MEASUREMENT AND ANALYSIS OF RADIO FREQUENCY RADIATION LEVELS FROM A BASE TRANSCIVER STATION (BTS) IN UNIBEN

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CERTIFICATION

This is to certify that this project work was carried out by Eguavoen Louis, with matriculation number **PSC1311423** of the department of physics, faculty of physical sciences, University of Benin, Benin city, Edo state, Nigeria carried out this research work under my supervision.

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EXTERNAL EXAMINER **DATE**

DEDICATION

This project work is dedicated to God almighty for seeing me through and standing by me. Despite all the numerous challenges I faced during this research. Furthermore this report is dedicated to my family, my friends, course mates and colleagues for their immense support, ideas and contributions to ensure I carry out a successful project work.

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ABSTRACT

Over the years, Nigeria has experienced a steady growth in the telecommunication industry, with over ten (10) mobile wireless telecommunication services providers, over fifteen thousand (15,000) Base Transceiver Stations (BTS) spreads across the country, and also over One Hundred and seventeen million lines actively connected. With this tremendous growth, the concern among Nigerians about the effects and possible health hazard of electromagnetic waves radiation from the BTS and the mobile handsets cannot be over emphasize. This study focuses on measurement of Electromagnetic waves Radiation (w/m2) radiated from Base Transceiver Stations (BTS). These measurements were carried out using the handheld **GQ EMF 390** digital meter. Maximum radiation values were measured and recorded from (BTS) of a selected site in **UNIBEN** and the results were compared with the standard provided by the International Commission on Non-Ionizing Radiation Protection, ICNIRP, 1998 *(4.5W/m2 for 900MHz and 9W/m2 for 18000MHz)* and an agreement was obtained.

CHAPTER 1

INTRODUCTION TO TELECOMMUNICATIONS

1.1 INTRODUCTION

Cellular wireless technology now allow the delivery of voice, text, images, music, video and other valuable services and it relies on an extensive network of base station to do this. However, base stations have generated much public concern. They need to be high up, so they are often located on towers or masts or rooftops. Towers, which are usually 25 to 80 meters tall, and sometimes, local residents object to their location, because of health concerns due to emissions or simply because of their appearance. Electrical and electronic devices, wireless cellular telephones and other mobile personal communication services is the fastest growing field in the world. There is uncertainty about the health effects of radio frequencies (RF).

The term radio frequency (RF) covering all frequencies used for communication, radar, satellites etc. is a rate of oscillation in the range of about 3kHz to 300 GHz, which corresponds to the frequency of radio waves, and the alternating currents which carry radio signals. RF usually refers to electrical rather than mechanical oscillations, perhaps since RF cannot be seen it has been confused with ionizing radiation. The consequence of exposure to both can be stated as been very different. Radio transmissions relatively a very new technology, which had its beginning in the theoretical work of Maxwell and experimental work of Hertz, a German physicist. Many others also made contributions, including the development of devices which could detect the presence of radio waves (Aslan,1972). Over the years, the transmission of radio waves has become an established technology which is taken for granted and which among other things provides for broadcasting to our homes for entertainment, the most recent development resulting in the domestic satellite dish antenna (Kitchen, 2001).

In the case of radio transmitters, however, the whole intention is to transmit RF energy into free space and the antenna used to do so is specifically designed to achieve this objective. Very low frequencies, e.g. mains power frequency do not give rise to any significant amount of radiation. However, as we increase the frequency, then it becomes increasingly possible to radiate electromagnetic waves, giving a suitable antenna to act as an efficient launcher. Wavelength (λ) is an important parameter in considering antenna system and propagation since it is a factor in determining the physical dimension of antennas. It relate to the velocity (c) and frequencies(f) of radiation as;

$$c = \lambda f$$

Radio waves can therefore be referred to either in terms of the wavelength or the frequency.

A certain amount of energy from radiation is absorbed by the body and converted to heat. This is called thermal effect. It results in public concern about possible health effects of human exposure to electromagnetic energy. Concerns about other possible thermal effects arising from exposure to RF include, suggestions of subtle effects on cells that could have an effect on cancer development or influences on electrically excitable tissue. It could influence the function of the brain and nervous tissue. There has also been concern about whether there could be effects on brain function, with particular emphasis on headaches and memory loss. Few studies have yet investigated these possibilities.

The basic limit of exposure is expressed by the quantity called “specific absorption rate” (SAR). SAR is the time rate at which electromagnetic energy (EM) is absorbed/ dissipated by an element of biological body mass, and is expressed in units of watts per kilogram (W/kg). The maximum local SAR, which is the most critical quantity in the context of potential health effects of RF energy radiated, depends on a large number of factors

The factors that influence how much RF an individual may be exposed to include: The power output, frequency and type of transmitter, the distance the person is from the transmitter, the location of the person with respect to the transmitted beam, the type of antenna and the direction of the transmitted beam; the presence of other structures near the person that may shield them or reflect the RF signals towards them; and the time spent in a particular area of the RF field.

1.2 AIMS AND OBJECTIVES OF STUDY:

The aim of this project work is to evaluate radio-frequency radiation level from a mobile base station of telecommunication network in Uniben.
This work is carried out to accomplish the following goals.

- To access radio frequency from levels from a selected BTS in Uniben, thereby estimating the exposure levels.
- Using the radiation power density (w/m^2) to plot a graph against distance (m) to observe the attenuation.
- To compare the radiation from the BTS with the standard given by the ICNIRP to see if harmful or not
- To evaluate and explore the safety limits and precautions of the closeness of BTS to humans.

1.3 STATEMENT OF RESEARCH PROBLEM:

The exposure levels in the accessible environment of base stations depend on several physical phenomena as reflection, diffraction, multi - path propagation and diffusion. This leads to the situation that the electromagnetic field levels in typical environments of base stations vary both in space and time. For this reason, the power density will be measured to find relationship, describes its behavior according to the change in the distance from base station.

1.4 JUSTIFICATION

Since individuals are exposed to different forms of non-ionizing radiations depending on their sources, effects and infiltrating power, specifically, impacts of Radio-wave and microwaves related by communication antennas erected within living regions. It is basic that we survey the circumstances in connection to health related issues that the public may be exposed to, and to draw attention of the appropriate body to it.

1.5 SCOPE AND LIMITATION

This research work is covers selected base transceiver station and its limited to those in the University of Benin, Benin city.

1.6 MATERIALS USED AND METHODS APPLIED

A handheld three-axis RF meter (The GQ EMF-390) was used for the measurement of the power density of electromagnetic radiation from mobile base stations around UNIBEN. The GQ EMF-390 advanced multi-function digital EMF meter is designed and developed by GQ Electronics, Seattle, USA. It is designed to be a portable and convenient device. It can be used as regular EMF, EF and RF radiation detection. This high sensitivity meter lets you check EMF/RF radiation easily.

The meter features multiple sensors to ensure maximum scale/range measurement and highest accuracy:

- Electromagnetic Fields
- Electric Field

- Radio Frequency

Additionally, the testing features also include:

- Radio Spectrum Power Analyzer.
- Real-time (every second) data logging.

The meter is able to identify the common source from EMF/RF measured, such as Power Line, WiFi/Cell phone, Cell Tower, Microwave etc. It also comes with built-in audible and visual alarm.

Most of the base stations have at least 3 sectorial antennas on it, which means that they cover 360˚ sector area. This implies that measurement can be taken at any direction for convenient sake. Measurements were taken at every 50m interval to a distance of 500m radius from each mast.

