Measurement and Analysis of Electromagnetic Field Strength in Port Harcourt and its Environs Due to Treasure FM Radio Transmitter

B. I. Bakare and J. C. Ozogbuda

Abstract—This paper Presents the measurement of electromagnetic field strength of Treasure FM transmitter operating at a frequency of 98.5MHz in Port Harcourt and its environs with the aid of an Automated Band Scanner GPS system. The measurement was carried out by taking the radio Station's transmitter as a reference point at the Centre and selecting 24 measuring points around the transmitter. These points were selected with 1km spacing taken as the interval between two measuring points, summing up to a total of 6km due North, East, West and South of the Radio Transmitter respectively. The result obtained was critically analyzed and interpreted with the aid of an attenuation decay curve. The behavior of the signal was seen to be a function of the Ground Constant of the terrain, reflection of the signal from the earth surface, Diffraction by obstacles and transmitter parameters such as transmitter Power, Antenna Gain and Antenna Height.

Index Terms—Attenuation; Measurement; Signal Strength; Transmitter.

I. INTRODUCTION

A radio wave is an Electromagnetic wave which emanates from a radiating source. The radio wave assumes all the properties of a plane wave; the wave-front is the plane which contains the Electric (E) and Magnetic (H) vectors and is at right angle to the direction of propagation and power flow. Usually, it is convenient to carry out studies in terms of the electric component, E of the wave which is known as the electric field strength of the wave (Radio wave). The quantitative measure of the strength of an Electric field is known as the Electric field strength (Intensity) measurement. From Electrostatics studies, we can loosely define Electric field strength at a point as the force on a unit positive charge at that point and is measured in Newton's per Coulomb or Volts per meter (Vm-1). The level of Electromagnetic field strength needed to provide adequate reception in the presence of an interfering signal(s) is referred to as the usable field strength. [1].

Treasure FM transmitter located at NTA premises Choba Road, Mgbuoba (latitude: 4°51'48.52"N, longitude: 6°57'48.80"E) transmits at a frequency of 98.5MHz with an output power of 3KW. The radio signal is propagated using space wave propagation mode. The measurement of electromagnetic field strength of Treasure FM signals at

different locations, that is, locations due EAST, NORTH, WEST and SOUTH of the Radio Transmitter respectively with 1Km interval was obtained using an automated mobile Band Scanner GPS system.

The transmitter has the following features: Antenna Load impedance: 50 ohms, Reflected power: 32watt, Polarization of Antenna: vertical polarization, Feeder line size:3/8 inch, Mast height: 540ft, Voltage of AVR:400V, Voltage of transmitter:24.8kv, Current of transmitter:45.7A and Wavelength:3.0456m

This paper presents the values and analysis of the measured Electromagnetic field strength of Treasure FM station at different locations, that is, locations due EAST, NORTH, WEST and SOUTH of the Radio Transmitter respectively with 1Km interval between two measuring points using an automated mobile Band Scanner GPS system

The measuring points were selected with 1km spacing taken as the interval between two measuring points, summing up to a total of 6km due North, East, West and South of the Radio Transmitter respectively. Fig. 1 below show the location of Treasure FM Radio Station in Port Harcourt, Nigeria

Fig. 1. Google Earth Map showing the Location of Treasure FM Radio Station in Port Harcourt, Nigeria

II. MODE OF PROPAGATION OF ELECTROMAGNETIC WAVES

Propagation of electromagnetic waves occurs in the different modes as shown in the Fig. 2 below

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Fig. 2. Modes of propagation of electromagnetic waves

A. Ground Wave Propagation

The propagation of the waves along the surface of the earth is called ground wave propagation. It is also known as surface wave propagation. These waves have the ability to propagate along the surface of earth as shown in Fig. 3 below. These waves bend around the obstacles which come in the path of these waves. Due to this rounding through the obstacles, the intensity of the electromagnetic waves will decrease rapidly. [2], [5]

Fig. 3. Ground wave propagation

B. Sky Wave Propagation:

Sky waves have frequency range between 2MHz to 30MHz. These radio waves have the ability to pass through earth's atmosphere. The ionosphere of our earth reflects these rays very efficiently. When these rays move along the atmosphere then their movement is from transmitter towards the receiver antenna as shown in Fig. 4 below This is called sky wave propagation of the waves [2].

