

A Smart Optimization-Enabled Omnidirectional Dipole Antenna Design for Campus and Conventional FM Radio: A Case Study of 92.3MHz Campus Radio FUT Minna

Ogechi Akamike, Caroline Alenoghena, Stephen S. Oyewobi
Department of Telecommunications Engineering,
Federal University of Technology, Minna.

ABSTRACT

An antenna performs the most important function in any communication system, this underscores the reason most researchers in the field of antenna design pay close attention to specifics in designing smart antennas. Radio on the other hand is a medium or channel through which information can be disseminated to the audience, to achieve this, an antenna is required. This paper presents a novel optimization based technique to design a smart antenna to meet the demands of both educational institutions and the broadcasting industry. There has been a paradigm shift from conventional antenna designs to smart antennas designs to meet the ever changing world of communication where end users demand high quality of service, and high connectivity, especially with the roll out of 5G wireless network and other evolving technologies. Optimization techniques can be leveraged when the available resources cannot be replaced. A case study of Search FM 92.3MHz FUT Minna has been carried out to address the poor signal coverage within Minna and environs.

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INTRODUCTION

Radio is a vital medium through which important information can be disseminated, as a result it is ubiquitous in nature. Information is so crucial to mankind that a wise man once said "if you are not informed, you are deformed" In order to bridge the information gap in various educational institutions, some higher institutions thought it wise to establish campus radio. Furthermore, some tertiary institutions establish campus radio as a training radio station for students (potential broadcasters) especially for those studying mass communication. Campus radio can be defined as a type of radio broadcasting service that is run wholly or completely by students of a college, university or any educational institution without any profit motive (Moses Segbenya, et al, 2022)

According to (Farzad et al, 2022), Campus radio can be defined as a type of radio broadcasting service model that is beyond

commercial and public benefit or purpose but primarily targeted at the host community's interest. Campus radio is also known as college radio, university radio, community radio or student radio. Furthermore, the programming content may be exclusively created or produced by students, or may include program contributions from the local community in which the radio station is based. Sometimes campus radio stations are operated for the purpose of training professional radio personnel, sometimes with the aim of broadcasting educational programming, while other radio stations exist to provide alternative to commercial broadcasting. A campus radio is not profit oriented. (Omid Bozorg-Haddad, 2018)

Antenna design and selection is so important that, a transmitter cannot perform optimally without. Hence it becomes imperative to select and design smart antennas that can take the available power of the transmitter and optimize it to target audience or location taking into

*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

Department of Telecommunications Engineering, Federal University of Technology, Minna.

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cognizance the topography, signal strength and coverage distance. Mohammed M. and MdZiaur R. (2020)

This paper is divided into sections such as: campus vs conventional FM radio, review of similar or related works, optimization defined radio approach, Results and conclusion

CAMPUS FM RADIO VS CONVENTIONAL FM RADIO

In 1962, the educational sector witness the first radio broadcasting service better known as the students' radio, with support from the British Broadcasting Corporation. In Nigeria, a unit was established at Ibadan with the mandate of transmitting lessons to students at all levels. This service was referred to as the National School Broadcasting (NSB) (Ubong & Okpor, 2018)

The Nigerian Broadcasting Commission and the Northern Nigeria Broadcasting Corporation were incorporated in 1978 and this union brought the emergence of Federal Radio Corporation of Nigeria (FRCN) which oversees numerous FM stations. The external service tagged Voice of Nigeria (VON) started broadcasting to West Africa in 1961.

In Nigeria, Community radio broadcasting became popular in 2002, when the students of University of Nigeria, Nsukka illegally transmitted signals to Nigerian government to channel their grievances, and inform the government that establishment of campus radio on the campuses for information dissemination in Nigerian tertiary institutions was long overdue. This singular act prompted Nigerian Broadcasting Commission (NBC) to review the national broadcasting code in order to incorporate the establishment of campus radio act. The first campus radio operational license was issued to University of Lagos to operate on 103.1 MHz

frequency band in July 2003 but it was commissioned on 14th of December, 2004.

It took another five years for additional Ten (10) operational licenses to be issued in 2007. Furthermore, another eighteen (18) campus radio licenses were approved and issued to some tertiary institutions in 2009 by Nigerian Broadcasting Commission (NBC), Federal university of Technology was lucky to take delivery of the license to commence full-fledged campus radio broadcasting on the 4th of March, 2009. The advent of students' radio has changed the narrative and status quo on our campuses across Nigeria, before the coming of campus radio on most campuses, students could only access information via notice boards, course representatives and Students' Union Government (SUG). The paradigm shift has benefitted the students in no small measure, as students who want to future broadcasters can be trained as broadcast interns, information can be disseminated to students living in remote locations and the entire programmes anchored by students for their delight.

