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A Compact Log-Periodic Monopole Array installed on top of vehicle

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Abstract

One serious drawback of Log-Periodic Dipole Array (LPDA) to operate down to VHF frequencies is their large size and difficulty to install on the roof of a vehicle. This could be tackled by reducing the LPDA to a monopole array reducing in one dimension the antenna by half. However converting dipoles to monopoles with the aim to use the conductor surface of the ceiling of the vehicle is not a simple process. Eliminating half of the LPDA dipoles changes the feeding mechanisms of the array. Several authors starting from mid 1960's proposed solutions which were not successful. In this effort a new type of Log-Periodic Monopole Array (LPMA) was developed based on the structure proposed by James M. Buzbee.

Several monopole geometries were tried in simulator. It is shown that the use of a full wavelength horizontal non-radiating structures allows the proper operation of the array. Theoretical simulation results as well as measurements will be presented.

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1 Introduction

The use of wideband VHF Log-Periodic Antennas operating down to 30 MHz frequencies installed in vehicles is required in many military applications. This rather low frequency requires antennas sizes of 5m of the largest dipole and boom length at least 7 m. Such antennas usually are mounted on expendable masts which require manual installation, first by placing the dipoles on the boom and then placing the boom with the dipoles on the top of the mast. Usually this process of installation needs at least 25-35 minutes which could be extremely important in an operational situation. In order to avoid this manual installation while keeping the same electromagnetic characteristics of the traditional log periodic dipole arrays, a new type antenna consisting of log-periodic monopole array was designed, constructed and measured.

In order to reduce the antenna size several techniques are proposed from 1960. The main aim is to reduce the size of antenna but without changing the bandwidth, radiation pattern and others characteristics.

A low-profile log-periodic monopole array antenna is introduced in [5] where the monopoles are of the same height but loaded with top hats of different sizes to achieve the required resonant frequency. In [6], a procedure to degrease the size of log-periodic dipole array has been presented where a short-circuited cylindrical hat cover installed at the end of each arm of the antenna which based in [12] a procedure to degrease monopoles. A novel miniaturized ultra wideband LPDA has been introduced in paper [7] and has been simulated. The proposed solution contains an arm that consisted by main-arm, a vertical-arm and a secondary-arm. In [10] T-top loaded dipoles are implemented to achieve a reduced size elements by half. In [1] a printed log-periodic Koch-dipole array introduced where Koch prefractal elements in a miniaturized wideband antenna used for first time.

Other methods are described in [3] and [9] a meander log-periodic antenna was designed, constructed and measured. In [4], demonstrated theoretically and experimentally a LPMA with a meander line modulated-impedance microstrip feeder. For more details about antenna design we refer to the book [2].

In Section 2 we describe the preliminary notes about the Log-Periodic Monopole and Dipole Array. Detailed construction of LPMA installed on a vehicle top is described in Section 3. Simulations of the proposed designs are presented in Section 4. In Section 5 measurement results are given. Finally, some conclusions are involved in section 6.

2 Preliminary Notes

Consider a LPDA antenna in Figure 1, where $L_1,L_2,\ldots,L_n$ are the lengths of the dipoles and $R_1,R_2,\ldots,R_n$ are the distances of the top K from the corresponding dipoles.

If $L_1>L_2>\ldots>L_n$ and $R_1>R_2>\ldots>R_n$ then we have

$$\frac{L_2}{L_1}=\frac{L_3}{L_2}=\ldots=\frac{L_n}{L_{n-1}}=\tau\ , \tag{1}$$

$$\frac{R_2}{R_1}=\frac{R_3}{R_2}=\ldots=\frac{R_n}{R_{n-1}}=\tau\ , \tag{2}$$

where the tape radio τ has value less than one. Also if d_n is the distance between the dipoles n and n+1 orders