Fig. 4. Sky wave propagation

C. Space Wave Propagation:

The space waves are the radio waves of very high frequency (i.e. between 30 MHz to 300 MHz or more). The space waves can travel through atmosphere from transmitter antenna to receiver antenna either directly or after reflection from ground in the earth's stratosphere region as shown in Fig. 5 below. That is why the space wave propagation is also called tropospheric propagation. [2], [5].

Fig. 5. Space wave propagation

III. MATHEMATICAL DESCRIPTION OF ELECTROMAGNETIC FIELD

There are different mathematical ways of representing the electromagnetic field. The first one views the Electric and Magnetic fields as three-dimensional vector fields. These vector fields each have a value defined at every point of space and time and are thus often regarded as functions of the space and time coordinates. As such, they are often written as $\mathbf{E}(x, y, z, t)$ electric field and $\mathbf{B}(x, y, z, t)$ magnetic field.

If only the electric field ($\mathbf{E}$) is non-zero, and is constant in time, the field is said to be an Electrostatic field. Similarly, if only the magnetic field ($\mathbf{B}$) is non-zero and is constant in time, the field is said to be a Magneto static field. However, if either the electric or magnetic field has a time-dependence, then both fields must be considered together as a coupled Electromagnetic field using Maxwell's equations. Maxwell's equations can be written in tensor form, generally viewed by physicists as a more elegant means of expressing physical laws [3], [6].

The behaviour of electric and magnetic fields, whether in cases of electrostatics, magneto statics, or electrodynamics (electromagnetic fields), is governed by Maxwell's equations. In the vector field formalism, these are:

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} \quad (1)$$

$$\nabla \cdot \mathbf{B} = 0 \quad (2)$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \quad (3)$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t} \quad (4)$$

where ρ is the charge density, which can (and often does) depend on time and position, ϵ_0 is the permittivity of free space, μ_0 is the permeability of free space, and $\mathbf{J}$ is the current density vector, also a function of time and position. The units used above are the standard SI units. Inside a linear material, Maxwell's equations change by switching the permeability and permittivity of free space with the permeability and permittivity of the linear material in question. Inside other materials which possess more complex responses to electromagnetic fields, these terms are often represented by complex numbers, or tensors [3],[6].

IV. GROUND CONSTANTS

The relative permittivity and Conductivity Values for different type of ground is shown in Table I below

TABLE I: GROUND CONSTANT VALUES

S/No	Type of Ground	Relative Permittivity	Conductivity (Ωm^{-1})
1.	Sea water	80	5
2.	Fresh water	80	0.005
3.	Moist soil	15-30	0.005-0.01
4.	Rocky ground	7	0.001
5.	Dry soil	4	0.001-0.01
6.	march	30	0.11
7.	Average soil	15	0.028
8.	Desert	3	0.11

V. MATERIALS AND METHODS

A. Measurement Procedure

The equipment for the electromagnetic field strength measurements is shown in Fig. 6 below:

Fig. 6. The equipment used for the measurement

- The receiver system (Band Scanner GPS) - to determine is received by the test antenna
- A Personal Computer (PC) system - serves as the visual output of the Band Scanner GPS.
- A module such as a USB cord - To power the receiver system and also serves as a medium or interface for the visual output.

Band Scanner GPS is a tool used to evaluate FM broadcast band and to log station identification parameters such as electromagnetic field strength, bandwidth, Received power at a distance and radio data system strength. "Band Scanner GPS" is a Google Earth compatible tool for visualization of selected FM Radio measurements [4].