In Nigeria, the first private conventional FM radio station started broadcasting in 1994, the late Raymond Dokpesi was granted operational license to broadcast on 100.5MHz frequency band and named Ray Power FM. Unlike campus FM radio broadcasting which is restricted to only the host community, conventional FM radio broadcasting is targeted to a larger population and audience.

REVIEW OF RELATED WORKS

This sub-section presents similar or related works carried out by other authors, the strengths and weakness of their models at a glance.

*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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Authors	Title of Paper	Strength	Weakness
Akimoto et al, 2018	Designed and presented an integrated diversity antenna by using both dipole and monopole modes with a high isolation property and a simple configuration.	The antenna design achieved good line of sight communication.	However, the two antenna modes integrated caused the transmitter to consume a lot of power in a bid to transmit power to different locations based on their different geographical; terrains.
Lai Jiexin et al, 2018	Designed a dual-band dual-polarized (DP) Omni-directional antenna for 2G/3G/Long Term Evolution (LTE) indoor communication systems	The antenna design achieved an improved impedance bandwidth and increase gain	However, the antenna design was for indoor applications and could not work optimally on outdoor applications such as FM and TV broadcast applications.
Yi Fan et al, 2019	Developed a polarized Omnidirectional antenna that can be reconfigured using crossed dipoles	The antenna design achieved an improved gain	However, the area of application of the designed antenna was not revealed
Chuwong et al, 2019	Proposed a circularly polarized single fed omnidirectional dipole antenna with an operating frequency of 2.45 GHz for industrial, scientific and medical (ISM) radio band applications.	Improved the antenna gain and realized omnidirectional radiation pattern.	However, the transmitter consumed a lot of power in a bid to transmit power to the antenna/
SrabantiDatta and Md. OmorFaruk (2019)	Design of a copper based dipole antenna for both present and future generation of wireless communication and internet of things using various lengths of antenna material.	The antenna designed provided strong robustness in terms of performance for 0.8m length of copper material with 14.89dB maximum return loss.	However, the antenna design was restricted to some few kilometers distance in terms of transmitting signals.
Qinlu Liu et al, 2020	Performance analysis of FM dipole antenna and array	The antenna achieved optimal values with a peak gain of 2.81dBi and acceptable Voltage standing wave ratio (VSWR) of 2:	A prototype of the FM dual dipole antenna was only suggested to researchers who intend to further build on their research.
Adebayo and Olabisi (2021),	Spatial Coverage of FM Signal Variation Measurement and Comparison of two Major Radio Stations within Akwa Ibom State,	Spectrum analyzer and GPS tools measured accurately the signal strength within the town.	Low signal coverage due to low transmitter power

*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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YuanzhiLui et al, 2021	Proposed a compact, broadband and Omni-directional antenna array design for 5G application.	The antenna design is configurable and eliminated the influence of the ground as reflector	The antenna design was only simulated and tested using the 26 GHz frequency band and not on other frequency bands and FM applications
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OPTIMIZATION DEFINED RADIO APPROACH

This subsection explains the materials and method used in carrying out the smart optimization based antenna design

Material Used

- (i) Computer (Laptop)
- (ii) Mobile Phone
- (iii) MATLAB R2020a software

METHODOLOGY

The following methodology was used

Optimize the selected omnidirectional array

In order to optimize the selected omnidirectional array such that the area is minimized and the gain is maximized, the developed optimization model parameters were set and constrained as follows:

Objective Function: $\min(\text{Area } m^2)$

$\text{Gain} \geq 2.04 \text{ dB}$

$1m \leq \text{length}$

$\leq 10m$

$0.0103m \leq \text{width}$

$\leq 1.4135m$

Design frequency = 92.3 MHz

Carry out the Port Analysis of Antennas

Port analysis is basically conducted to determine how well the designed antenna element is radiating, some parameters used in carrying out port analysis include: s-parameter, return loss, impedance and VSWR

Plotting the Reflection Coefficients for Some Antenna Lengths

Plotting of the reflection coefficient was done with the help of the codes written and MATLAB software was used to run the codes in order to generate the results. This plot gives one an idea of the quantity of electromagnetic waves that is returned due to impedance discontinuity