On getting to the site, a quick environmental assessment was made. Such as the density of buildings around, direction to get the desired length, vegetation and the visibility of any other mast were also accessed.

The meter was set to the RF measurement mode and also to the maximum instantaneous measurement mode, to measure the maximum instantaneous power density at each point. Each measurement was made by holding the meter away from the body, at arm's length and at about 1.5m above the sea level pointing towards the mast002E

Five (5) close values of the power density were taken and recorded and an average value was calculated. Precautions were taken as much as possible, so that the measured value were not influenced by other sources. Movement of the meter while measurements were taken was avoided to reduce excessive field strength values due to electrostatic charges.

1.7 HISTORICAL PERSPECTIVE OF TELECOMMUNICATION IN NIGERIA.

Telecommunication is the transmission of information, over significant distances to communicate. It makes use of electrical devices such as telephones and telegraphs, the use of radio and microwave communications, as well as fiber optics and their associated electronics, plus use of the broadcasting satellites and the internet.

The original term broadcast referred to the literal sowing of seeds on farms by scattering them over a wide field. It was first adopted by early radio engineers from the Midwestern United States to refer to the analogous dissemination of radio signals.

Telecommunications actually started in 1886 in Nigeria because of the need of the colonial government to connect with other colonial administration in Ghana, Sierra Leone, Gambia and England. By 1893 colonial offices in Lagos, Jebba and Ilorin were provided with telephone services. Gradually a national telecommunication network was emerging.

It was in 1923 that the first commercial telephone service between the towns of the Itu and Calabar was established. Between 1946 and 1952, a three channel line carrier system was commissioned between Lagos and Ibadan and was extended to Oshogbo, Kaduna, Kano, Benin and Enugu; this connected the colonial office in London with Lagos likewise the commercial centres in the country with local authority offices. The need of the telephony system in the colonial Nigeria then led to the 1955-622 development program. It provided for the expansion of the trunk using a VHF multichannel radio system on a nationwide basis and a short microwave link between Lagos and Ibadan.

After the independence of 1960, there was a need for the expansion of the network to meet the needs of the fledging commercial and industrial growth of the young nation. This led to the establishment of Nigeria External Telecommunications (NET) Limited which was responsible for the external telecommunication services.

The Department of posts and telecommunication was in charge of internal network. It may be of interest to know that telecommunications was always an item in each of the development plan of Nigeria.

However both parastatals were merged in 1985 to form Nigerian Telecommunications Ltd. (NITEL), a limited Liability company which administered both the internal and external telecommunications services in Nigeria. NITEL is currently under privatization.

Telecommunications industry in Nigeria was underdeveloped until the deregulation of the sector in 1992 and the formulation of a regulatory body known as the Nigerian Communications Commission (NCC) was established. To regulate Telecommunications in the Country the then Decree No. 75 of 1992 was promulgated now known as the Nigerian communication commission Act, LFN 2009. The Decree created the Nigerian communication which was first inaugurated in 1995. The commission is to regulate, monitor and control telecommunications in Nigeria.

The mobile communication services made its entrance into the Nigerian telecommunications market in 1993 with NITEL providing a national service alongside a Lagos Service provided by the Mobile Telecommunications Services (MTS). Some of the services provided by these companies were voicemail, paging and voice services over the analogue E-TACS network. MTS shut down due to failure to pay interconnection charges to NITEL.

The history of the Global System for Mobile Communication in Nigeria can be traced back to the year 2001 during the deregulation of the telecommunications industry. It has been eighteen years since the GSM has been set in place. Since the debut of the Global System of Mobile Communication (GSM) in 2001, there has been an unbelievable exponential growth in the number of subscribers from about a million to over a hundred million subscribers.

Telecommunication in itself has evolved throughout the centuries from the analogue era with organizations such as INTELSAT and INMARSAT controlling the traffic of international messages with the limitation of services such as voice telephony, telex, facsimile, telegraphy etc. to the digital era with the launch of satellites for Global Personal Communication Systems (GMPCS), Voice Over Internet Protocol (VOIP), the debut of companies and infrastructure provider to the telecommunication industry such as cable broadcasting networks and introduction of Integrated Services Digital Network (ISGDN).

Prior to this revolution, the Nigeria Telecommunication Ltd was burdened with the responsibility of providing a means of communication which was fundamentally the landline and it was ruined by flagrant inefficiency and corruption. This responsibility was taken over by the various GSM network providers we have, the first of which was ECONET (which is known as Airtel today) was formally launched on the 6th August, 2001 and Mobile Telephone Networks (MTN) followed suit almost immediately. The renewable GSM licenses which had a 5 year expiration date were awarded to the operators and they were allowed to operate within the 850 MHz and 1900 MHz spectrum bands. Specific targets had been set for the operators by the NCC and some of these targets were a minimum of a 100,000 subscribers each in the beginning year of operations, 1.5 million subscribers in the next five years, and a minimum of 5% geographical coverage within each of the country's geopolitical states. The NCC also made known that its main goal is in achieving a comprehensive secure and efficient mobile network.

Studies have shown that the concurrent launching of three service providers in the GSM market caused a growth opportunity similar to the rapid growth that happens in many individual markets. The intensity of the competition caused an expansion in the packages offered at a better rate and the introduction of value added services to attract and retain customers.

It is also empowered to issue licenses to telecommunication providers. The first licenses round was in 2002. It has issued over 200 licenses to different companies to date.

CHAPTER TWO

LITERATURE RIVIEW

2.1 HOW WIRELESS COMMUNICATION WORKS

Have you ever wondered how text messages, pictures, and videos are sent to your wireless phone Everyday billions of devices around the world connect and share data at the speed of light. It may look like magic, but it’s really just a powerful, invisible, and under-appreciated force known as electromagnetism**.**

Electromagnetism is one of the four fundamental forces in nature. As the name suggests it is the interaction between the electric and magnetic fields. Electricity and magnetism were originally thought to be separate forces, but were unified when James Clerk Maxwell published his Treatise on Electricity and Magnetism in 1873 showing that both phenomena could be explained by one force.

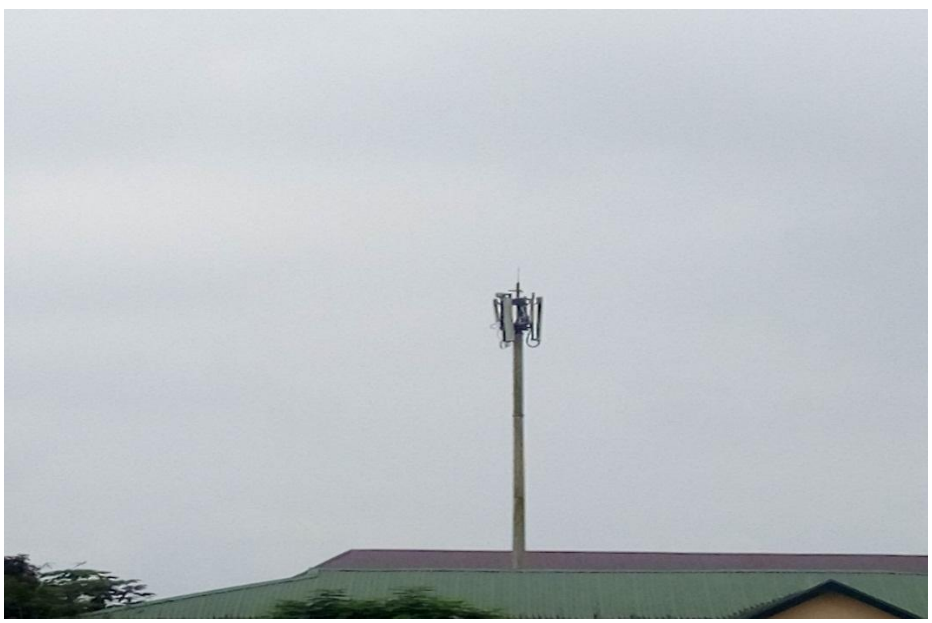


Fig 1.1 Uniben ICT radio antenna

2.1.1 ELECTROMAGNETIC WAVES

An electromagnetic wave is a disturbance in the electromagnetic field. This field exists everywhere, and disturbances in this field exist around the presence of electricity or magnetism. Electromagnetic waves are formed when an electric field comes in contact with a magnetic field. They are hence known as ‘electromagnetic’ waves. The electric field and magnetic field of an electromagnetic wave are perpendicular (at right angles) to each other. They are also perpendicular to the direction of the EM wave.