After connecting the device to the PC where the software is already installed, the USB indicator will become bright green. The software will adjust the unit with the initial data. In case of previous usage of the device, the last settings like frequency and levels will be assigned in the device. If everything is Okay and no problems are detected the software will look like Fig. 7:

Fig. 7. Band Scanner GPS software display

B. Selection of Data points

As shown on the map of Fig. 8 about, six circles are drawn on the map taking Treasure FM Transmitter located at NTA premises Choba Road, Mgbuoba as the Centre point, a distance of 6KM radius at the four cardinal points taking 1km apart from the transmitter was measured at different locations due North, South, East, and West respectively. This was easily achieved with the use of Google Earth application as it depicts the location of the transmitter after inputting its coordinates. With the help of Google Earth visual, 1km intervals from the transmitter were easily projected and a measurement is taken with help of the GPS band scanner. The coordinates gotten from Google Earth application were easily imputed on the GPS Band Scanner since it's a Google Earth Compatible tool and can log stations identification parameters such as electromagnetic field strength, bandwidth, received power at a distance and radio data system strength [4].

Fig. 8. Showing the 24 measuring points due East, West, North and South of the Transmitter

C. Presentation of Data

TABLE II: ELECTROMAGNETIC FIELD STRENGTH OF TREASURE FM AT A RANGE (1KM INTERVAL) OF 6KM DUE EAST

S/No	Distance from transmitter	Location Coordinates: Latitude(Lat) and longitude(long)	Measured value (dB μ v)	Field strength μ v/m	Time of measurement
1	1km East	Lat: 4°52'14.69"N Long: 6°58'9.17"E	52.6	0.0526	12:57pm
2	2km East	Lat: 4°52'9.51"N Long: 6°58'51.48"E	48.3	0.02415	1:00pm
3	3km East	Lat: 4°52'5.64"N Long: 6°59'25.06"E	54.4	0.01813	1:03pm
4	4km East	Lat: 4°52'19.36"N Long: 6°59'55.96"E	43.2	0.0108	1:25pm
5	5km East	Lat: 4°53'12.03"N Long: 7° 0'9.29"E	35.3	0.00706	1:35pm
6	6km East	Lat: 4°54'14.01"N Long: 7° 0'0.44"E	48.6	0.0081	1:38pm

TABLE III: ELECTROMAGNETIC FIELD STRENGTH OF TREASURE FM AT A RANGE (1KM INTERVAL) OF 6KM DUE NORTH

S/No	Distance from transmitter	Coordinates: Latitude(Lat) and longitude(long)	Measured value (dB μ v)	Field strength μ v/m	Time of measurement
1	1km west	Lat: 4°51'16.05"N Long: 6°57'50.88"E	52.6	0.0526	2:16pm
2	2km west	Lat: 4°50'59.55"N Long: 6°57'6.85"E	54.6	0.0273	2:29pm
3	3km west	Lat: 4°50'30.98"N Long: 6°56'34.99"E	52.7	0.0175	2:50pm
4	4km west	Lat: 4°49'43.83"N Long: 6°57'11.05"E	43.2	0.0108	2:48pm
5	5km west	Lat: 4°49'6.98"N Long: 6°57'22.40"E	45.3	0.00906	2:54pm
6	6km west	Lat: 4°49'32.26"N Long: 6°57'42.85"E	50.6	0.00843	2:56pm

TABLE IV: ELECTROMAGNETIC FIELD STRENGTH OF TREASURE FM AT A RANGE OF 6KM (1KM INTERVAL) DUE WEST

S/No	Distance from transmitter	Location Coordinates: Latitude(Lat) and longitude(long)	Measured value (dB μ v)	Field strength (μ v/m)	Time of measurement
1	1km north	Lat: 4°52'8.10"N Long: 6°57'21.83"E	47.8	0.0478	12:54pm
2	2km north	Lat: 4°52'38.93"N Long: 6°57'4.82"E	24.1	0.01205	12:52pm
3	3km north	Lat: 4°52'53.00"N Long: 6°56'34.60"E	22.3	0.00743	12:50pm
4	4km north	Lat: 4°53'5.17"N Long: 6°56'3.74"E	20.7	0.005175	12:46pm
5	5km north	Lat: 4°53'12.32"N Long: 6°55'29.56"E	25.6	0.00512	12:44pm
6	6km north	Lat: 4°53'30.12"N Long: 6°55'1.32"E	35.5	0.005917	12:39pm