Linear Antenna Array Design

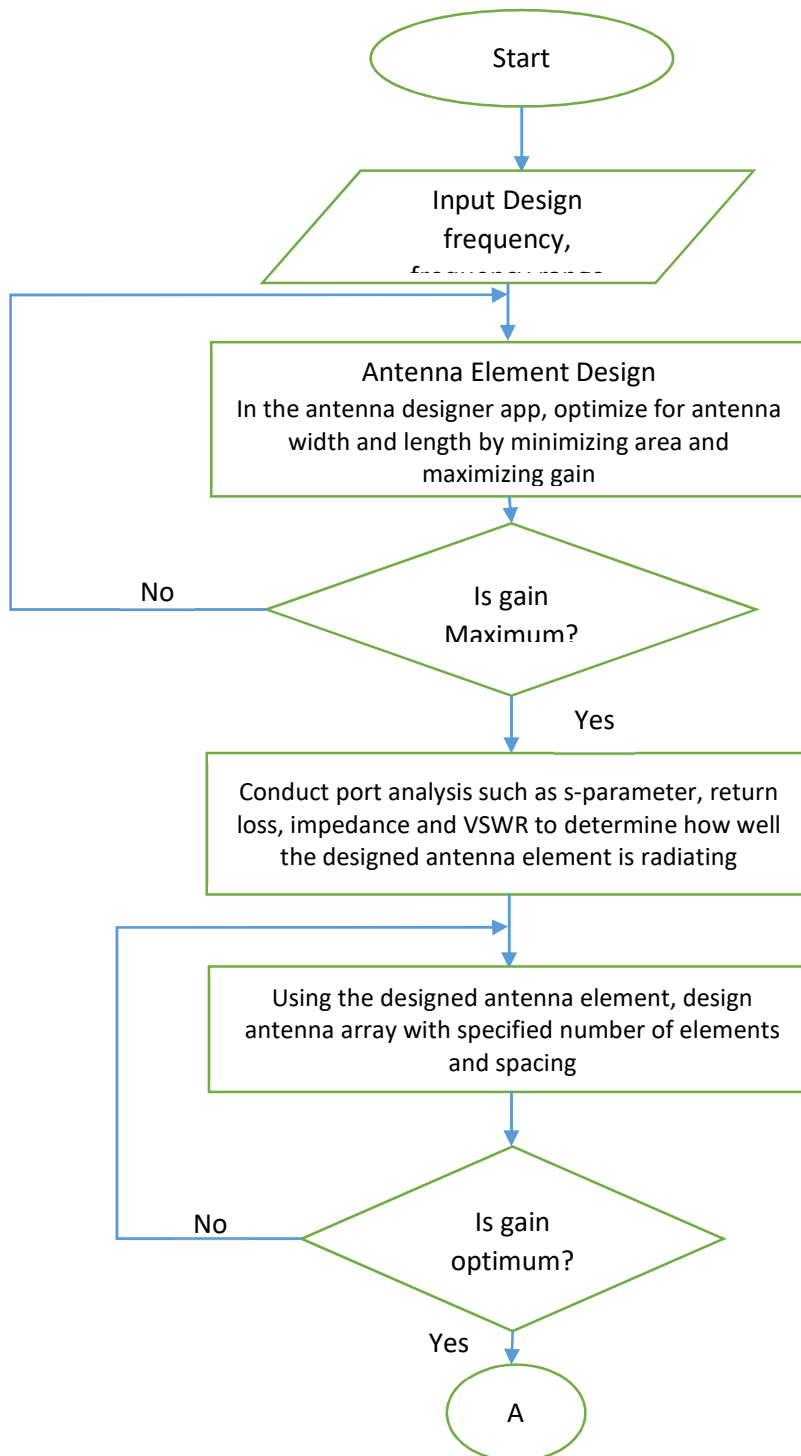
The linear antenna design was carried out using 92.3MHz as the design frequency and 12 array elements. The flowchart of this smart antenna is illustrated in figure 1

*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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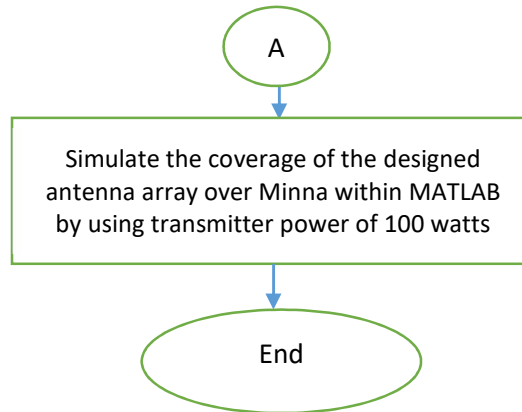


Figure 1: Flowchart of the designed smart Antenna

RESULTS AND DISCUSSION

This subsection presents the results of the simulation obtained and the analysis of the designed smart dipole Omni-directional antenna.

