Design and Implementation of a 1 to 10 GHz Ultra Wide Band Logarithmic Antenna for High-Frequency Antenna Characterization

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Abstract

This report describes the design and implementation of a logarithmic periodic ultra-wideband antenna from 1 to 10 GHz for the characterization of antennas; its development was carried out in the electromagnetic simulation software Ansoft Designer, taking as a starting point the mathematical calculations necessary to generate the logarithmic structure of the antenna. This type of antenna allows working with electromagnetic waves in the VHF and UHF frequency range. The antenna implementation was performed on a computer numerical control (CNC) router RUIDIAO RD-HA1325 on a sheet of dielectric substrate Roger RT/Duroid 5880. Finally, the antenna was evaluated by collecting data with measurements in the Anritsu MG3690C signal generator and the Anritsu MS2724C electromagnetic spectrum analyzer, obtaining a range of frequencies according to the proposed design.

Keywords: *TELECOMMUNICATIONS, ANTHENAS, PATTER LOGARITHMIC ANTHENA, MICROSTRIP, COMPUTER NUMERICAL CONTROL (CNC), PARAMETER EVALUATION.*

1. INTRODUCTION

Electromagnetic phenomena have been the object of interest and study for their ability to transport information through space. Telecommunications, through electronic devices, are responsible for communicating with people. These electronic devices make up a wireless communication system, which through antennas, allows the transport of information between distant places through space.

2. CONTENTS

2.1 Periodic Logarithmic Antenna

Logarithmic periodic antennas were the initial work of V.H. Rumsey, J.D. Dyson,

R. DuHamel, and D. Isbell at the University of Illinois in 1957, deriving the analysis from the principles of logarithmic periodicity and adding a mathematical description to the antenna's geometry, obtaining a logarithmic-shaped dipole array [22].

This antenna maintains its input impedance, gain and radiation pattern continuously. It can work in the VHF (30 - 300 MHz) and UHF (0.3- 3 GHz) bands. In the microwave field, it can work in a frequency range from 0.38 GHz to 18 GHz [22].

Since the radiating element is a dipole, the polarization is linear. From this reasoning, it is understood that the bandwidth of a logarithmic cluster will be fixed by the length of the longest dipole and the shortest dipole. The design of a logarithmic cluster is largely based on using curves and tables that have been obtained either empirically or by approximate models [6].

Fig 1 - 2: Planar periodic logarithmic periodic antenna.

Source: [22]

Figures 1 - 2 shows the logarithmic periodic antenna composed of aluminum dipoles and in microstrip technology. The logarithmic periodic antenna greatly impacts commercial and military applications worldwide [18].

2.2 Antenna Parameter Calculations

Table 1 shows the calculation results of the antenna's main mathematical parameters.

Table 1 Main antenna parameters.

Virtual Angle (α)	17.93
Bandwidth (B)	10 GHz
Bandwidth Active Region (B_{ar})	1.298
Structure Bandwidth (B_S)	12.979
Feed line width	5 mm
Number of elements	
Total length	643.69 mm
Effective Dielectric Constant (ε_{reff})	2.2

The following table shows the lengths and spacing of each element that make up the antenna.

Table 2 Antenna lengths in free space.

No. of dipole	L mm	D mm
1	96.52	32.21
2	84.66	27.8
3	74.27	24.28
4	65.37	20.28
5	57.96	18.82
6	50.54	15.85
7	44.61	14.35
8	38.67	12.88
9	34.23	11.41
10	29.78	9.96
11	25.33	8.44
12	22.36	6.96
13	19.39	--

Table 3 shows the lengths and spacing of each element, taking into account the dielectric permittivity.

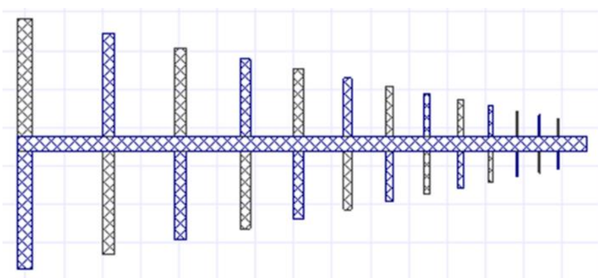
Table 3 Dipole Lengths and Spacings.