$$d_n=R_n-R_{n+1}\,, \tag{3}$$

then

$$\frac{d_n}{d_{n-1}}=\tau\ . \tag{4}$$

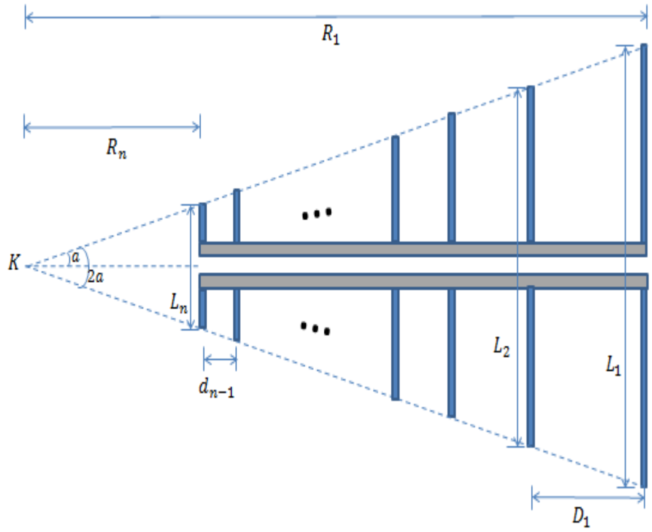

Figure 1: Parameters of Log-Periodic Dipole Array.

The density of dipoles is described from the spacing ratio σ

$$\sigma = \frac{d_n}{2L_n}, \tag{5}$$

Another geometrical parameter that characterize the LPMA antenna is the angle α (half apex angle) which the is half of the angle that defined by the lines pass through outer boundary and from the corresponding triangle we have

$$\alpha = \tan^{-1}\left(\frac{L_n}{2R_n}\right). \tag{6}$$

From (1) and (4) - (6) we take

$$\alpha = \tan^{-1}\left(\frac{1-\tau}{4\sigma}\right). \tag{7}$$

At the LPMA the ground plane near the antenna change the radiation pattern due to the reflection of the metallic surface. Ground plane creates an image of the monopoles vertically to the boom. Due to the ground plane we created virtually a full length antenna (Figure 2).

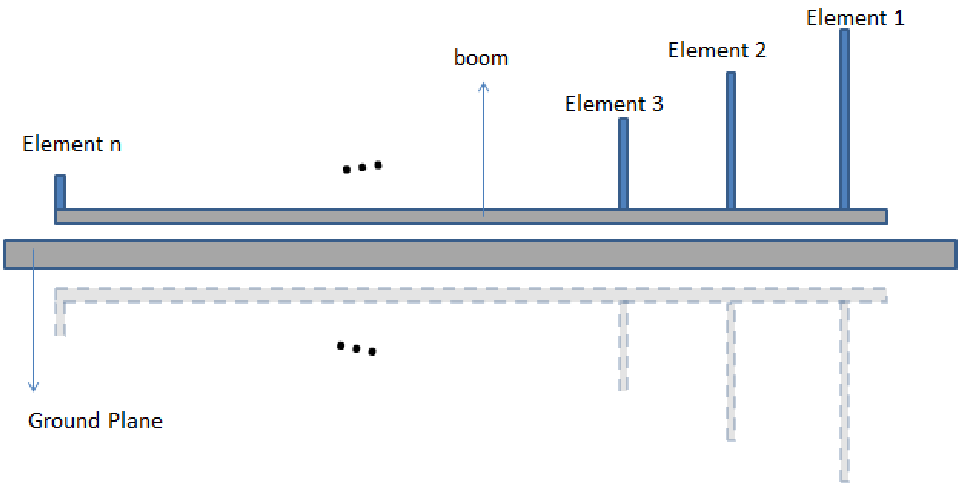

Figure 2: Image of Log-Periodic Monopole Array with ground plane.

3 Design LPMA

The principles we relied on to construct the antenna are to design a compact, ready to use in less than 5 minutes and a smart way to mount in a top of vehicle so it could be transferred in any place fast. This led us, to design a LPMA (Figure 3) to take advantage of lighter construction and smaller dimensions in compare to classic antenna. We have tested in simulation much proposed antenna geometries until we ended up in one that fulfills the requested performance for our frequency range.