Results of the Simulations Obtained from the Smart Antenna design Optimization Model

Result based on optimum length and width of the antenna

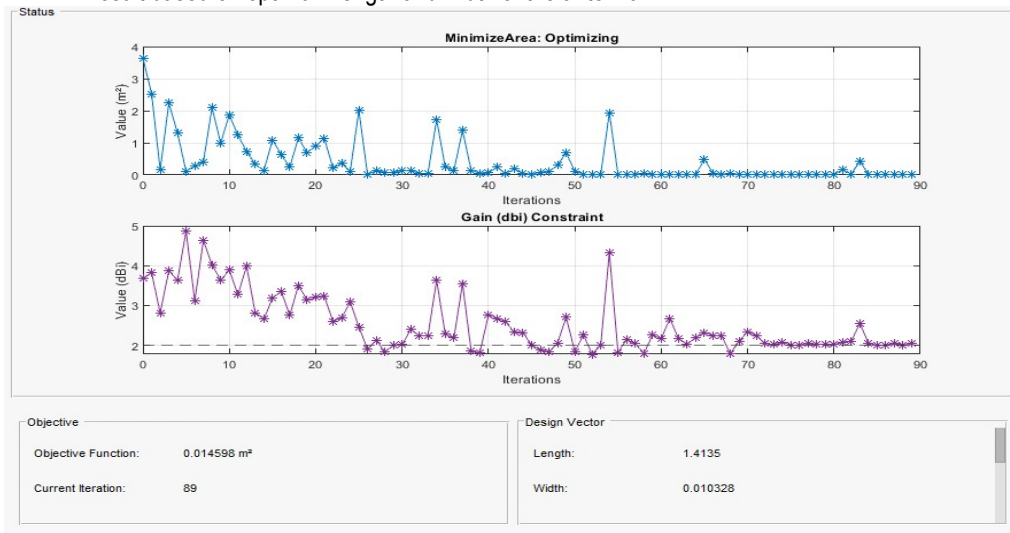


Figure 2 Optimization result

From figure 2; it can be deduce that, the minimum area of the omnidirectional antenna that leads to maximum gain is 0.014598 m².

Furthermore, Optimum Length = 1.4135m and Optimum Width = 0.010328m

*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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In the same vein; it can be observe from the 3D Pattern diagram illustrated in figure 3 that, the maximum gain/directivity is 2.04dB. This clearly validates that, the designed smart antenna is

performing optimally and by implication this higher value of gain is an indication that, the designed smart antenna has out-performed that of search FM 92,3MHz which has a maximum gain of 1.8dB.

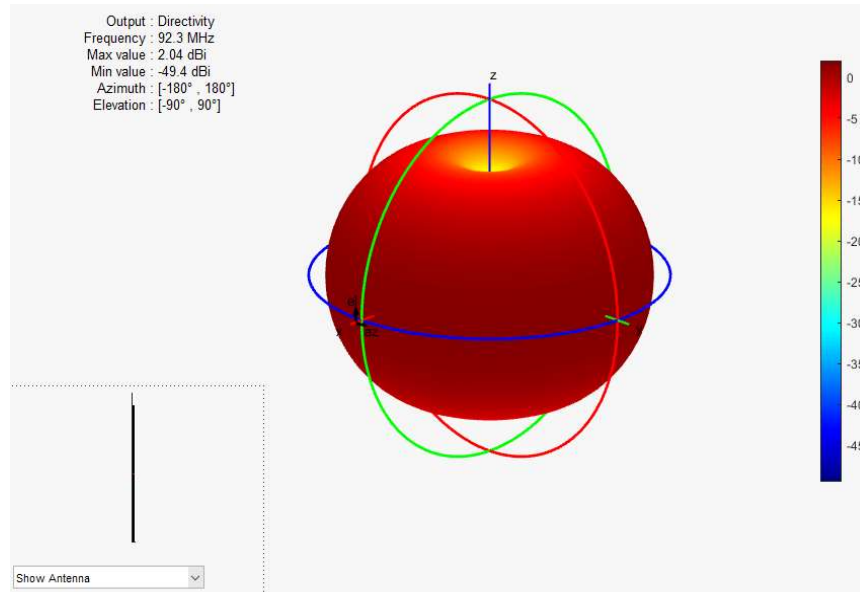


Figure 3: 3D Radiation Pattern

Port Analysis of Antennas

The s-parameter (reflection coefficient) plot shows a minimum power of -15.5dB. Indicating that the antenna is radiating very well from the available power of the transmitter. The reflection coefficient describes a relative fraction of the incident RF power that is reflected back due

to the impedance mismatch. This mismatch is the difference between the input impedance of the antenna and the characteristic impedance of the transmission line (or the generator impedance when the transmission line is not present). Figure 4 illustrates the plot of the s-parameters over the specified frequency range.