No. of dipole	L_{ef} mm	D_{ef} mm
1	65, 078	21,721
2	57,078	18,748
3	50,078	16,637
4	44,078	13,677

5	39,078	12,692
6	34,078	10,688
7	30,078	9,675
8	26,078	8,688
9	23,078	7,696
10	20,078	6,716
11	17,078	5,695
12	15,078	4,696
13	13,078	------

With the results of the previous table, the vectors are introduced into Designer and Fig 4 - 2 is formed.

Fig 4 - 2 Ultra Wide Band Logarithmic Antenna.



Performed by: Peñafiel Ortega, Irvin. 2019.

Fig 5 - 2 Antenna Delay Losses.

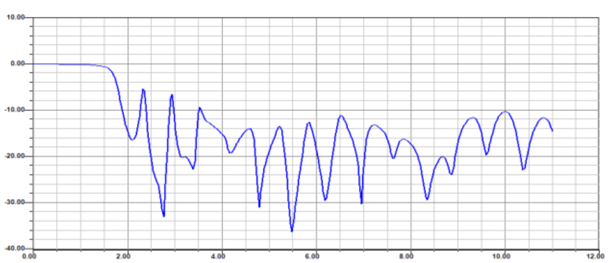


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Fig 5 - 2 shows the reflection coefficient resulting from the simulation. Therefore, an optimization of the antenna parameters, reflected in Table 4, is performed, improving the antenna response at low frequencies.

Table 4 Main antenna parameters.

Virtual Angle (α)	9.23
Bandwidth (B)	10 GHz
Bandwidth Active Region (B_{ar})	1.433
Structure Bandwidth (B_S)	14.326
Feed line width	3.95 mm
Number of elements	
Total length	376.02 mm
Effective Dielectric Constant (ε_{reff})	2.2

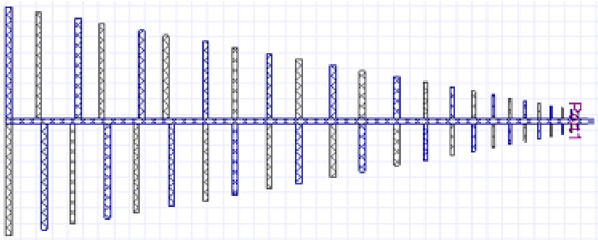
With the optimized calculations' results, we relate them to the dielectric permittivity, and the following table is obtained.

Table 5 Element dimensions and clearances.

No. of dipole	L_{ef} mm	D_{ef} mm
1	13.078	0
2	15.078	4.649
3	17.078	5.36
4	20.078	6.058
5	23.078	6.774
6	26.078	7.453
7	30.078	8.181
8	34.078	8.845
9	39.078	10.541
10	44.078	11.246
11	50.078	13.935
12	57.078	15.675
13	65.078	18.243
14	72.078	15.448
15	80.078	18.337
16	87.078	15.402
17	95.078	18.382
18	102.078	15.311
19	110.078	18.428 / 21.913
20	117.078	18.996 / 11.736
21	125.078	22.044 / 14.718
22	132.078	11.8 / 19.062
23	140.078	21.979 / 14.784
24	147.078	--

The optimization results are shown in Table 5 and transferred to the electromagnetic simulation software, resulting in Fig 6 - 2 consisting of 24 elements.

Fig 6 - 2 Ultra Wide Band Logarithmic Antenna.



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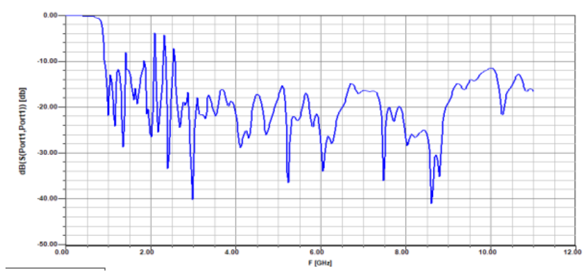
The antenna reflection coefficient is shown in Fig 7 - 2.

Fig 7 - 2 Antenna reflection coefficient.



