determination of the coordinates (L1 and L2) of the loads selected taking into account the initial length of the monopole (See Fig. 1). The location and space allocated to each load is defined by the following system of linear equations (1 and 2):

$$2 \cdot L_1 + (n-1) \cdot L_2 + n \cdot d = \frac{\lambda}{4} \qquad (1)$$

$$L_1 - \left(\frac{\lambda}{2}\right) = L_2 \qquad (2)$$

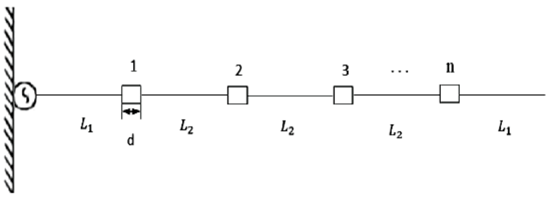

Fig 1: Structural representation of the antenna

Where:

L1: The sections between the initial and final ends of the antenna and the first loads in both directions.
L2: The intermediate sections between the loads of the antenna
d: Physical space that is included within the Linitial = λ / 4 and that allows to locate the load physically.
n: Number of loads

7. Simulation and optimization of the structure of the antenna using the CST Microwave Study program.

During the simulation process it is recommended to use the following independent variables:

1. Antenna radius (R).
2. Initial Gap (G) (space between the ground plane and the lower end of the antenna, the antenna being perpendicular to the selected ground plane).
3. Values of the resistors R1, R2, R3, ..,Rn. These resistances are the elements parallel to each inductance, in each of the loads. See Fig. 2.

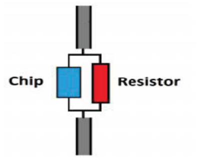

Fig 2: Internal structure of one of the loads to be used in the antenna, where the resistance can be seen parallel to a miniaturized "chip" inductance of 1μH to 2μH.

As dependent variables to control the results of the simulation and optimization process were used: S11, SWR, Zin (real and imaginary parts of the input impedance), gain and directivity.

III.DESIGN MONOPOLE A PROTOTYPE ANTENNA TYPE BROADBAND FREQUENCY RANGE FROM 20 MHZ TO 100 MHZ LOADED WITH 4 PASSIVE LOADS IN ITS STRUCTURE.

To carry out the design of the selected prototype antenna, the following initial data were established:

1. The frequency of 30 MHz was selected as the design initial frequency in the range of 20 MHz to 100 MHz.
2. The initial length of the unloaded monopole (Linicial) corresponds to aLinitial = λ / 4 = 2500mm.
3. Initial radius (Rinitial) of the monopole equal to Linitial / 100.Taking into account that the initial length of the antenna is 2500mm fulfilling the condition then the Rinitial = Linitial / 100 = 25mm.
4. The number of chip loads RL (n) that will be placed on the antenna is 4. This decision was recommended to meet the criterion of the minimum amount and necessary to achieve the required bandwidth. The increase in the number of these can threaten the efficiency of the antenna. Taking into account the experimental results obtained in [3], n = 4 was selected, which corresponds to the design of a monopole antenna for broadband in the frequency range of interest.
5. 5. The initial values of the elements R and L that will be used in each load are: R = 100 Ω and L = 1.12 μH. The value of the inductance L was selected taking into account that the inductance of the range between 1 μH and 2 μH, can be conformed by two inductances

connected in series equal to 560nH which is value that is referred to in the commercial series and according to the datasheet consulted in [7], were measured at the 25MHz frequency.

6. Determination of the coordinates (L1 and L2) of the loads selected taking into account the initial length of the monopole (See Fig.1 and equations 1 and 2):Data: Linitial = λ / 4 = 2500mm, L1 = 497.5mm, L2 = 495mm, n = 4, d = 5mm.
7. The dimensions of the long and wide ground plane are 1.5λ x 1.5λ, according to the recommendations of the Magus Antenna software [8] and the thickness of the ground plane can be chosen as T = 5mm.
8. G = 10mm (space available for the location of the antenna input port), this value is an initial data that will be used as an independent variable for the optimization of the design.
9. The material chosen for the radiating elements of the antenna and the ground plane will be considered as perfect conductor (PEC).

In Fig. 3, the simulated antenna with the data applied in the CST simulator program is shown.

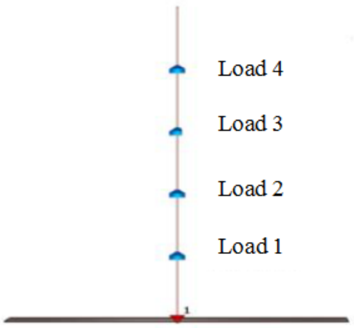

Fig3: Structure of the antenna in the user environment of the CST simulator program. 3D side view.