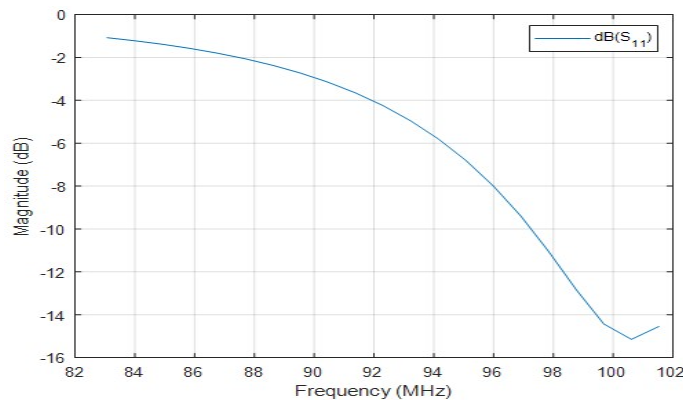


Figure 4: Plot of the s-parameters over the specified frequency range

*Corresponding author: Ogechi Akamike.
 ✉ ogechi.pg2011252@futminna.edu.ng
 Department of Telecommunications Engineering, Federal University of Technology, Minna.
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The antenna impedance is calculated as the ratio of the phasor voltage (which is simply 1) and the phasor current at the port. The plot displays the real part of the impedance, i.e. resistance as well as its imaginary part, i.e. reactance, over the entire frequency band. Antenna resonant frequency is defined as the frequency at which the reactance (capacitive and

inductive) of the antenna is exactly zero or cancels out leaving behind a purely resistive antenna. Looking at the plot in figure 5, the dipole omnidirectional antenna resonates at about 101.2 MHz, The implication of this value obtained is that, at this frequency, the antenna will be purely resistive in nature due to the combined effect of radiation resistance and resistance losses.

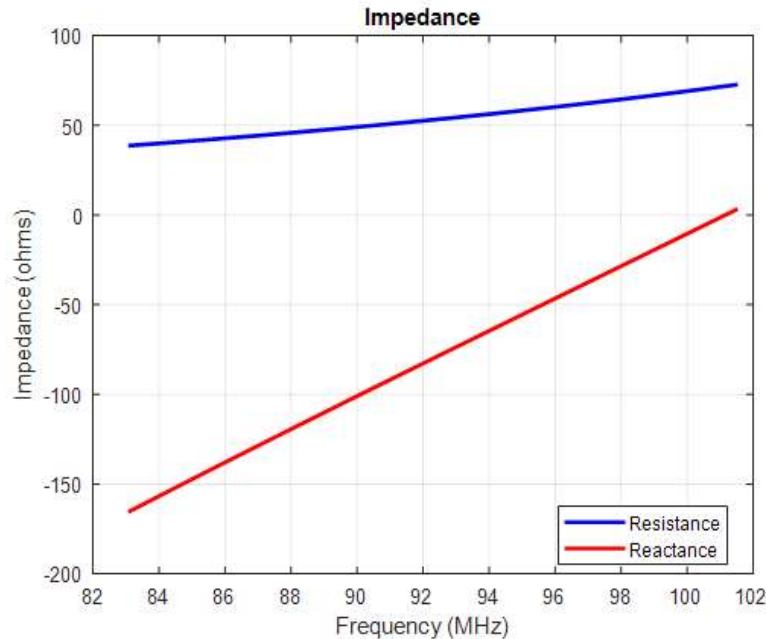


Figure 5: Impedance plot

Return loss is the measure of the effectiveness of power delivery from the transmission line to an antenna. Quantitatively, the return loss is the ratio, in dB, of the power sent towards the antenna and the power reflected back. It is a positive quantity for passive devices. A negative return loss is possible with active devices. Figure 6 illustrates the plot of the return

loss of the designed antenna, it can be observed from the plot that, the antenna gives a maximum return loss of 15.56dB which is within the range for any antenna system design to perform optimally because the signal power loss is not high, this also validates the fact that no system is perfect in nature as a result little signal reflections are bound to occur