EM waves travel with a constant velocity of $3x10^8$ ms^{-1} in vacuum. They are deflected neither by the electric field, nor by the magnetic field. However, they are capable of showing interference or diffraction. An electromagnetic wave can travel through anything - be it air, a solid material or vacuum. It does not need a medium to propagate or travel from one place to another. Mechanical waves (like sound waves or water waves), on the other hand, need a medium to travel. EM waves are 'transverse' waves. This means that they are measured by their amplitude (height) and wavelength (distance between the highest/lowest points of two consecutive waves).

2.1.2 HOW WAVES ARE TRANSMITTED

An electromagnetic wave is created when there is a disturbance in the electromagnetic field. A disturbance like this can be created when you do something as simple as briefly touch both ends of a wire to the terminals of a battery. This allows an electric current to flow through the wire, which in turn creates a weak electromagnetic wave which expands outward in all directions. The wave created in our example would not travel far and would not contain any information. If it were intercepted by a radio transmitter, it would just sound like static. But it's actually easy to create an electromagnetic wave, and it's not much harder to use them to send information.

2.1.3 HOW WAVES CARRY INFORMATION

In the early 20th century radio waves transmitted data as Morse code. This process of information transfer was slow and had limited capabilities. This is also called modulation. Modulation is the act of embedding a wave "into" another wave to produce an information carrying signal. The two broadest categories of modulation are analog and digital. The information is embedded by carefully controlling certain aspects of the wave (amplitude, frequency and phase) which then can be "demodulated" on the receiving end.

Today electromagnetic waves can carry virtually any type of data. Just as waves in a lake move up and down as they expand outward, we can make electromagnetic waves do the same thing. Note that these kinds of waves resemble a sine function, as seen below.

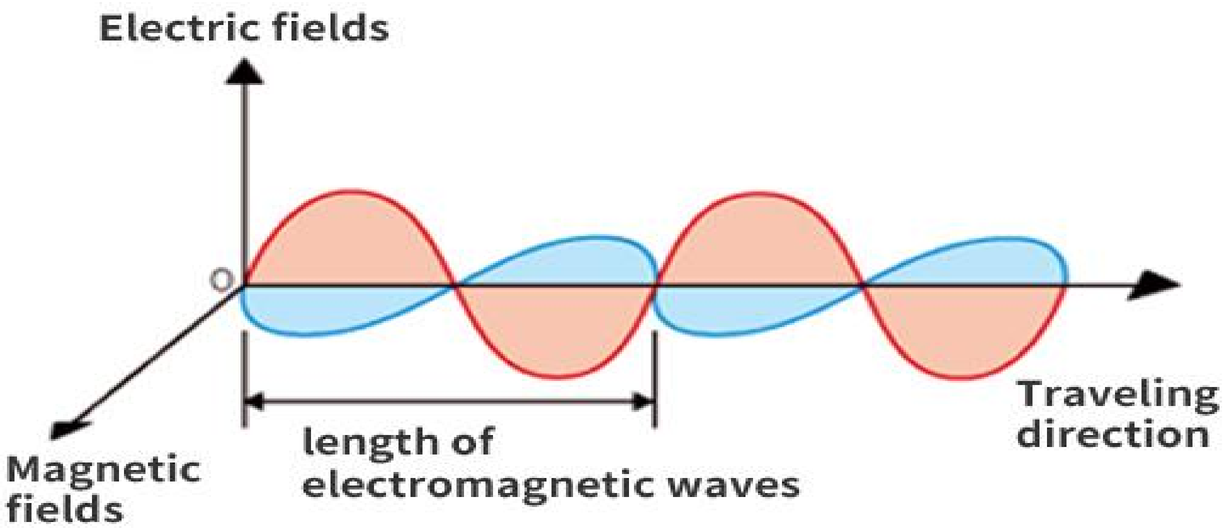


Fig 1.2 Electromagnetic wave pattern

We can encode information into these waves by modulating (or changing) some property of the standard sine function such as amplitude, frequency, or phase. The wave is then sent through the air to be intercepted by an electrical conductor, like an antenna, where the original information can be obtained by decoding the modulated function. In general, we can encode information into sine functions. We can then send this information to other devices by transmitting the modulated functions as electromagnetic waves. When the waves are received by other devices, the data can be decoded and the original information obtained.

2.1.4 SENDING AND RECEIVING INFORMATION

Transmitting information between two devices using radio waves requires a transmitter and a receiver. The transmitter takes information like audio or video, encodes it into a sine function, and transmits the function into the air in the form of an electromagnetic wave. The receiver detects the wave and decodes the data.

Antennas are used by both transmitters to transmit waves and by receivers to detect them.

Electromagnetic waves can travel anywhere from a few miles (for television broadcasts) to millions of kilometers (for deep space transmissions) depending on the power of the transmission. Because radio waves travel out in every direction, their signal becomes weaker the further they travel. It is for this reason that you must use a higher powered transmitter to send a radio wave over a longer distance.

2.1.5 THE FORCE IS ALL AROUND YOU

The ability to sense electromagnetic waves is known as magnetoreception, and is an ability shared by many in the animal kingdom including birds, bats, fruit flies, and mice. Birds are known to use the earth's magnetic field for navigation — an ability that helps them orient themselves relative to the ground and develop regional maps.

Although we can't see them, there are countless electromagnetic waves all around us traveling at the speed of light. Electromagnetic waves are used for television broadcasts, cell phones, Bluetooth, radio, and every other form of wireless communication.

