PERFORMANCE EVALUATION OF A HYBRID UNIFORM LENGTH AND UNIFORM SPACING ARRAY OF 7-ELEMENT FOLDED DIPOLE ANTENNA (HULUSA7FDA) OPERATING AT 900 – 2000MHz BAND

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ABSTRACT

In this paper, the design, implementation and experimental analysis of the performance of the proposed hybrid Uniform Length and Uniform Spacing Array of 7-element Folded Dipole Antenna (HULUSA7FDA) operating at 900 – 2000MHz band for wireless communication networks particularly Global System for Mobile Communication (GSM) are reported. The design techniques employed is the integration (hybrid) of the existing Log- periodic dipole array design parameters with K7MEM folded dipole online simulator and folded dipole feeder characteristics impedance matching online simulator. The data obtained during field experimentation were used to evaluate the performance of the proposed antenna in terms of its two major parameters which are the frequency responses and radiation patterns. The results obtained show that the proposed antenna demonstrates Chebyshev measured frequency responses, and highly directional measured radiation patterns over the desired wide bandwidth. The chosen gain for the design of the antenna is 7.5±0.1dBi and the computed beamwidth from the measured radiation patterns is 15 ± 0.1^0.

Keywords: *Performance Evaluation, Hybrid, Folded Dipole Antenna Array, 900 – 2000MHz Band.*

1. INTRODUCTION

The increase in demand for wireless communication services in Nigeria and other African countries, particularly in the era of Information Communication Technology, has necessitated the need for antennas capable of operating at a broad band frequency range. Since the numbers of subscribers for GSM are on increase daily, it is necessary to design a typical antenna system that can transmit and receive over wider bandwidth than the existing antennas. Due to ineffectiveness of some antennas employed by communication industries, fluctuations and inconsistencies in signal transmissions and receptions experienced by the subscribers have been the major challenges facing the GSM industries [1 – 8]. Despite numerous types of antennas that are available based on their frequencies of operation, characteristics and applications, only very few can satisfied the wide bandwidth characteristics requirement. In this regard, a bandwidth compensation antenna such as the folded dipole antenna is considered as a suitable candidate for the proposed antenna array design in this paper.

This paper investigates the performance of the proposed high gain, light weight and low cost Uniform length and Uniform Spacing Array of 7-element Folded Dipole Antenna (HULUSA7FDA) using integration (hybrid) of the existing Log- periodic dipole array design parameters with K7MEM folded dipole online simulator and folded dipole feeder characteristics impedance marching online simulator [9 – 15]. The proposed antenna array is a broadside type and designed to be mounted on a mast either horizontal or vertical orientation for the purpose of pulling down GSM signals in the wide frequency range of 900 - 2000MHz as much as possible to alleviate the problems of signals transmissions and receptions fluctuations as a result of poor bandwidth of GSM infrastructures.

2. DESIGN METHOD

STEP 1: The initial boundary conditions for the design of the proposed antenna:

The maximum frequency (F_{MAX}) and the minimum frequency (F_{MIN}) for the design are 900MHz and 2000MHz respectively. The bandwidth ratio (B) is obtained using the formula [4, 10]:

$$B = \frac{F_{MAX}}{F_{MIN}} = \frac{2000}{900} = 2.22 \qquad (1)$$

The centre frequency $F_C = \frac{F_{MAX} + F_{MIN}}{2} = \frac{2000 + 900}{2} = 1450 MHz$ (2)

STEP 2: The proposed Antenna's design parameters:

The initial guesses for the antenna's design parameters: gain, **G** and design constant (scale factor), **k** is determined using the graph in the Figure 1 [9, 10].