*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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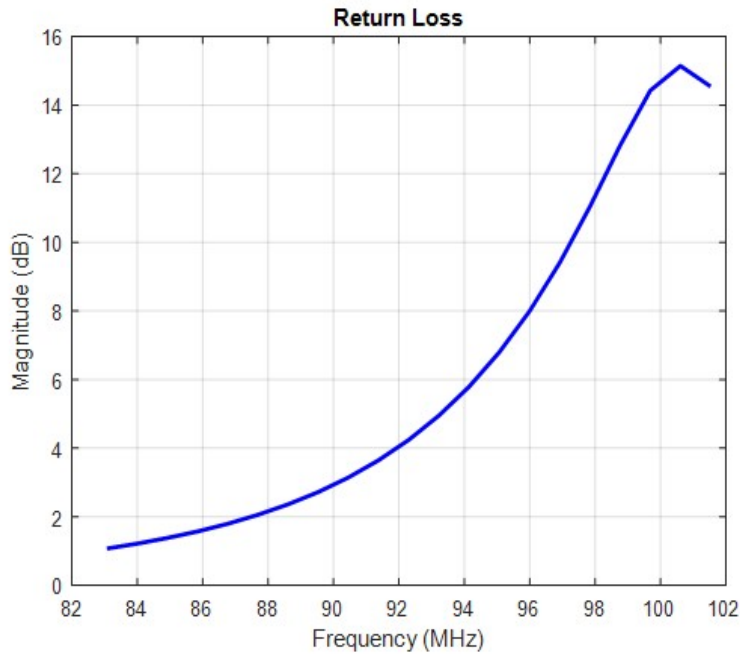


Figure 6: Return loss

Bandwidth is a fundamental antenna parameter. The antenna bandwidth is the band of frequencies over which the antenna can properly radiate or receive power. Often, the desired bandwidth is one of the critical parameters used to decide an antenna type. Antenna bandwidth is usually the frequency band over which the magnitude of the reflection coefficient is below -10 dB, or the magnitude of the return loss is greater

than 10 dB, or the VSWR is less than approximately 2. All these criteria are equivalent.

Thus, it can be observed from the plots of figure 7-, that the omnidirectional antenna has operating bandwidth over the frequency band from 83.2 to 101.8 MHz This is the antenna bandwidth. It also validates how efficient the radio waves are being transmitted to the target locations or areas.

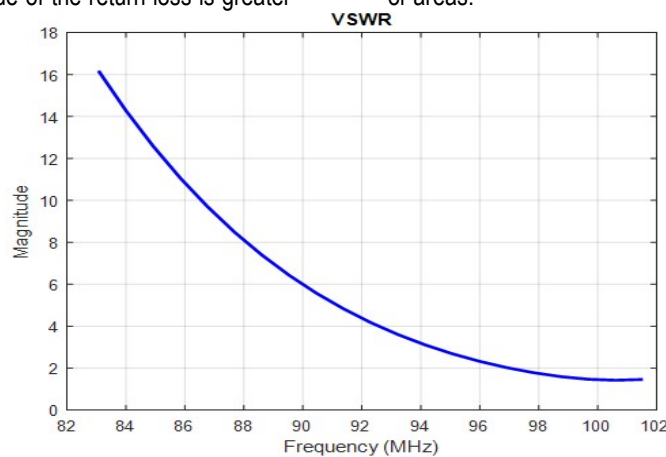


Figure 7: VSWR

*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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Plotting the reflection coefficients for some antenna lengths (1, 1.4135, 2, 2.5 and 3m), and the designed antenna length

From the plot of figure 8, it can be observed that the 1.4135m (designed length)

antenna has the lowest s-parameter value. Thus, it is the optimum length that if utilized in the fabrication process, the antenna will perform optimally.

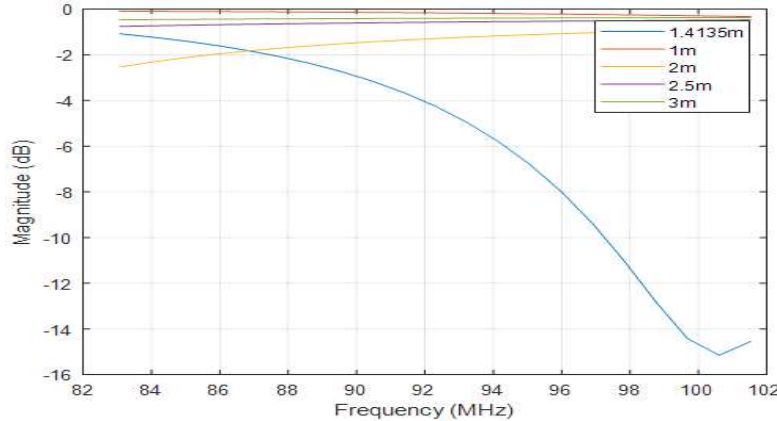


Figure 8: s-parameters (reflection coefficient) for various antenna lengths

5.4 Linear antenna array design using a design frequency value of 92.3 MHz and 12 elements

Figure 9 illustrates the Antenna configuration of the designed smart dipole Omnidirectional antenna. The antenna element spacing is 1.624m between one element and the other, therefore giving it a uniformly spaced linear antenna array design. When compared to the FM dipole installed at Gidan Kwano campus, this

antenna design outperforms it in terms of better signal propagation, improved signal strength and higher gain, which obvious are the key performance indicators of a good antenna design. It is also an established fact that, the physical size of an antenna determines the extent to which it can transmit signals, this informed the choice of 12-elements array.