2.2 THE ELECTROMAGNETIC SINE WAVE EQUATION

The **electromagnetic wave equation** is a second-order partial differential equation that describes the propagation of electromagnetic waves through a medium or in a vacuum. It is a three-dimensional form of the wave equation. The homogeneous form of the equation, written in terms of either the electric field **E** or the magnetic field **B**, takes the form:

$$\left(V_{ph}^2\nabla^2 - \frac{\partial^2}{\partial t^2}\right)E = 0$$

$$\left(V_{ph}^2\nabla^2 - \frac{\partial^2}{\partial t^2}\right)B = 0$$

Where; $V_{ph} = \frac{1}{\sqrt{\mu\varepsilon}}$

is the speed of light (i.e. phase velocity) in a medium with permeability μ, and permittivity ε, and ∇^2 is the Laplace operator. In a vacuum, $v_{ph} = c_0 =$ 299,792,458 meters per second, a fundamental physical constant. The electromagnetic wave equation derives from Maxwell's equations. In older literature, **B** is called the *magnetic flux density* or *magnetic induction*. Maxwell's derivation of the electromagnetic wave equation has been replaced in modern physics education by a much less cumbersome method involving combining the corrected version of Ampère's circuital law with Faraday's law of induction. To obtain the electromagnetic wave equation in a vacuum using the modern method, we begin with the modern **'Heaviside' form of Maxwell's equations**. In a vacuum- and charge-free space, these equations are:

$$\nabla . \mathrm{E} = 0$$

$$\nabla \times \mathrm{E} = -\frac{\partial \mathrm{B}}{\partial t}$$

$$\nabla . B = 0$$

$$\nabla \times B = \mu_o \varepsilon_o \frac{\partial \mathrm{E}}{\partial \mathrm{t}}$$

These are the general Maxwell's equations specialized to the case with charge and current both set to zero. Taking the curl of the curl equations gives:

$$\nabla \times (\nabla \times \mathbf{E}) = -\frac{\partial}{\partial t}\nabla \times \mathbf{B} = -\mu_0 \varepsilon_0 \frac{\partial^2 \mathbf{E}}{\partial t^2}$$

$$\nabla \times (\nabla \times \mathbf{B}) = \mu_0 \varepsilon_0 \frac{\partial}{\partial t}\nabla \times \mathbf{E} = -\mu_0 \varepsilon_0 \frac{\partial^2 \mathbf{B}}{\partial t^2}$$

We can use the vector identity

$$\nabla\times\left(\nabla\times\mathrm{V}\right) = \nabla\left(\nabla . \mathrm{V}\right) - \nabla^2\mathrm{V}$$

Where V is any vector function of space and

$$\nabla^2\mathrm{V} = \nabla.\left(\nabla\mathrm{V}\right)$$

Where **∇V** is a dyadic which when operated on by the divergence operator ∇ yields a vector. Since

$$\nabla . \mathrm{E} = 0$$

$$\nabla . \mathrm{B} = 0$$

Then the first term on the right in the identity vanishes and we obtain the electromagnetic wave equation

$$\frac{1}{C_0^2}\frac{\partial^2 \mathrm{E}}{\partial t^2} - \nabla^2 \mathrm{E} = 0$$

$$\frac{1}{C_0^2}\frac{\partial^2 \mathrm{B}}{\partial t^2} - \nabla^2 \mathrm{B} = 0$$

Where $C_0 = \frac{1}{\sqrt{\mu_o \varepsilon_0}}$ = 2.99792450x10^8m/s is the speed of light.

Since the speed of light in a given medium or vacuum does not change, high-frequency Electromagnetic waves have short wavelengths and low-frequency waves have long Wavelengths. The electromagnetic "spectrum" includes all the various forms of electromagnetic energy from extremely low frequency (ELF) energy, with very long Wavelengths, to X-rays and gamma rays, which have very high frequencies and correspondingly short wavelengths. In between these extremes are radio waves, Microwaves, infrared radiation, visible light, and ultraviolet radiation, in that order. The RF part of the electromagnetic spectrum is generally defined as that part of the spectrum where electromagnetic waves have frequencies in the range of about 3 kilohertz to 300 gigahertz. One kilohertz (kHz) equals one thousand hertz, one megahertz (MHz) equals one million hertz, and one gigahertz (GHz) equals one billion hertz.

The general solution to the electromagnetic wave equation is a linear superposition of waves of the form

$$\mathrm{E}(x,t) = \mathrm{E}_0 \sin\left[2\pi\left(ft - \frac{x}{\lambda} + \varphi\right)\right]\hat{\jmath}$$

$$\mathrm{B}(x,t) = \mathrm{B}_0 \sin\left[2\pi\left(ft - \frac{x}{\lambda} + \varphi\right)\right]k$$

This particular example is one dimensional, but there are two dimensional solutions as well — many of them. The interesting ones have electric and magnetic fields that change in time. These changes then propagate away at a finite speed. Such a solution is an *electromagnetic wave*.

2.3 THE ELECTROMAGNETIC SPECTRUM

The **electromagnetic spectrum** is the range of frequencies (the spectrum) of electromagnetic radiation and their respective wavelengths and photon energies.

The electromagnetic spectrum covers electromagnetic waves with frequencies ranging from below one hertz to above 10^{25} hertz, corresponding to wavelengths from thousands of kilometers down to a fraction of the size of an atomic nucleus. This frequency range is divided into separate bands, and the electromagnetic waves within each frequency band are called by different names; beginning at the low frequency (long wavelength) end of the spectrum these are: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays at the high-frequency (short wavelength) end. The electromagnetic waves in each of these bands have different characteristics, such as how they are produced, how they interact with matter, and their practical applications. The limit for long wavelengths is the size of the universe itself, while it is thought that the short wavelength limit is in the vicinity of the Planck length. Gamma rays, X-rays, and high ultraviolet are classified as *ionizing radiation* as their photons have enough energy to ionize atoms, causing chemical reactions.

Spectrum of Electromagnetic Radiation				
Region	Wavelength (Angstroms)	Wavelength (centimeters)	Frequency (Hz)	Energy (eV)
Radio	$> 10^9$	> 10	$< 3 \times 10^9$	$< 10^{-5}$
Microwave	$10^9 - 10^6$	10 - 0.01	$3 \times 10^9 - 3 \times 10^{12}$	$10^{-5} - 0.01$
Infrared	$10^6 - 7000$	$0.01 - 7 \times 10^{-5}$	$3 \times 10^{12} - 4.3 \times 10^{14}$	0.01 - 2
Visible	7000 - 4000	$7 \times 10^{-5} - 4 \times 10^{-5}$	$4.3 \times 10^{14} - 7.5 \times 10^{14}$	2 - 3
Ultraviolet	4000 - 10	$4 \times 10^{-5} - 10^{-7}$	$7.5 \times 10^{14} - 3 \times 10^{17}$	$3 - 10^3$
X-Rays	10 - 0.1	$10^{-7} - 10^{-9}$	$3 \times 10^{17} - 3 \times 10^{19}$	$10^3 - 10^5$
Gamma Rays	< 0.1	$< 10^{-9}$	$> 3 \times 10^{19}$	$> 10^5$

Fig 1.3 EM spectrum wavelength and frequency

2.4 RADIO FREQUENCY RADIATION

Radio waves and microwaves are forms of electromagnetic energy that are collectively described by the term "radiofrequency" or "RF." RF emissions and associated Phenomena can be discussed in terms of "energy," "radiation" or "fields." Radiation is defined as the propagation of energy through space in the form of waves or particles.

Electromagnetic "radiation" can best be described as waves of electric and magnetic Energy moving together (i.e., radiating) through space. These waves are generated by the movement of electrical charges such as in a conductive metal object or antenna. For example, the alternating movement of charge (i.e., the "current") in an antenna used by a radio or television broadcast station or in a cellular base station antenna generates electromagnetic waves that radiate away from the "transmit" antenna and are then intercepted by a "receive" antenna such as a rooftop TV antenna, car radio antenna or an antenna integrated into a hand-held device such as a cellular telephone.

The term "electromagnetic field" is used to indicate the presence of electromagnetic energy at a given location. The RF field can be described in terms of the electric and/or magnetic field strength at that location. Like any wave-related phenomenon, electromagnetic energy can be characterized by a wavelength and a frequency. The wavelength (λ) is the distance covered by one complete electromagnetic wave cycle. The frequency is the number of electromagnetic waves passing a given point in one second. For example, a typical radio wave transmitted by an FM radio station has a wavelength of about three (3) meters and a frequency of about 100 million cycles (waves) per second or "100 MHz." One "hertz" (abbreviated "Hz") equals one cycle per second. Therefore, in this case, about 100 million RF electromagnetic waves would be transmitted to a given point every second.