3.1 Proposed solution

The main construction steps for the LPMA antenna are the following (Figure 4). At the top of the vehicle we have installed a trapezoid ground plane, with bases 4 m and 0,8 m and height 3,5 m, which consist of metallic grid with 25 mm square holes. Each boom has length 3,5 m and its cross section is an rectangle with dimensions 20 mm × 40 mm. The two booms, where the elements based, are

located 6 cm over the ground plane and the distance between them is 20 mm.
All elements have a part of them fixed length which is implementing with aluminum tube for 150 mm and the remaining metal surface needed is completed with a flexible cable.

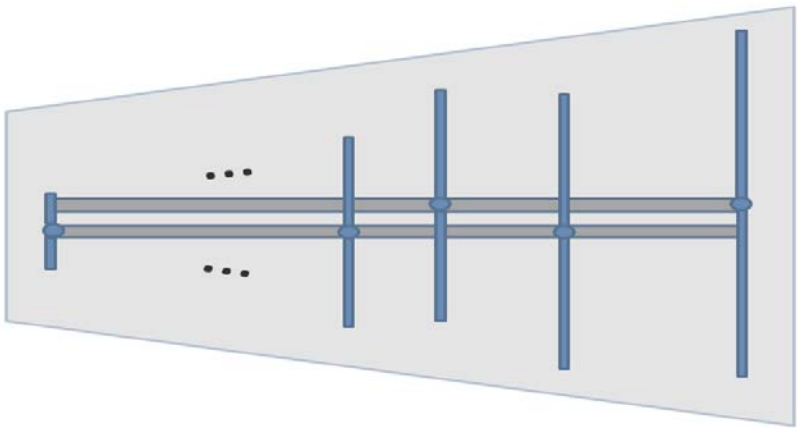

Figure 3: Top view of the proposed antenna.

On the back side of the construction where we could find the longest monopole, there is a pillar 0,5 m long that rises up to 15 m. A rope is extended from the top of the pillar to the front of the antenna, where the smallest element is located, and forms a rectangular triangle. From the hypotenuse of the triangle are hung ropes vertically relative to vehicle top, as many as the elements of the antenna. Part of the rope consists of a metal cable which is connected to the aluminum tube completing the physical size of each element. On both sides of each element extends cable of equal length with the monopole. Also part of the trapezoid ground plane is foldable such that any part not extended beyond the vehicle.

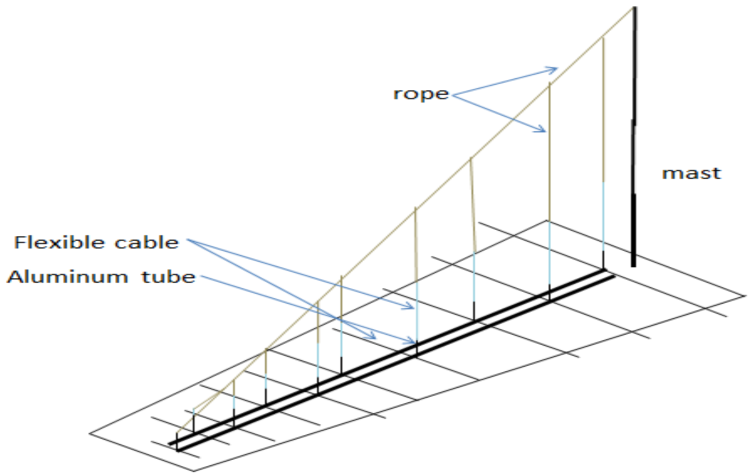

Figure 4 Prospective view of the LPMA antenna.

This is a smart idea to reduce the actual size of the LPMA antenna (Figure 5) during transportation, permitting city transit (below bridge, etc.) and off-road routes (forest path).