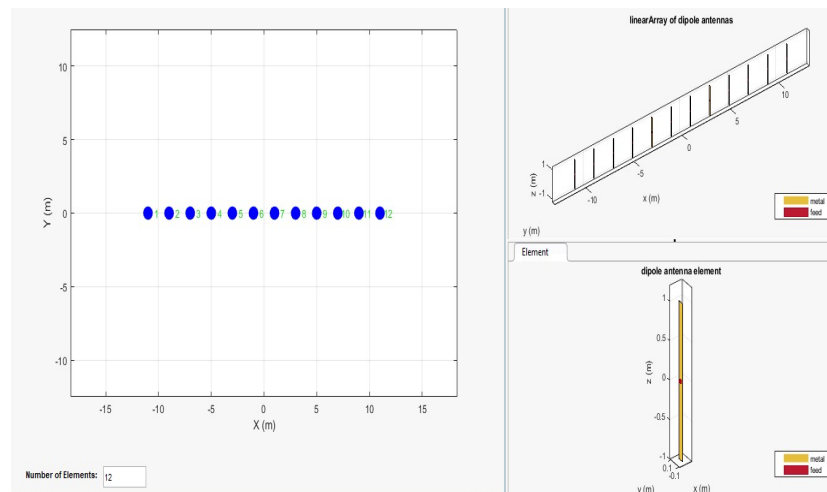


Figure 9: Antenna Configuration

*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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Figure 10 illustrates the 3D Antenna radiation pattern of the 12 elements linear antenna array design. It can be observed from

the simulation result that, the antenna's radiation pattern is good, which obvious implies that, it is performing optimally

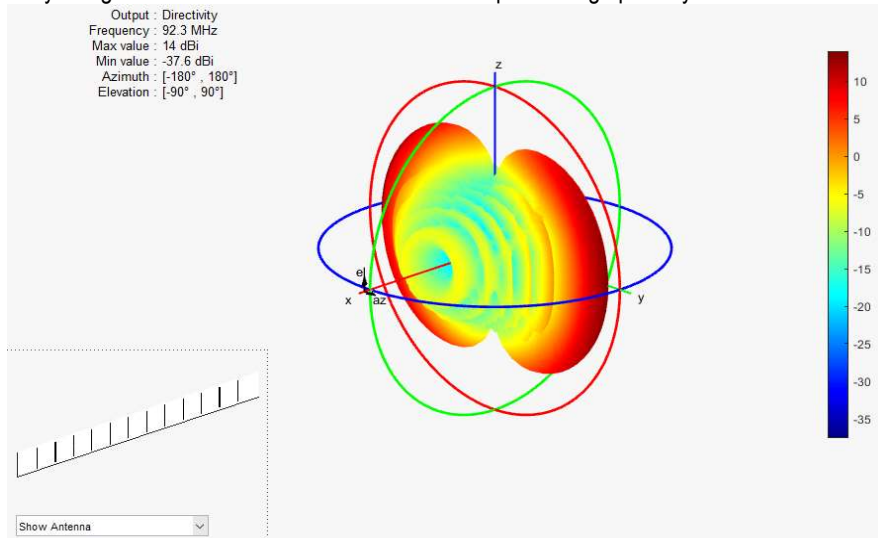


Figure 10: 3D Antenna Radiation Pattern

The azimuth pattern of the designed antenna is illustrated in figure 11. It can be observed from the plot that a HPBW of, FNBW is,