2.5 STAGES INVOLVED IN TELECOMMUNICATION

Communication process consists of some interrelated steps or parts through which messages are sent form sender to receiver. The process of communication begins when the sender wants to transmit a fact, idea, opinion or other information to the receiver and ends with receiver's feedback to the sender. It consists of a chain of related actions and reactions which together result in the exchange of information. The main components of communication process are sender, message, channel, receiver and feedback.

In order to understand the process of communication, it is necessary to describe each of these components.

SENDER: The **sender** is the first component of the process of communication. The sender may be a speaker, a writer or any other person. He is the one who has a message and wants it to share it for some purpose.

IDEATION: Ideation is the preliminary step in communication where sender creates an idea to communicate. This idea is the content and the basis of the message to be communicated. Several ideas may generate in the sender's mind.

The sender must identify, analyze and arrange the ideas sequentially before transmitting them to the receiver.

MESSAGE: The message is the heart of communication. It is what the sender wants to convey to the receiver. It may be verbal i.e. written or spoken or non-verbal i.e. body language, space language etc.

ENCODING: To encode is to put the idea into words. In this step the communicator organizes his ideas into a series of symbols or words which will be communicated to the intended receiver. Thus the ideas are converted into words or symbols.

The words and the symbols should be selected carefully. It should be according to the purpose of communication. It should be understandable and most of all it should be suitable for transmission and reception.

TRANSMISSION: Next in the process of communication is the transmission of the message as encoded messages are transmitted through various media and channels of communication channel connects the sender and the receiver.

The channel and media should be selected keeping in mind the requirement of the receiver, the communication to be effective and efficient the channel should be appropriate.

RECEIVER: Receiver is the person or group for whom the message is meant. He may be a listener, a reader or a viewer. Any neglect on the part of the receiver may make the communication ineffective.

The receiver is thus the ultimate destination of the message. If the message does not reach the receiver the communication is said to be incomplete.

DECODING: Decoding means translation of symbols encoded by the sender into ideas for understanding. Understanding the message by the receiver is the key to the decoding process.

The message should be accurately reproduced in the receiver's mind. If the receiver is unable to understand the message correctly the communication is ineffective.

BEHAVIOUR OF THE RECEIVER: It refers to the response by the receiver of the communication received from the sender. He may like to ignore the message or to store the information received or to perform the task assigned by the sender. This communication is complete as soon as the receiver responds.

FEEDBACK: Feedback indicates the result of communication. It is the key element in the communication and is the only way of judging the effectiveness of communication it enables the sender to know whether his message has been properly interpreted or not.

Systematic use of feedback helps to improve future messages. Feedback, like the message could be oral, written or non-verbal. It has to be collected from the receiver.

2.6 THE BASE TRANCIEVER SATATION:

A base transceiver station (BTS) is a piece of equipment that facilitates wireless communication between user equipment (UE) and a network. UEs are devices like mobile phones (handsets), WLL phones, and computers with wireless Internet connectivity. A network may be any wireless technology, like Code Division Multiple Access (CDMA), Global System for Mobile Communications (GSM), Worldwide Interoperability for Microwave Access (WiMAX) or Wi-Fi. However, because a BTS is associated with mobile communications technologies, it refers to the equipment that creates the "cell" in a cellular network. Sometimes, an entire base station, plus its tower, are improperly referred to as a BTS or cellphone tower.

BTS is also referred to as the *node B* (in 3G Networks) or, simply, the *Base Station* (BS). For discussion of the LTE standard the abbreviation *eNB* for evolved node B is widely used.

As part of a cellular network, a BTS has equipment for the encryption and decryption of communications, spectrum filtering equipment (band pass filters), antennas and transceivers (TRX) to name a few. A BTS typically has multiple transceivers that allow it to serve many of the cell's different frequencies and sectors.

Though the term BTS can be applicable to any of the wireless communication standards, it is generally associated with mobile communication technologies like GSM and CDMA. In this regard, a BTS forms part of the base station subsystem (BSS) developments for system management.

A BTS is controlled by a parent base station controller via the base station control function (BCF). The BCF is implemented as a discrete unit or even incorporated in a TRX in compact base stations. The BCF provides an operations and maintenance (O&M) connection to the network management system (NMS), and manages operational states of each TRX, as well as software handling and alarm collection. The basic structure and functions of the BTS remains the same regardless of the wireless technologies.

Fig 2.1: Electronic equipment box at the base of cellphone tower.

2.7 ARCHITECTURE OF BTS

The general architecture of BTS system reveals the following parts.

Transceiver (TRX)/Data Receiver (DRx): Provides transmission and reception of signals. It also does sending and reception of signals to and from higher network entities (like the base station controller in mobile telephony). Transceivers handles the user calls. Usually there are 12 TRx in a BTS and can handle 8 calls/sec.

Power amplifier (PA): Amplifies the signal from TRX for transmission through antenna; may be integrated with TRX.

Combiner: Combines feeds from several TRXs so that they could be sent out through a single antenna. Allows for a reduction in the number of antenna used.

Multiplexer: For separating sending and receiving signals to/from antenna. Does sending and receiving signals through the same antenna ports (cables to antenna).

Baseband receiver Unit (BB2F): A BB2F is used for digital signal processing and frequency hopping. It connects the BOIA card to TRx.

Base Operation and Interface Unit (BOIA): It processes the baseband signals received from the BB2F and interfaces the processed signal with transmission cards such as RRI, E1/T1 etc. Also BTS initialization, power amplification, O&M signaling, clock functions, timing functions, etc. So it is considered as the brain of the BTS.

Radio Receiver Card (RRI): It provides E1 connectivity to the BTS. Also it creates the microwave link between BTS & BSC.

Multicouplers and Duplexers: Multicouplers are used to connect different TRxs also into the duplexer.

Alarm extension system: Collects working status alarms of various units in the BTS and extends them to operations and maintenance (O&M) monitoring stations.

Control function: Controls and manages the various units of BTS, including any software. On-the-spot configurations, status changes, software upgrades, etc. are done through the control function.

Power Cards: A power card is used to provide fixed current and voltage levels to circuit components. A BTS usually uses -48V power whose positive is grounded to reduce noise.