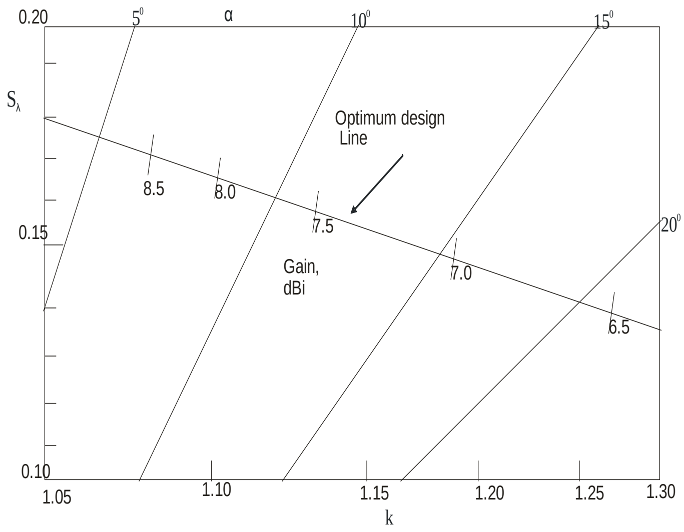


Figure1. Log-Periodic array design parameters curve.

G is chosen to be 7.5dBi (6≤G≤10)

From the LPDA design parameters curve above, the value of design constant *k* corresponding to the 7.5dBi gain is approximately equal to1.13.

STEP 3: The Apex angle of the proposed Antenna corresponding to the 7.5dBi gain:

The apex angle corresponding to 7.5dBi and the design constant *k* of 1.13 is determined by [4]:

$$\tan\alpha = \frac{1-\frac{1}{k}}{4S_{\lambda}} \qquad (3)$$

From the Figure 1, the value of relative spacing S_{λ} corresponding to the initial guesses: *G* = 7.5dBi and *k* = 1.13 is equal to 0.16.

Therefore, the computed apex angle, α is equal to 10^{0} which confirm the accuracy of the initial guesses of the proposed antenna's design parameters: gain G and design constant *k* in agreement with the Figure 1.

STEP 4: Number of elements required for the design of the proposed Folded Dipole Antenna Array:

The number *n* of elements required for effective design of the geometrical structure of the antenna is given by [4, 9, 10]:

$$n = \frac{\ln B}{\ln k} \qquad (4)$$

The computed value of the number of elements, n is equal to 6.526, which is approximated to 7-element.

STEP 5: Geometrical structural length/size of the folded dipole antenna element:

The structural geometrical dimension of each folded dipole antenna element of the proposed HULUSA7FDA is determined using online simulator by Martins, M. 2007 available at http://www.dxzone.com/cgi-bin/dir/jump2.cgi (Figure 2).

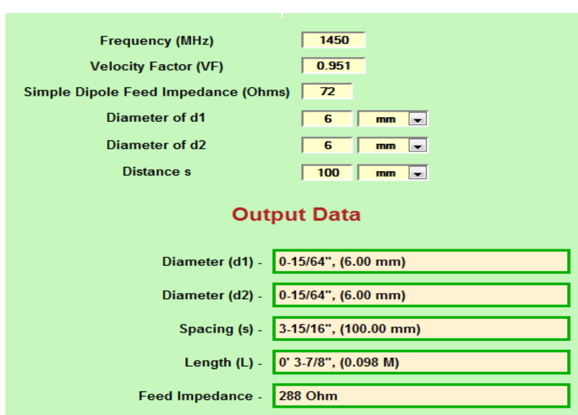


Figure 2: Showing the input and output data in the K7MEM Folded Dipole Antenna Online Simulator (http://www.dxzone.com/cgi-bin/dir/jump2.cgi)

STEP 6: Spacing between the elements of the array:

The spacing X_n between the elements of the proposed antenna array is calculated using the expression [3, 10]:

$$\frac{X_n + 1}{X_n} = k \qquad (5)$$

$$X_n = \frac{1}{(k-1)} = \frac{1}{(1.13-1)} = 7.69cm$$

The spacing between the elements is 7.69cm. The geometrical structural configuration of the proposed HULUSA7FDA is as shown in the Figure 3.