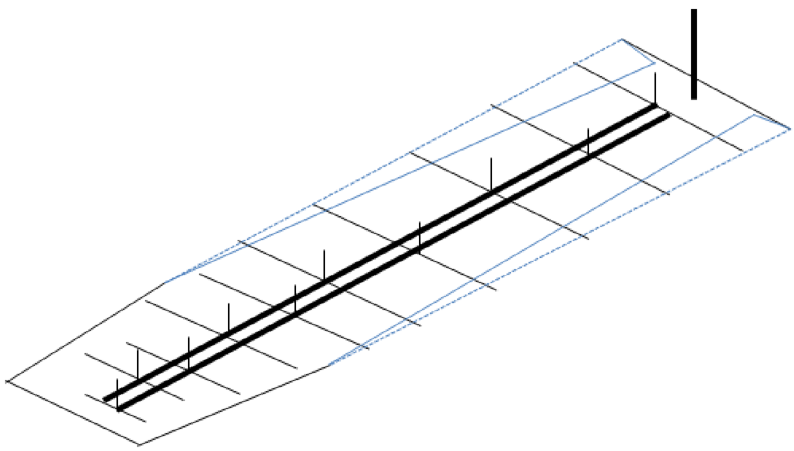

Figure 5: Prospective view of the LPMA antenna.

This above design of LPMA with horizontal structure simulated to verify the performance and later constructed and measured.

3.2 Antenna simulation tested

In our effort to create a LPMA that fulfills the objectives which we set in the begging of the section we tested much more designs.

Below we will present the most basic ones.

1. LPMA with boom below the ground plane with small holes for transit the elements.

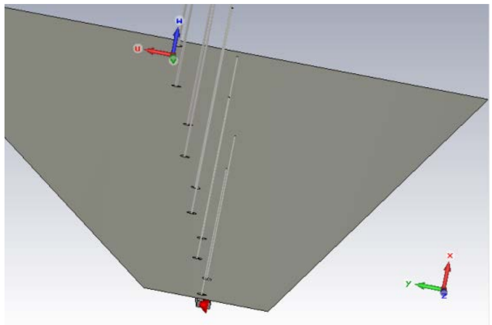

Figure 6: Design LMPA with boom below ground plane.

2. LPMA with boom above the ground plane.

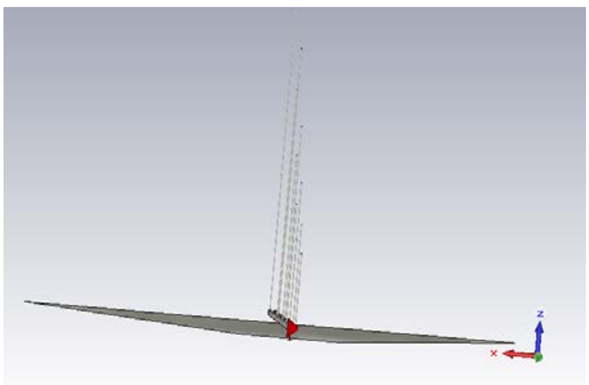

Figure 7: Design LMPA with boom above ground plane.

3. LPMA with two sources. First source is between the boom and the ground plane across the smaller element at the boom which the element is missing. The second source is placed in the other boom, between the boom and the ground plane intermediate the smaller element and the next. The two

sources have opposite polarity.

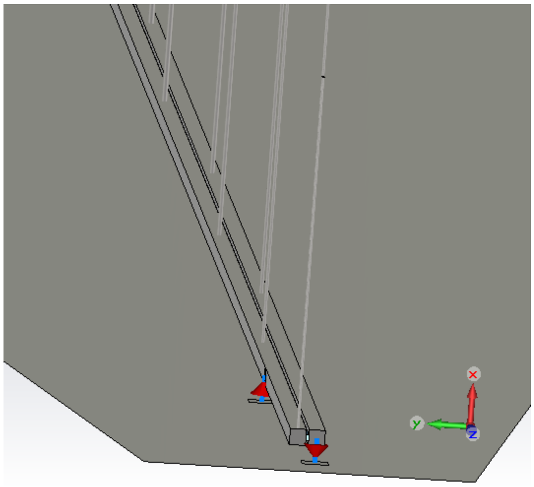

Figure 8: LPMA with two sources.