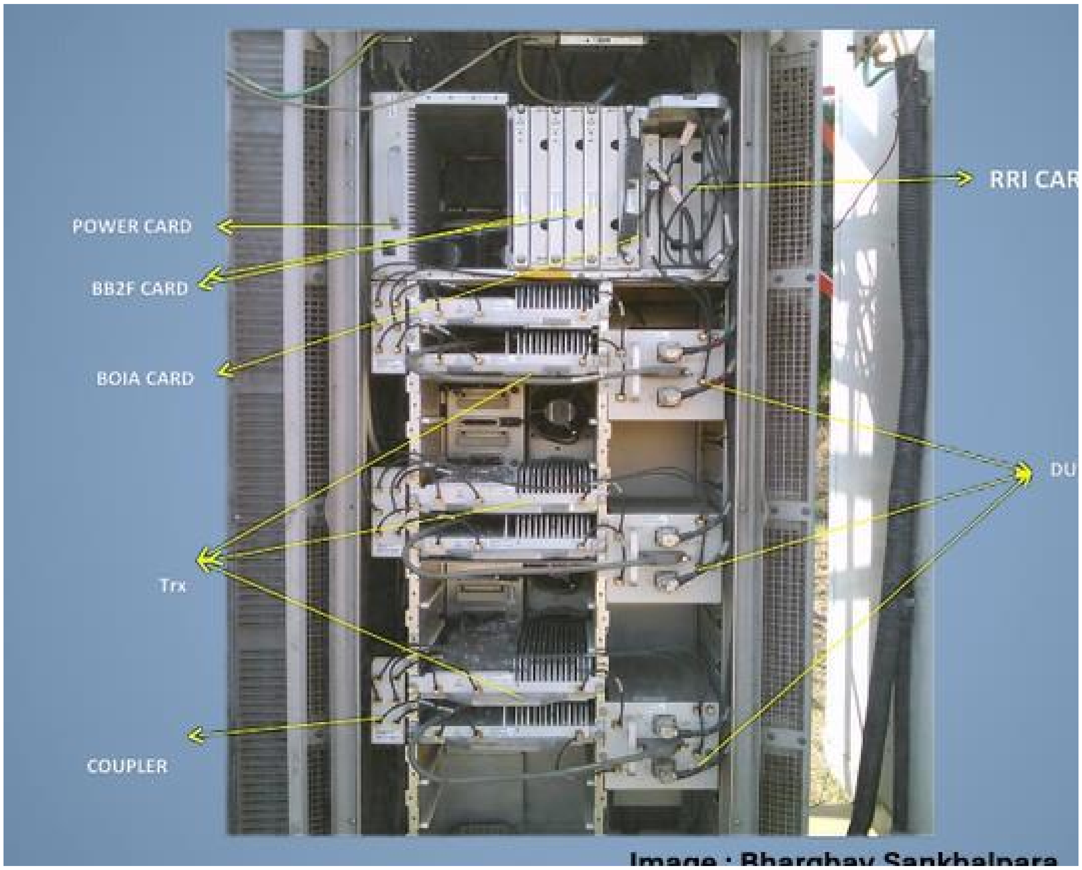


Fig 2.2 Architecture of BTS

2.8 THE BASE STATION ANTENNA

In radio an antenna is the interface between radio waves propagating through space and electric currents moving in metal conductors, used with a transmitter or receiver. In transmission, a base station transmitter supplies an electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna (in our mobile devices) intercepts some of the power of an electromagnetic wave in order to produce an electric current at its terminals that is applied to a receiver to be amplified. Antennas are essential components of all radio equipment, and are used in radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, satellite communications and other devices.

An antenna is an array of conductors (elements), electrically connected to the receiver or transmitter. During transmission, the oscillating current applied to the antenna by a transmitter creates an oscillating electric field and magnetic field around the antenna elements. These time-varying fields radiate energy away from the antenna into space as a moving transverse electromagnetic field wave. Conversely, during reception, the oscillating electric and magnetic fields of an incoming radio wave exert force on the electrons in the antenna elements, causing them to move back and forth, creating oscillating currents in the antenna.

Antennas can be designed to transmit and receive radio waves in all horizontal directions equally (omnidirectional antennas), or preferentially in a particular direction (directional or high gain antennas). An antenna may include parasitic elements, parabolic reflectors or horns, which serve to direct the radio waves into a beam or other desired radiation pattern.

The first antennas were built in 1888 by German physicist Heinrich Hertz in his pioneering experiments to prove the existence of electromagnetic waves predicted by the theory of James Clerk Maxwell. Hertz placed dipole antennas at the focal point of parabolic reflectors for both transmitting and receiving.

There are two major types of antennas are used in the BTS. They are:

A. **GSM Antenna:** It is used for the transmission and reception of the user's signals. It is plane or a dipole antenna.

B. **Microwave/Drum Antenna:** These are parabolic or horn antenna. It works based on Line of Sight propagation (LOS) and connects BTS to BTS or with the BSC.

Antennas are usually directional so as to avoid power loss and more area coverage. To improve the quality of the signal usually a process called antenna diversity or space diversity is employed.

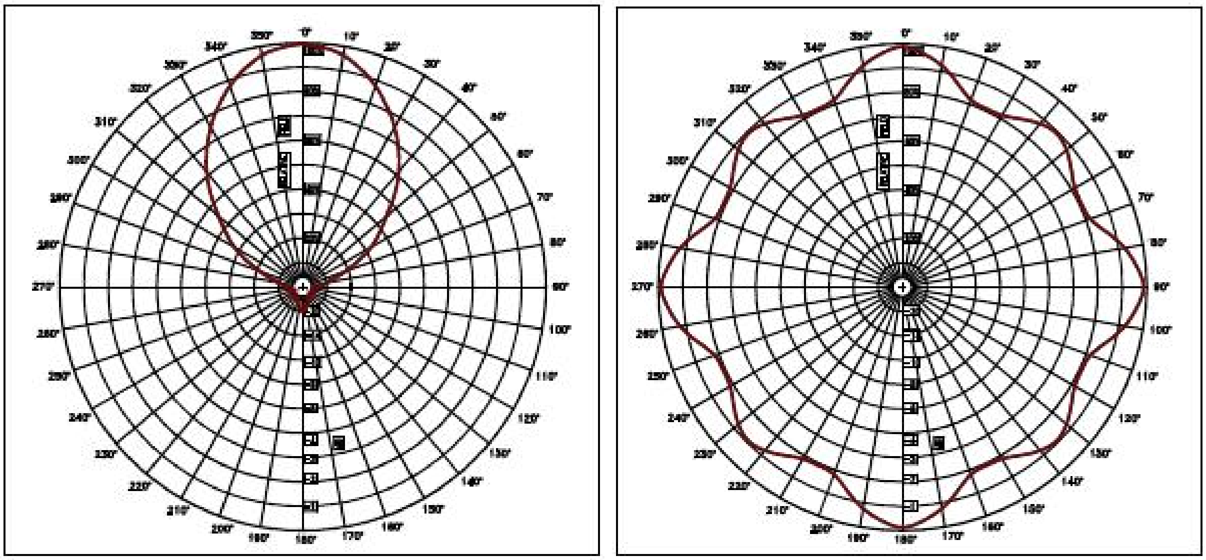
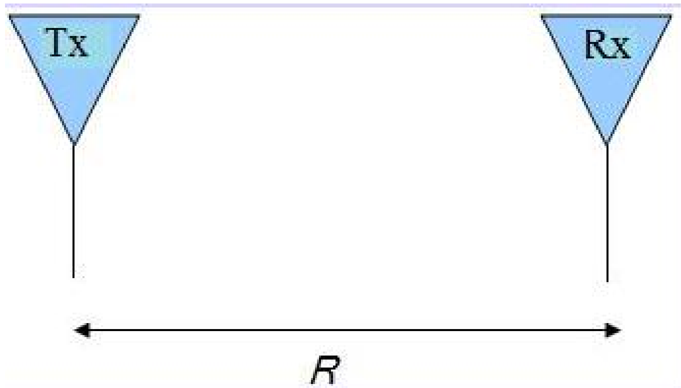


Fig 2.3: One direction (Lobe) and Omni-directional radiation pattern.

2.9 THE FRIIS TRANSMISSION EQUATION

We introduce one of the most fundamental equations in antenna theory, **THE FRIIS TRANSMISSION EQUATION.** The Friis Transmission Equation is used to calculate the power received from one antenna (with gain G1), when transmitted from another antenna (with gain G2), separated by a distance R, and operating at frequency f or wavelength lambda.