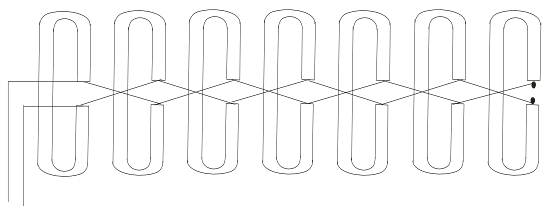


Figure3: Diagram representing HULUSA7FDA and its Broadside coupling Techniques.

STEP 7: Feeder characteristics impedance of the proposed Antenna:

The feeder characteristics impedance Z that provide good matching impedance with the 75Ω coaxial cable was determined by using feeder simulator which automatically determines the length of the cable required to form a U-Shape balun matching techniques employed in this work, by supplying necessary information (figures 4 and 5).

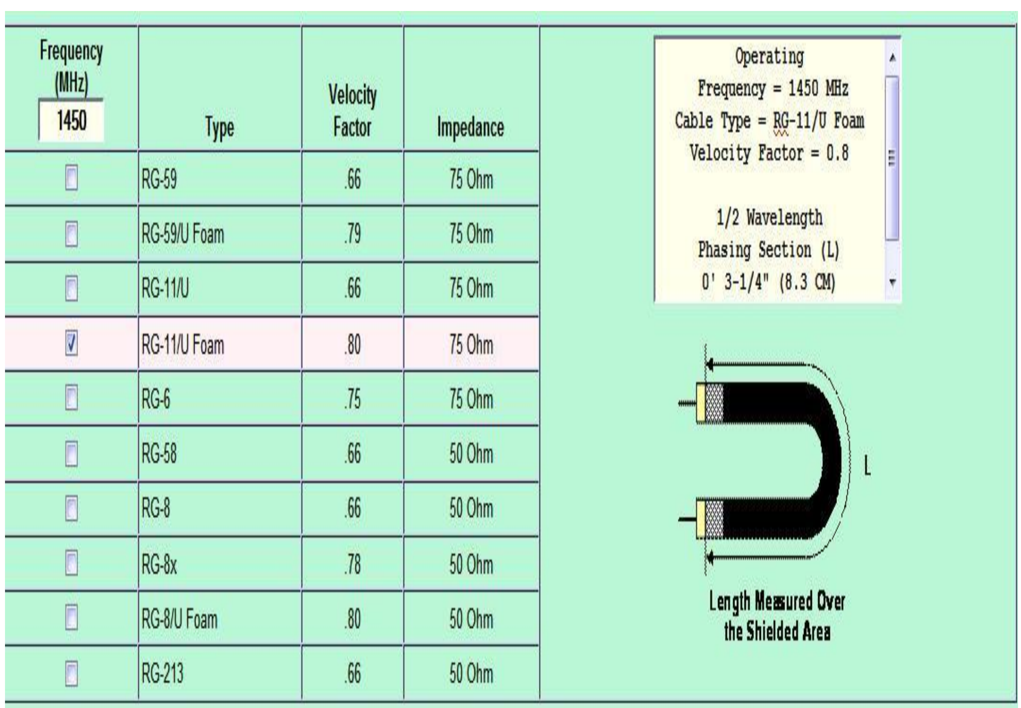


Figure 4: Online simulator for folded dipole antenna matching technique

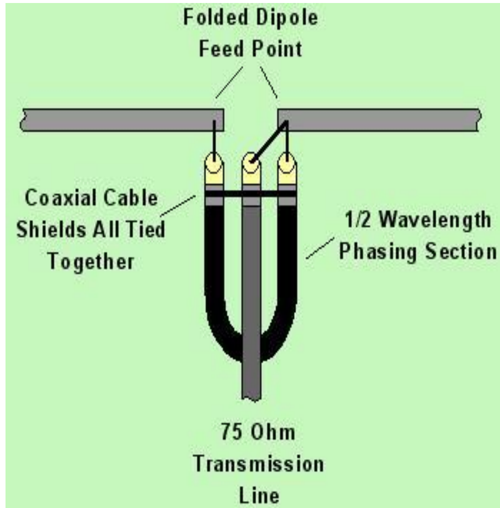


Figure 5: Showing the antenna matching technique with the 75Ω coaxial cable.