4. LPMA with one ground in the first element (the largest) and two sources in smallest element. The sources are connected between each boom and the ground plane with opposite polarity. Also, across the largest element, in the boom which the element is missing we place a ground between the boom and the ground plane.

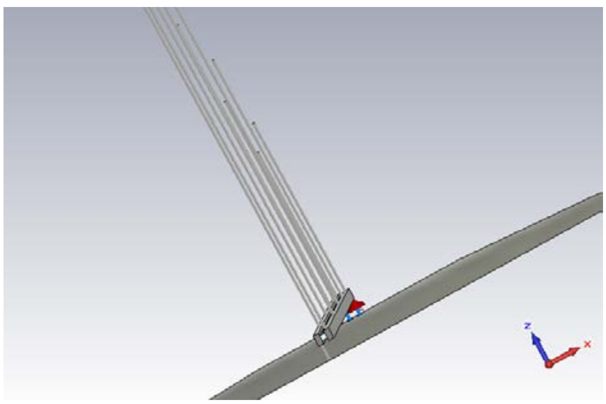

Figure 9: LPMA with two sources and one ground.

5. LPMA with ground plane and grounds, as many as the elements we have and placed across where the elements are missing.

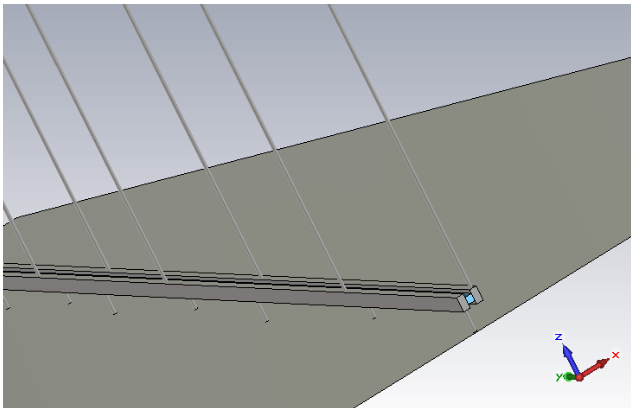

Figure 10: LPMA with grounds.

6. LPMA with horizontal structure proposed design and construction detailed described.

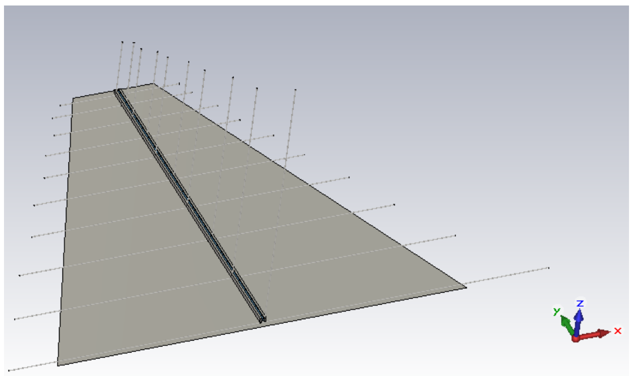

Figure 11: LPMA with horizontal structure.

7. LPMA with horizontal structure, where we reduced 10% the length of the horizontal structure in each side.

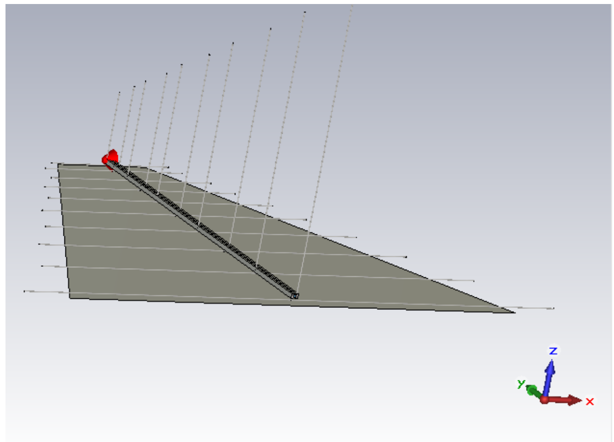

Figure 12: LPMA with horizontal structure 10% reduced.