main lobe is 12.2dB and a reduced SLL of 0.0000562dB

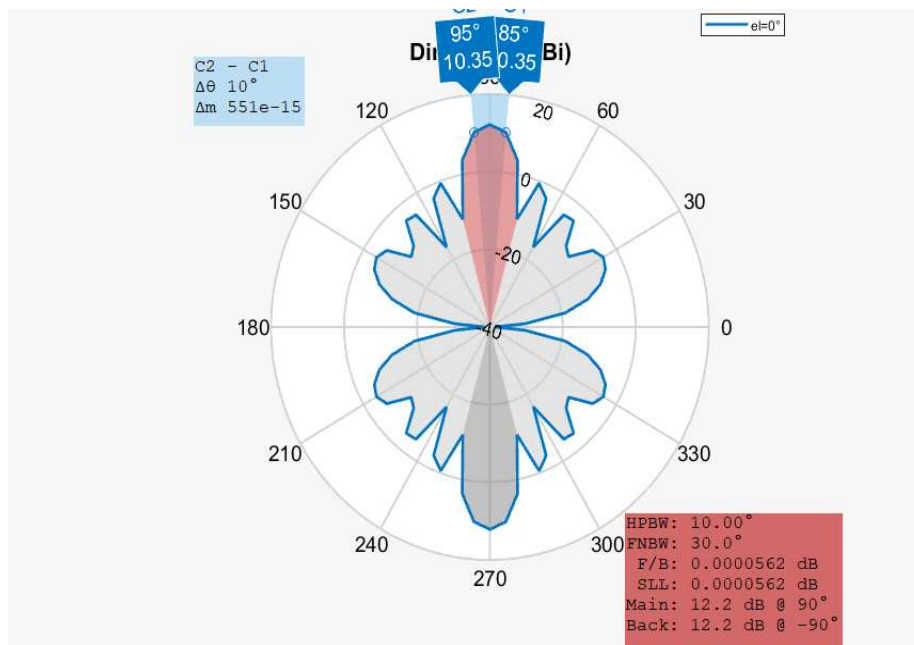


Figure 11: Azimuth pattern

*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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Figure 12 illustrates the pattern of the elevation, in antenna theory and propagation, antenna elevation is the visualization of the antenna plot pattern with reference to the vertical mounting

position.as opposed to the azimuth pattern plot which is the visualization of the antenna when it is mounted in the horizontal direction or orientation.

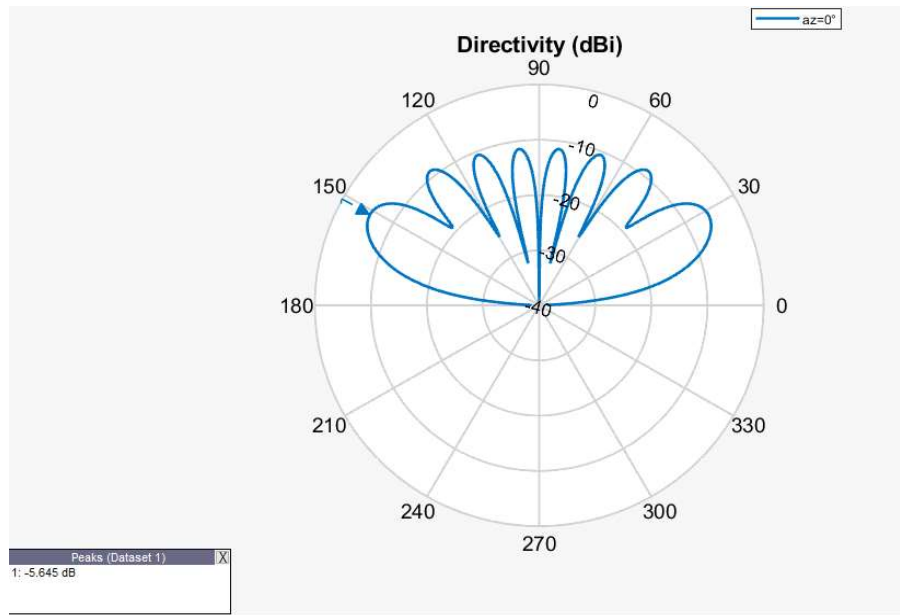


Figure 12: Elevation Pattern

The RF Propagation and visualization was carried out to ascertain the extent to which the radio waves are propagated through the entire Minna metropolis as well as visualize the area of coverage of the designed antenna from the transmitter site located at the main campus (Gidan Kwano) using the following transmitter Site properties/parameters: Latitude, Longitude, Antenna height, transmitter frequency, transmitter power

CONCLUSION

This paper presents the fundamental knowledge required for designing smart antennas leveraging an optimization based technique in an ever changing world of communication engineering where antennas are required to be designed to meet the needs of the end users. The smart antenna design out-performed other conventional antenna designs in terms of increasing the gain to reach a wider area of

coverage utilizing the available transmission power of 100W and design frequency of 92.3MHz. This smart design can be fabricated and used by various educational institutions operating campus FM radio and in search for optimum solution to extend the signal coverage to other locations especially for institutions operating multiple campuses. Furthermore, conventional FM radio stations can also use this smart antenna design to address signal coverage issues.

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*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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*Corresponding author: Ogechi Akamike.

✉ ogechi.pg2011252@futminna.edu.ng

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