3. CONSTRUCTION AND MEASUREMENT DETAILS

Figure 6 shows the diagram of the realized proposed Hybrid Uniform length and uniform spacing array of Folded Dipole Antenna (HULUSA7FDA). Light weight Aluminium metal rod of diameter 6mm was cut and folded to give a length of 0.098m long, feeding impedance of 288Ω and of spacing (X_n) of 7.69cm between the elements.

A wooden plank is used for the boom on which the folded dipole elements are fixed at appropriate positions with accurate spacing (X_n) as in figure 6. The folded dipole elements are coupled together using 900/2000MHzEPD-12 model frequency splitters in coupling the elements inductively on the wooden boom. One end of the antenna is connected to 75Ω coaxial cable using $\frac{\lambda}{2}$ U-Shape balun matching techniques (Figure 5). The proposed antenna system was connected to the Spectrum Analyzer GSP810 for the frequency responses and radiation patterns measurements.

The performance of the antenna (HULUSA7FDA) was investigated by measuring the signal strengths received in the wide frequency range of 900 - 2000MHz as the antenna was suspended on a mast 4meters above the ground level while varying the azimuth angles about the horizontal plane from 0^0 to 360^0 using open air far field measurement technique. The data obtained were used to determine the two major parameters namely: the frequency responses and radiation patterns of the proposed antennas.

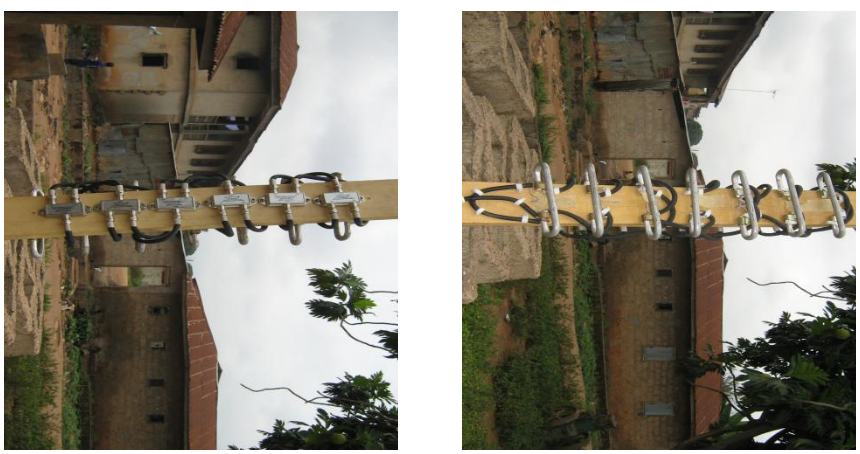


Figure 6: Showing the front and back of the implemented HULUSA7FDA

4. RESULTS AND DISCUSSION

The experimental analysis of the performance of the proposed hybrid Uniform Length and Uniform Spacing Array of 7-element Folded Dipole Antenna (HULUSA7FDA) operating at 900 – 2000MHz band is presented in this paper. The integration of the existing Log-periodic dipole array design technique with K7MEM folded dipole design online simulator and folded dipole feeder characteristics impedance matching online simulator is used to design the proposed antenna. The measured experimental data were used to determine the performance of the proposed antenna in terms of its parameters: the frequency responses and radiation patterns.

Figure 7 shows the plot of the measured signal strength received as the frequency is varied from 900 - 2000MHz in steps of 5MHz at the direction of maximum directivity. Practical Chebyshev frequency responses were obtained for the proposed antenna at the desired frequency range, which shows that the proposed antenna (HULUSA7FDA) has demonstrated broadband ability.