8. LPMA with horizontal structure where we reduced 20% the length of the horizontal structure in each side.

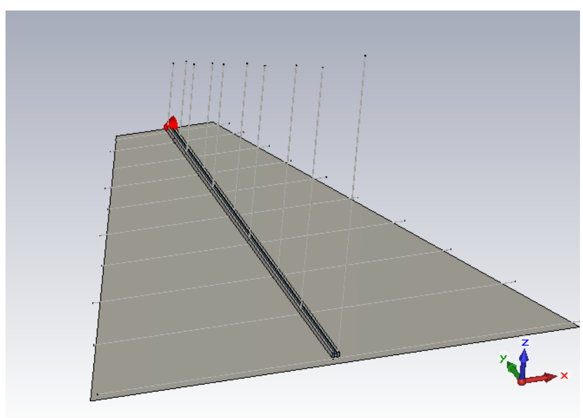

Figure 13: LPMA with horizontal structure 20% reduced.

4 Simulation

Simulations of all models of LPMA designs were performed in CST studio. The frequency range that antenna was tested is 1-100 MHz. The indicator where relied to evaluate the performance of the antenna is the S_{11} parameter. The graph must be below -5dB continuously as well as having a long interval below -10dB.

Below we have the all simulations for each model design:

Design LMPA with boom below ground plane.

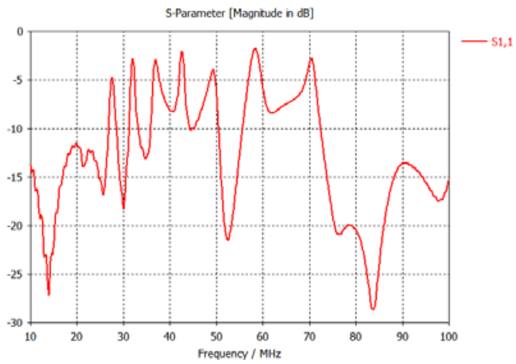

Figure 14: S_{11} of figure 6 – Satisfactory results

Design LMPA with boom above ground plane.

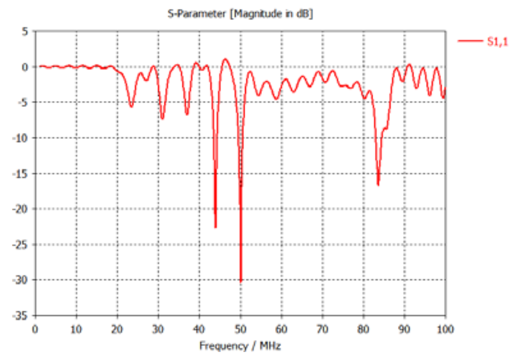

Figure 15: S_{11} of figure 7 – Poor results

LPMA with two sources.

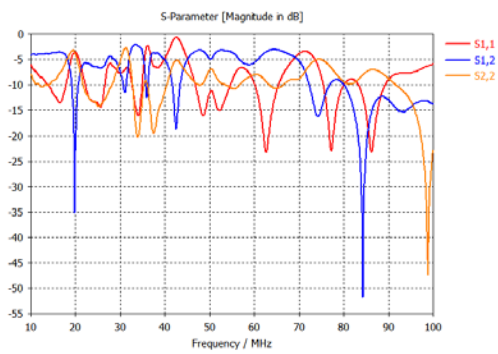

Figure 16: S_{11} of figure 8 – Poor results

LPMA with two sources and one ground.

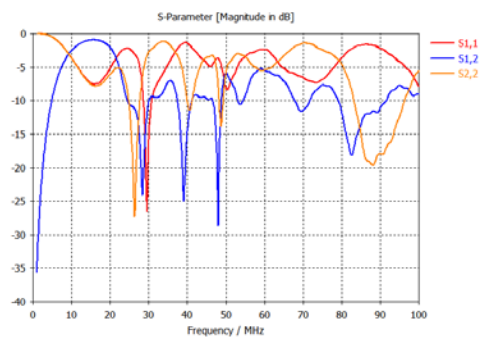

Figure 17: S_{11} of figure 9 – Poor results

LPMA with grounds.