To begin the derivation of the Friis Equation, consider two antennas in free space (no obstructions nearby) separated by a distance R:



Then the power density p (in Watts per square meter) of the plane wave incident on the receive antenna a distance R from the transmit antenna is given by:

$$p = \frac{P_T}{4\pi R^2}$$

If the transmit antenna has an antenna gain in the direction of the receive antenna given by G_T, then the power density equation above becomes:

$$p = \frac{P_T}{4\pi R^2} G_T$$

The gain term factors in the directionality and losses of a real antenna. Assume now that the receive antenna has an effective aperture given by A_{ER}. Then the power received by this antenna P_R is given by:

$$P_R = \frac{P_T}{4\pi R^2} G_T A_{ER}$$

Since the effective aperture of any antenna can also be expressed as

$$A_e = \frac{\lambda^2}{4\pi} G$$

The resulting received power can now be written as:

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi R)^2}$$

This is known as the Friis Transmission Formula. It relates the free space path loss, antenna gains and wavelength to the received and transmit powers. This is one of the fundamental equations in antenna theory.

Another useful form of the Friis Transmission Equation is given below, Since wavelength and frequency *f* are related by the speed of light *c*, we have the Friis Transmission Formula in terms of frequency:

$$P_R = \frac{P_T G_T G_R c^2}{(4\pi R f)^2}$$

Where: P_R = Received power

P_T = Transmitted power

G_T = Antenna gain of the transmitter

G_R = Antenna gain of the Receiver

C = Speed of light

λ = Wave length of the signal

R = Distance between the transmitter and receiver antenna

This equation above shows that more power is lost at higher frequencies. This is a fundamental result of the Friis Transmission Equation. This means that for antennas with specified gains, the energy transfer will be highest at lower frequencies. The difference between the power received and the power transmitted is known as path loss. Said in a different way, Friis Transmission Equation says that the path loss is higher for higher frequencies.

2.10 BTS TOWERS

Usually the tower is ground based or roof top based; roof top based used in the congested city area. GBT are near the BTS having height of usually 30-40m. Towers may be self-supporting or guyed tower. Based on their applications towers may be of following types

2.10.1 The Monopole Tower: This is a single tube tower. It typically stands between 100-200 ft. with antennas mounted on the exterior of the tower. Its primary use is telephony.

2.10.2 The Lattice Tower: This is sometimes referred to as "self-support" or SST because it is free-standing. It stands 200-400 ft. tall with a triangular base and three-four sides. It is typically used for telephony. The Eiffel Tower is a lattice tower.

2.10.3 The Guyed Tower is basically a straight rod supported by wires that attach to the ground as support. It's cheapest to construct, especially at heights of 300 ft and beyond. Some guyed towers reach as high as 2,000 ft. Typical uses are: telephony, radio, television, and paging.

2.10.4 Concealed and Stealth Towers: Stealth towers are a particular brand of concealed towers. Concealed towers are deployed to satisfy zoning regulations, and can range in size to accommodate their surroundings. They are more expensive than other types of towers because they require additional material to create a "concealed appearance," yet at the same time, they provide less capacity to tenants than other towers do. Below is one of the more interesting concealed towers, located at a church in California.

2.10.5 Broadcast Towers: provide mounting space for FM radio, AM radio, and Television (TV) antennas. Their antennas are massive, weighing anywhere from 1,000 pounds to 15 tons depending upon the type of service they provide and the coverage they are purposed to deploy. Most broadcast towers are guyed towers with three or more guy wires attached to grounded anchors. Broadcast towers can take up a great deal of ground space – up to 300 acres, which is why they are typically found in rural areas or on mountaintops where natural elevation provides the best means of transmitting signals.

2.10.6 OTHER EQUIPMENT

a. Antenna Array: An **Antenna Array** is a platform where tenants mount antennas, which signal transmission and reception to mobile devices within a specific area. The number of antennas (typically between 3-18) is based on several factors, including the number of tenants (wireless carriers); the type (voice or data) and volume of transmission; the technology being used (eg: CDMA, GSM, LTE, WiMAX) and the frequency of spectrum (in MgH) utilized.

b. Microwave dish: The **Microwave Dish** is a large round antenna, which is used for long distance and specific type of transmission, mainly for communications between two BTS and also commonly used for backhaul.

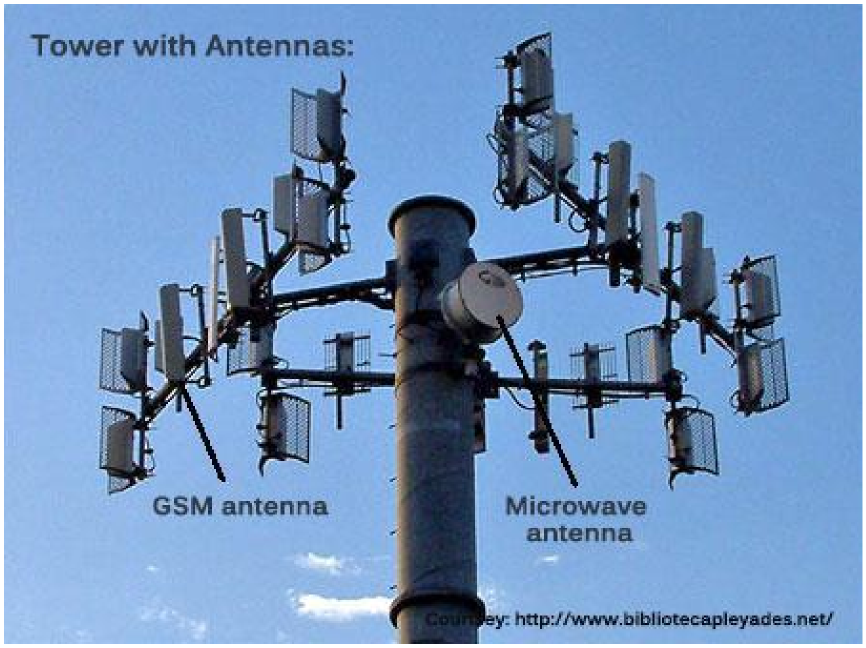


Fig 2.3: Antennas in BTS

2.11 RADIO FREQUENCIES

Radio frequency (RF) refers to the rate of oscillation of electromagnetic radio waves in the range of 3 kHz to 300 GHz, as well as the alternating currents carrying the radio signals. This is the frequency band that is used for communications transmission and broadcasting. Although RF really stands for the rate of oscillation of the waves, it is synonymous to the term "radio," or simply wireless communication.

Radio frequency is being used in a lot of fields, but in the context of information and communications technology it refers to the frequency band at which wireless telecommunications signals are being transmitted and broadcast. The frequency band is being divided into different parts, which are then assigned to different technology industries. This is known as the radio spectrum. For example, the VHF (very high frequency) band, which ranges from 30-300 MHz, is being used for FM radio, TV broadcasts, and amateur radio and its counterparts. For a lot of electronic communication devices, the ultra-high frequency (UHF) band is being used. This is the space used by mobile phones, wireless LAN, Bluetooth, and TV and land radio.

Radio frequency is produced by oscillating current a specified number of times and then radiating it off a conductor, referred to as an antenna, into empty space (this refers to space occupied by air rather than solid objects and does not refer to outer space) as electromagnetic radio waves. RF signals are sent and received using conductors through the phenomenon known as the skin effect, where RF current latches itself and flows through the surface of conductors rather than penetrating and passing through them like it does with other non-conducting solids. This effect is the core and basis of radio technology.