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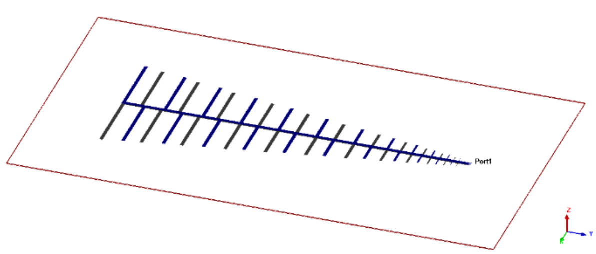
2.3 Antenna Construction

Fig 8 - 2 shows the results obtained in the Designer program in three dimensions and generating a file with DFX extension.

Fig 8 - 2 Ultra Wide Band Logarithmic Antenna.



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The construction stage of the antenna pattern was made on a CNC Router located in OZALID, an advertising and engraving company located in the city of Ambato.

Fig 9 - 2 Ultra Wide Band Logarithmic Antenna.

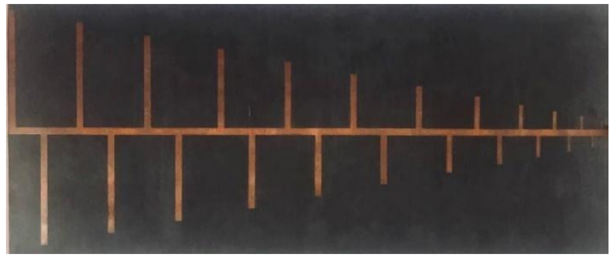

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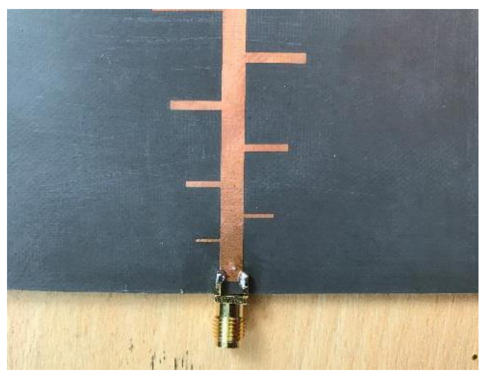
Fig 9 - 2 is the result of the engraving process of the antenna, the next step is the assembly of the antenna, which refers to join by soldering the female SMA connector to the antenna. Resulting in Fig 10 - 2.

Fig 10 - 2 Ultra Wide Band Logarithmic Antenna.



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3. RESULTS FRAMEWORK, DISCUSSION AND ANALYSIS.

3.1 Data analysis

To carry out the evaluation process, a communication system is established between a transmitter and a receiver represented in Fig. 11 - 2 to obtain information about the characteristics of the antenna designed and built in this research.

Fig 11 - 2 to obtain information about the characteristics of the antenna designed and built in this research.

Fig 11 - 2 Antenna characterization system

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The Anritsu MS2724C spectrum analyzer, a Hyperlog 60200x antenna, two Pigtail RG 174 coaxial transmission lines, and an Anritsu MG3690C signal generator were used to measure the antenna transmission coefficient.

Fig 12 - 2 Measured center frequency of the antenna.

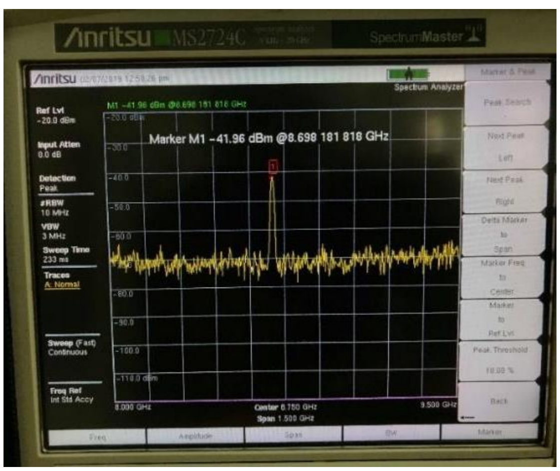

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Figure 12 - 2 shows the samples collected in the spectrum analyzer with respect to the transmission coefficient of the antenna. These samples are transferred into the following table.