In Fig. 3 can be seen: The ground plane (PEC), the Gap selected, the four loads and sections L1 and L2 of the antenna, in correspondence with Fig. 1.

After the optimization process was carried out, the following results were obtained:

1. Return losses (S11). See Fig. 4.

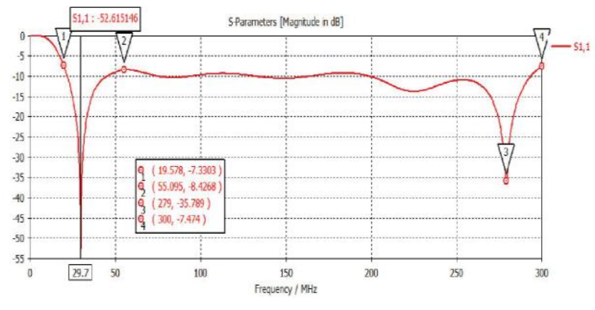

Fig4: Graphical representation of the behavior of parameter S11 after the optimization process in the CST simulator program.

2.Stationary wave ratio (SWR). See Fig. 5.

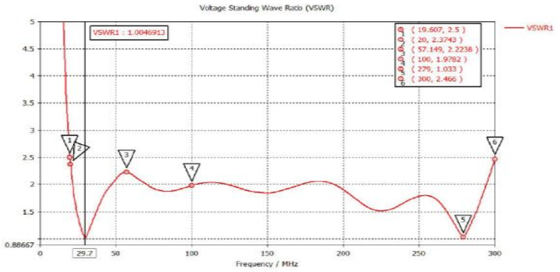

Fig 5: Graphical representation of the behavior of the SWR parameter of the monopole antenna optimized for 4 RL chip loads (Linitial = 2500mm).

As seen in figures 4 and 5, the return losses have an optimal value (S11 <-50dB), as does the SWR (close to 1) for the resonance frequency. The band of interest was defined by a level of SWR = 2.5 reference lower than the level of 3 initially recommended. A bandwidth of 280MHz was achieved higher than the one proposed in the design requirements for 175% with respect to the center frequency of the band obtained, thus meeting the proposed design specifications.

3.Antenna input impedance (Z11). See figures 6 and 7.

As shown in figures 6 and 7, for the design resonance frequency of the antenna, the real part of the impedance has a value close to 300 Ω and close to 0 Ω for the imaginary part, this result is good because evidence that the antenna was correctly coupled to the resonance frequency. For the rest of the frequencies, the complex value of the impedance fluctuates close to 200Ω impedance, this allows the coupling in those frequencies to 50 Ω lines, whenever a 4: 1 coupling transformer is used.

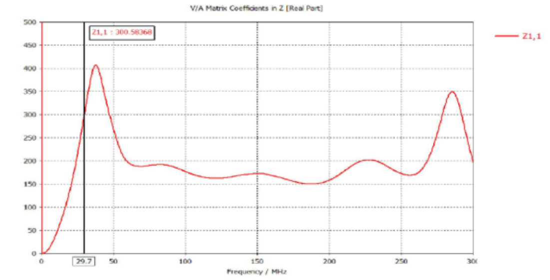

Fig 6: Real part of the input impedance of the antenna optimized in the frequency range of the band of interest.

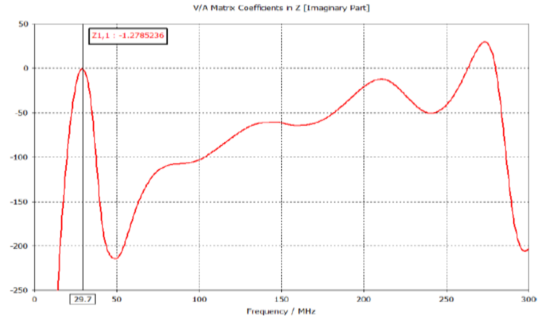

Fig7: Imaginary part of the input impedance of the antenna optimized in the frequency range of the band of interest.

4.Radiation diagram of the antenna. See Fig. 8 a) b) and c).