Figure 8(a, b) depicts some of the measured radiation patterns, of the proposed antenna, plotted in the rectangular coordinate systems. The results of all measured radiation patterns within the desired band show that the HULUSA7FDA is highly bidirectional. The measured beamwidth of the antenna is about 15^0.

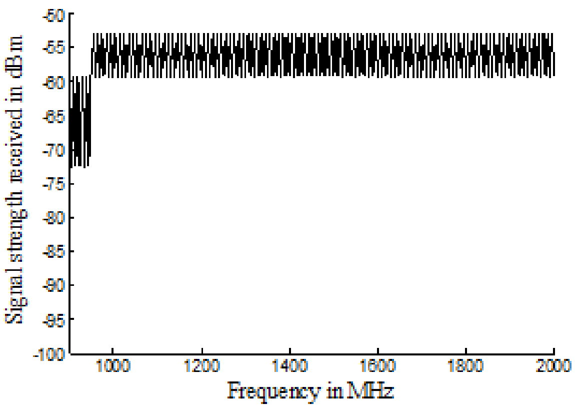
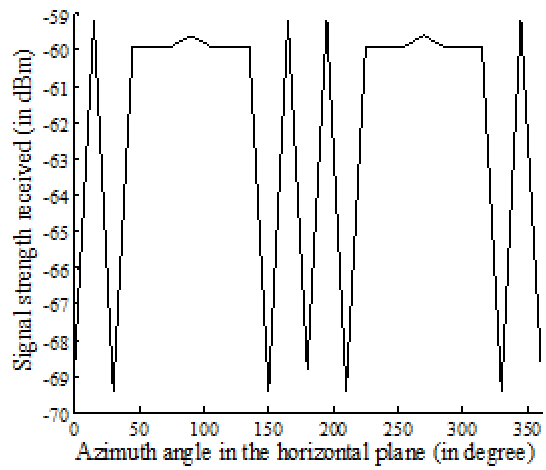
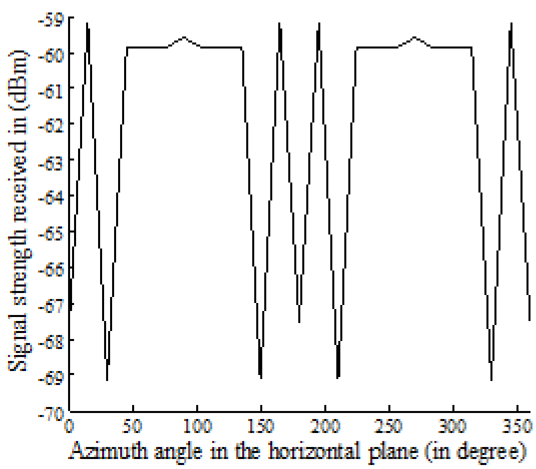


Figure 7: Showing the frequency response of the signal received by the proposed HULUSA7FDA.



(a) f = 900MHz



(b) f = 950MHz

Figure 8(a, b): Showing some of the measured radiation patterns of the proposed HULUSA7FDA.

5. CONCLUSIONS

In conclusion, this paper presents the design, construction and performance evaluation of hybrid Uniform Length and Uniform Spacing Array of 7-element Folded Dipole Antenna (HULUSA7FDA) operating at 900 – 2000MHz band. The chosen gain for the design of the antenna is 7.5±0.1dBi and the calculated beamwidth from the measured radiation patterns is 15 ± 0.1^0 within the desired band. The proposed antenna demonstrates Chebyshev measured frequency responses and highly bi-directional measured radiation patterns over the desired wide bandwidth. The proposed antenna designed in this work is useful for wireless communication networks (cell sites infrastructures) particularly Global System for Mobile Communication (GSM).

6. ACKNOWLEDGMENT

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