TABLE V: ELECTROMAGNETIC FIELD STRENGTH OF TREASURE FM AT A RANGE OF 6KM (1KM INTERVAL) DUE SOUTH

S/No	Distance from transmitter	Coordinates: Latitude(Lat) and longitude(long)	Measured value (dB μ v)	Field strength μ v/m	Time of measurement
1	1km south	Lat: 4°51'25.87"N Long: 6°58'12.52"E	54.1	0.0541	2:08pm
2	2km south	Lat: 4°51'5.24"N Long: 6°58'36.88"E	53.6	0.0268	2:06pm
3	3km south	Lat: 4°50'39.42"N Long: 6°58'57.47"E	54.6	0.0182	2:04pm
4	4km south	Lat: 4°50'14.77"N Long: 6°59'18.80"E	53.2	0.0133	3:05pm
5	5km south	Lat: 4°49'58.54"N Long: 6°59'48.49"E	40.1	0.00802	3:07pm
6	6km south	Lat: 4°49'57.82"N Long: 7° 0'20.28"E	47.1	0.00785	3:15pm

VI. RESULTS AND DISCUSSIONS

A. Results

Graphical representation of the Field strength of Treasure FM 6km from the Transmitter due North, South, East and West are shown below

Fig. 9. Graph of Field Strength against Distance Due North

From Fig.9 above, it was observed that at 1km away from the transmitter where the field strength was measured to be $0.0478 \mu\text{v/m}$, the signal was very high and at 2km away from the transmitter, the value of the field strength decreased considerably to $0.01205 \mu\text{v/m}$, however, between 3km from the transmitter to 6km there was only slight changes observed in the value of the Field Strength

Fig. 10. Graph of Field Strength against Distance Due East

Fig. 10 above shows the graphical representation of the field strength of Treasure FM due East 6km away from the transmitter. At 1km from the transmitter the signal at the time of measurement was significantly high having a field strength of $0.0526 \mu\text{v/m}$ and decreased considerably to $0.02415 \mu\text{v/m}$ at 2km away from the transmitter. The signal decreased slightly from 3km to 5km away from the transmitted and also increased slightly at 6km away from the transmitter at the time.

Fig. 11. Graph of Field Strength against Distance Due South

From the graphical representation of the field strength due South it was observed that at 1km away from the transmitter where the field strength was measured to be $0.0541 \mu\text{v/m}$, the signal was very high and at 2km away from the transmitter, the value of the field strength decreased considerably to $0.0268 \mu\text{v/m}$, however, between 3km from the transmitter to 6km there was only slight changes observed in the calculated Field Strength value

Fig. 12. Graph of Field Strength against Distance Due West

Fig. 12 shows the graphical representation of the field strength due West and it was observed from the figure that at 1km away from the transmitter where the field strength was measured to be $0.0526 \mu\text{v/m}$, the signal was very high and at 2km away from the transmitter, the value of the field strength decreased considerably to $0.02783 \mu\text{v/m}$, however, between 3km from the transmitter to 6km there was only slight changes observed in the Field Strength value.

B. Discussions

For an ideal isotropic radiating antenna, the signal Strength is always equal in all directions, but for this work the Signal Strength is not the same in all direction as the signal level due north is lowest relative to east, south and west as shown in Fig. 13 below

Fig. 13. Comparative Analysis of the Signal Strength in all directions

In summary, the figure above shows the Signal Strength level due North, East, South and West of the transmitter at a 6km range. The graph indicates the lowest field strength from transmitter due North relative to the highest due west of the transmitter. This is due to factors such as weather, topography of the area, mode of propagation and the Ground Constant at the time of measurement

VII. CONCLUSION

This paper was able to demonstrate how electromagnetic field strength of Treasure FM Radio can be measured and from the analysis of the result gotten from the measurement, the electromagnetic field strength of Treasure FM signal within 6km range from the transmitter was highest due West and lowest due North of the transmitter at the time of measurement. it was observed that at certain distances close to the transmitter the field strength at some locations were high while at locations far from the transmitter, the Received Signal Strength (RSS) was low.

The behavior of the signal was seen to be a function of the Ground Constant of the terrain, reflection of the signal from the earth surface, Diffraction by obstacles and transmitter parameters such as transmitter Power, Antenna Gain and Antenna Height

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