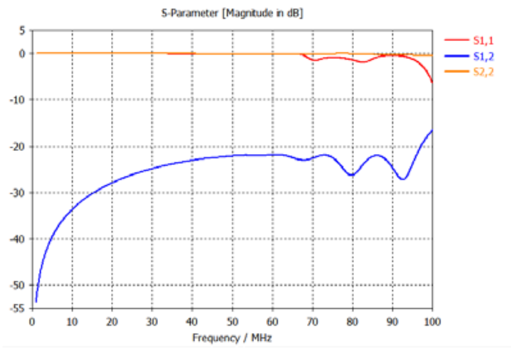

Figure 18: S_{11} of figure 10 – Poor results

LPMA with horizontal structure.

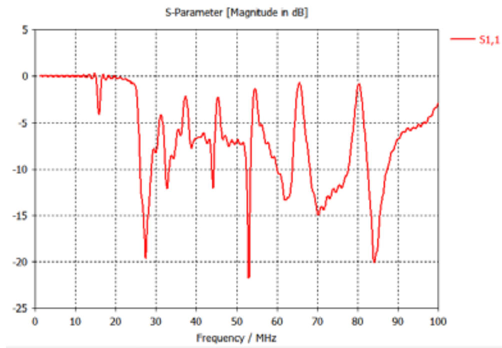

Figure 19: S_{11} of figure 7 – Good results

LPMA with horizontal structure 10% reduced.

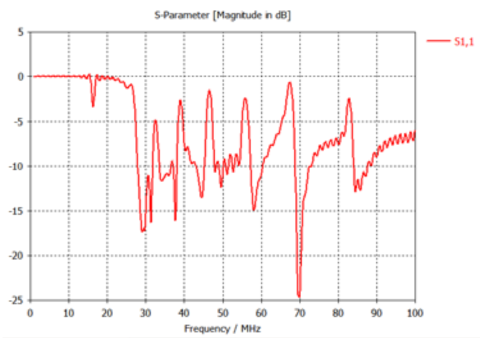

Figure 20: S_{11} of figure 7 – Good results

LPMA with horizontal structure 20% reduced.

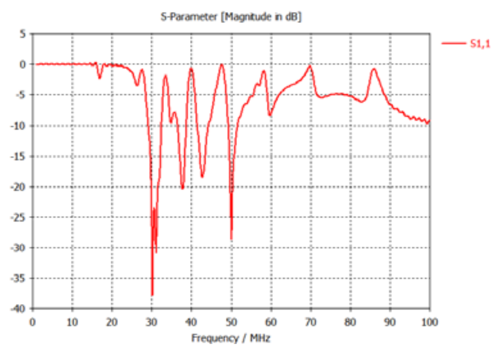

Figure 21: S_{11} of figure 7 – Poor results

The best results are showed (Figure 19 and Figure 20) at the proposed antenna with horizontal structure. Between those solutions we prefer the one with the horizontal structure reduced 10% since we have the advantage of smaller construction. The antenna starts radiate at 30 MHz and its seams optimized in relation to the others graphs. Below we have the graph of the far-field of this antenna (Figure 12) at 50 MHz.

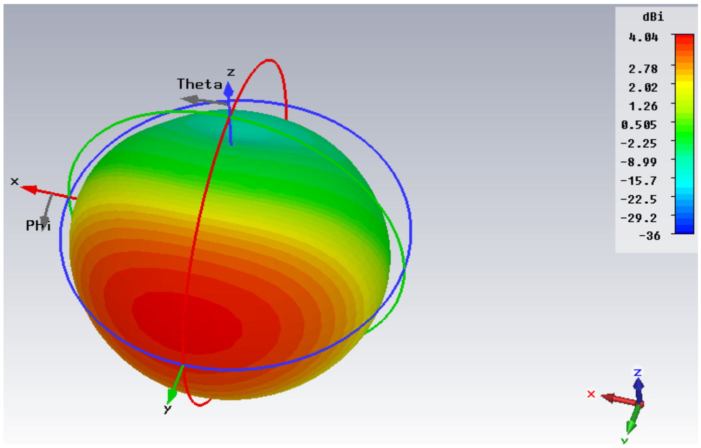

Figure 22: Farfield at 50 MHz of LPMA with horizontal structure 10% reduced.