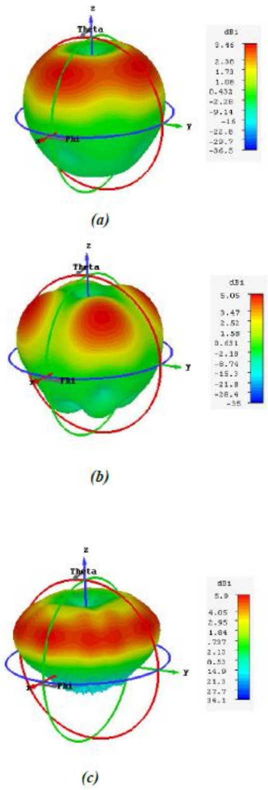

Fig 8: Graphic representation of the directional diagram of the antenna at different frequencies a) 20 MHz,b) 30 MHz and c) 100 MHz.

Regarding the characteristics shown in Fig. 8 a), b) and c), it can be seen that an increase in frequency allows the appearance of secondary lobes in the radiation pattern, and therefore deterioration in the radiation characteristics of the antenna.

5. Gain and radiation efficiency of the antenna. See Fig. 9.

In Fig. 9 an increase in gain is observed with the increase in frequency. It should be noted that the gain presents small values in the whole band of interest (negative). The maximum gain for 20 MHz, 30 MHz and 100MHz are respectively: -5.6952dB, -3.5831dB, -0.51459dB respectively.

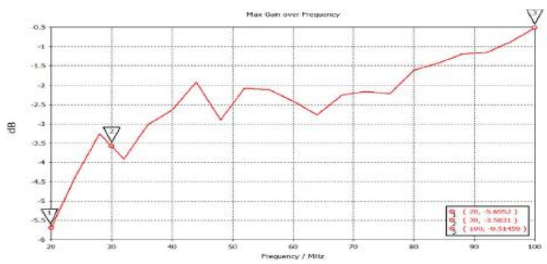

Fig 9: Graphical representation of the behavior of the gain within the band of 20 MHz up to 100 MHz.

As shown in Fig. 10, efficiency has a similar behavior to gain due to the directly proportional relationship between both parameters. It is observed that the efficiency is not good because the value of the total efficiency ranges between 10 and 20.5%, while the radiation efficiency presents values between 11.5 and 23.4% for the band of interest which means that the antenna is not very efficient.

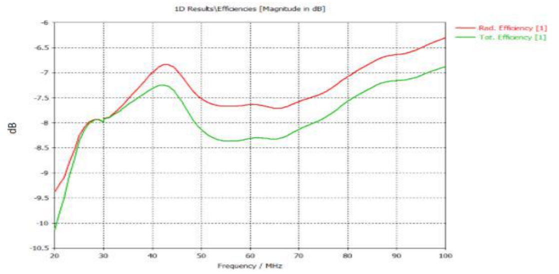

Fig10: Graphical representation of the behavior of the efficiency of the antenna in the frequency range from 20 MHz to 100 MHz.

After obtained the values of resistance in loads in the process of optimization, these must adjust to the commercial values for the later construction of the antenna. See Fig. 11.

Fig11: Image of the prototype broadband monopole antenna built with 4 inserted loads, where you can see all the elements of its structure including the recommended 4: 1 coupling transformer

IV. Conclusions

By means of the proposed design method to improve the bandwidth of the monopole antennas, it was possible to obtain the specifications proposed at the beginning of the chapter, which implies that by inserting load sections chip RL it is possible to obtain a broad bandwidth in the range from 20 to 100MHz, and even for higher frequencies up to 300MHz.

In the initial phase of this project, several topologies of monopole antennas were investigated. The traditional monopole antenna of λ / 4 is selected, due to its ease of construction, flexibility and that its structure can allow an easy installation in a mobile station (vehicle).

To achieve a broadband behavior, the introduction of four RL chip load sections was carried out along the structure, where the component values were numerically optimized to find the best suitable design for a band antenna wide VHF.

The simulations of this topology made in the CST reveal different design criteria. The addition of loads from an inductor and resistor in parallel (loads RL) in an antenna, increases the capacity of the antenna to radiate energy at different frequencies.

The use of RL loads are studied using small inductive loads in the chip form increasing the inductive loads at the limit of the required operating frequencies (RL chip loads). The position of the loads RL, magnitude and quantity are investigated in a monopole antenna and compared in the design with which the length of the antenna was increased. The best design topology found was that of a simple monopole antenna, with 4 RL load sections added along its length. Each RL section consists of series inductors that are commercially available and a resistor in parallel to these inductors.

Finally, it can be affirmed that in this thesis a method of design of broadband monopole antennas is described, so it can be affirmed that the objectives of the investigation were fulfilled.

Future lines of research include the construction process of the proposed monopole antenna, through the use of better components located to handle high power levels up to 200W, as well as evaluating possible changes in the structure of the monopole antenna in order to improve substantially the efficiency of it.

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