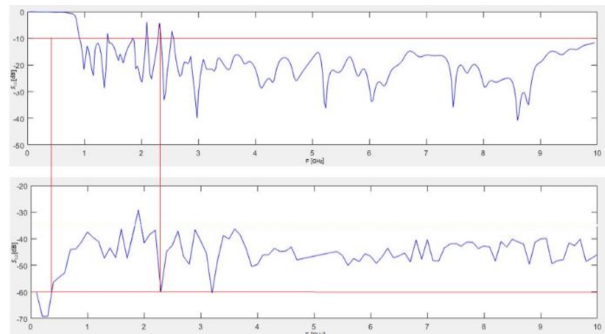
Table 6 Reflection coefficient.

Operating frequency [GHz].	S_{11} [dBm] [dBm
0,103	-60,23
0,205	-69,18
0,300	-69,16
0,400	-56,33
0,500	-54.52
0,600	-52.79
0,700	-43,98
0,800	-43,73
0,900	-41,00
1,000	-37,44
1,100	-39,51
1,198	-41,02
1,300	-47,38
1,398	-43,38
1,500	-47,20
1,598	-36,31
1,700	-47,40
1,798	-38,91
1,900	-29,15
2,000	-41,61
2,100	-38,36
2,199	-36,76
2,297	-59,96
2,398	-44,75
2,499	-42,44
2,600	-37,06
2,698	-46,76
2,799	-29,63
2,900	-36,60
2,998	-40,75
3,099	-45,29
3,200	-60,37
3,298	-48,10
3,400	-38,80
3,499	-40,06
3,600	-36,27
3,698	-38,60
3,799	-43,57
3,900	-50.48
4,000	-49,72
4,099	-46,12
4,200	-45,99
4,300	-43,52
4,400	-44,78
4,499	-44,58
4,600	-43,06
4,698	-47,99
4,799	-56,18
4,897	-52,25
5,000	-51,99

5,099	-50,63
5,197	-58,37
5,300	-55,66
5,400	-44,74
5,499	-26,27
5,600	-30,10
5,698	-37,48
5,799	-38,60
5,900	-45,67
5,998	-46,62
6,099	-39,30
6,200	-36,90
6,300	-33,47
6,400	-27,20
6,499	-26,49
6,600	-35,35
6,700	-38,76
6,801	-40,36
6,900	-37,77
7,000	-40,26
7,099	-38,22
7,200	-38,44
7,300	-33,45
7,400	-41,94
7,499	-41,77
7,600	-42,75
7,698	-41,18
7,801	-41,32
7,900	-43,64
8,000	-42,65
8,099	-33,05
8,200	-38,43
8,300	-41,00
8,400	-43,06
8,499	-40,16
8,600	-41,13
8,698	-41,96
8,801	-39,59
8,900	-41,30
9,000	-40,02
9,099	-39,86
9,199	-49,40
9,300	-48,26
9,400	-47,88
9,499	-41,52
9,600	-42,61
9,698	-40,12
9,799	-38,56
9,900	-37,34
10,000	-36,01
10,300	-42,01

Figure 13 - 2 shows the reflection and transmission coefficient of the antenna, highlighting that the theoretical response differs from the measurements of the real behavior of the antenna since its bandwidth starts before 1 Ghz and its transmission coefficient below -35 dBm exceeding the -10 dBm obtained from the antenna's reflection coefficient.

Fig.12 Simulated and real bandwidth of the logarithmic antenna.



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4. CONCLUSIONS

- An ultra-wide band logarithmic antenna with bandwidth from 1 to 10 GHz, was developed using planar technology on a Rogers 5880 dielectric sheet for antenna characterization, case study, communications and microwave laboratory.
- The geometrical characteristics of the antenna are in accordance with the requirements to be met by the standard antenna within the communications and microwave laboratory of the FIE-ESPOCH.
- An ultra wide band logarithmic antenna, with a bandwidth of 1 to 10 GHz, was designed using the Rogers 5880 dielectric for Antenna characterization.
- The ultra wideband logarithmic pattern logarithmic antenna with a bandwidth of 1 to 10 GHz was built.
- The logarithmic ultra-wideband pattern antenna was analyzed and determined that it is considered an instrument of the

communications and microwave laboratory.

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