5 Experimental Data

Figure 23 shows the measurements of the S_{11} of the constructed antenna at Figure 4. At the graph we observe that almost in every frequency the S_{11} is below -5 dB and in a lot of areas. We have succeeded to be under -10 dB.

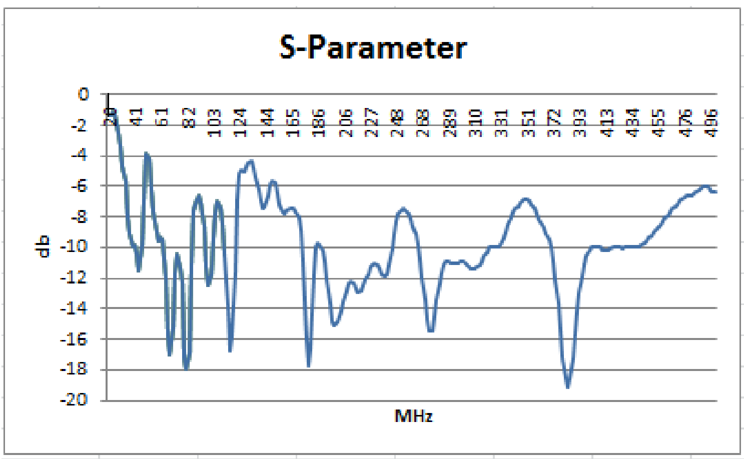

Figure 23: S_{11} of the constructed antenna

The experimental done between frequencies 20 MHz and 500 MHz. The best result is at frequency 383 MHz with return loss -19 dB and SWR 1,25 and the worst result is at frequency 23 MHz with return loss -1,1 dB and SWR 15,1.

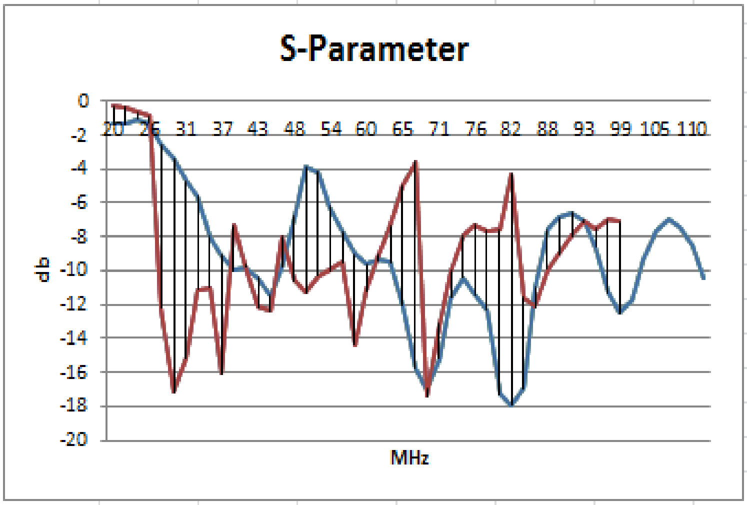

Figure 24: S_{11} of contracted antenna and from the simulation

Figure 24 shows in the same graph, the S_{11} of the constructed antenna and the simulated antenna. With the blue line are the results of the constructed antenna and with red color we have the simulated results.

6 Conclusion

The proposed LPMA could install in a top of a vehicle which is fully functional and can be moved like any one and with an automatic mechanism could be ready for use less than 5 minutes. The performance is pretty close to a LPDA. The trade-off reducing the antenna to a LPMA is the reduction of the gain.

In the other hand we have a compact LPMA which is not in use for radiation, is much smaller and can be transferred quick and easy in relation to its size.

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