Frequency range	Wavelength range	ITU designation		IEEE bands[5]
		Full name	Abbreviation[6]	
3–30 Hz	10^5–10^4 km	Extremely low frequency	ELF	N/A
30–300 Hz	10^4–10^3 km	Super low frequency	SLF	N/A
300–3000 Hz	10^3–100 km	Ultra low frequency	ULF	N/A
3–30 kHz	100–10 km	Very low frequency	VLF	N/A
30–300 kHz	10–1 km	Low frequency	LF	N/A
300 kHz – 3 MHz	1 km – 100 m	Medium frequency	MF	N/A
3–30 MHz	100–10 m	High frequency	HF	HF
30–300 MHz	10–1 m	Very high frequency	VHF	VHF
300 MHz – 3 GHz	1 m – 10 cm	Ultra high frequency	UHF	UHF, L, S
3–30 GHz	10–1 cm	Super high frequency	SHF	S, C, X, Ku, K, Ka
30–300 GHz	1 cm – 1 mm	Extremely high frequency	EHF	Ka, V, W, mm
300 GHz – 3 THz	1 mm – 0.1 mm	Tremendously high frequency	THF	N/A

2.12 POWER DENSITY OF RADIO FRENQUENCY

As an electromagnetic wave travels through space, energy is transferred from the source to other objects (receivers). The rate of this energy transfer depends on the strength of the EM field components. Simply put, the rate of energy transfer per unit area (power density) is the product of the electric field strength (E) times the magnetic field strength (H).

For time harmonic fields, the time averaging Instantaneous power density is;

$$P_{avg} = \frac{1}{T} \oint (E \times H) dt$$

$$\text{Where } E = \mathrm{Re}\{Ee^{j\omega t}\} \text{ and } H = \mathrm{Re}\{He^{j\omega t}\}$$

The instantaneous magnetic field may be rewritten as;

$$H = \mathrm{Re}\left\{\frac{1}{2}[He^{j\omega t} + H * e^{j\omega t}]\right\}$$

Which gives an instantaneous power density of;

$$S = E \times H = \frac{1}{2}\mathrm{Re}\{[E \times H] + [E \times H^*]\}$$

$$S = [E][H]sin\theta$$

The above equation yields units of W/m^2 .

The simplified relationships stated above apply at distances of about two or more wavelengths from the radiating source. This distance can be a far distance at low frequencies, and is called the far field.

Also, Antennas, an isotropic radiator is a theoretical, lossless, Omni-directional (spherical) antenna. That is, it radiates uniformly in all directions. The power of a transmitter that is radiated from an isotropic antenna will have a uniform power density (power per unit area) in all directions. The power density at any distance from an isotropic antenna Is simply the transmitter power divided by the surface area of a sphere ($4\pi R^2$) at that distance. The surface area of the sphere increases by the square of the radius, therefore the power density, PD, (watts/square meter) decreases by the square of the radius.

Power density from an isotropic antenna "P_D" = $\frac{Pt}{4\pi R2}$

Where: Pt = Transmitter Power

R =Range from Antenna (*i.e. radius of sphere*)

2.13 FIELD STRENGHT OF A RADIO FREQUENCY

In telecommunications, particularly in radio frequency, **signal strength** (also referred to as **field strength**) refers to the transmitter power output as received by a reference antenna at a distance from the transmitting antenna. High-powered transmissions, such as those used in broadcasting, are expressed in dB-millivolts per meter (dBmV/m). For very low-power systems, such as mobile phones, signal strength is usually expressed in dB-microvolts per meter (dBμV/m) or in decibels above a reference level of one milliwatt (dBm). In broadcasting terminology.

The electric field strength at a specific point can be determined from the power delivered to the transmitting antenna, its geometry and radiation resistance. Consider the case of a center-fed half-wave dipole antenna in free space, where the total length L is equal to one half wavelength (λ/2).

Radio frequency (far field) field strength measurements are taken with dedicated instruments composed by a calibrated receiving antenna and a calibrated instrumentation receiver. Basically, any antenna connected to any receiver capable of measuring the signal strength can be used for the same purpose, but with less precision. This page explains how to find the field strength at a given point, given the received power and the gain of the antenna.

CHAPTER THREE

MATERIALS AND METHOD

3.1 INTRODUCTION AND EXPERIMENTAL SETUP

The process of measuring the power density from a base station is the greatest and the most important part of the project. The steps of the measurement process and the equipment used in the course of this project will be explain in details in this chapter. Hence, the importance of this chapter is obvious. Also, this chapter points to the important problems that faced during the work and how dealt with .At the end of this chapter, we will show the expected form for the result and how to use the results to meet the objectives of the project.

3.2 EXPERIMENT SCOPE

The experiment is mainly aimed to measure the power density from a base station at the University of Benin, opposite Junior staff quarters at coordinates 6˚23'46"N, 5˚37'11.6"E (6.396264, 5.619884) and then analyze this measurements statistically to find curves and relationships describing the power density behavior according to change in distance and in antenna height. The measurements were taken using RF EMF strength meter which give an accurate reading of the power density at a specific point. The measurement process covered.

3.3 EQUIPMENT USED

In our project we use two main devices:

1. GQ EMF-390 EMF Multi-Field/Multi-Function Meter: to measure radiation density from base station.
2. A mobile phone GPS: to determine the coordinates of the base station.

3. A measuring tape.
4. A protractor, tied to thread and a weight (clinometer).
5. A pen and paper for recording data.

3.3.1 GQ EMF-390 Multi-Field/Multi-Function Meter

This meter is a broadband device for monitoring high-frequency radiation. It can measure up to 10GHz of radiation. The unit of measurement and the measurement types are expressed in units of electrical and magnetic field strength and power density.

In this project, our main aim is to measure the power density which is the Power per unit area in the direction of propagation, usually expressed in units of watts per square meter (W/m2) or, for convenience, units such as milliwatts per square centimeter (mW/cm2) and microwatts per square centimeter (µW/cm2). In this work milli watts per square meter (mw/m^2) was employed.
The power density provides a measure of the power absorbed by a person exposed to the field. This power level must be kept as low as possible at high frequencies. Figure (3.1) show this device.

Fig 3.1 GQ EMF-390

3.3.2 THE MOBILE PHONE GPS METER

A GPS navigation device is any device that receives Global Positioning System (GPS) signals for the purpose of determining the device's current location on Earth. GPS is a radio navigation system. It uses radio waves between satellites and a receiver inside your phone to provide location and time information to any software that needs to use it. You don't have to send any actual data back into space for GPS to work; you only need to be able to receive data from four or more of the 28 satellites in orbit that are dedicated for geo-location use.

Three satellites might seem enough to solve for position since space has three dimensions and a position near the Earth's surface can be assumed. However, even a very small clock error multiplied by the very large speed of light— the speed at which satellite signals propagate — results in a large positional error. Therefore receivers use four or more satellites to solve for the receiver's location and time.

Your phone's GPS receiver uses the data from these signals to triangulate where you are and what time it is. Notice the word triangulation and the mention above that **four** satellites are required for GPS to work. The fourth signal is used to determine altitude so you can get your geo-location data on a map with only three signals.

3.3.3 A MEASURING TAPE

A **tape measure** or **measuring tape** is a flexible ruler and used to measure distance. It consists of a ribbon of cloth, plastic, fibre glass, or metal strip with linear-measurement markings. It is a common measuring tool. Its design allows for a measure of great length to be easily carried in pocket or toolkit and permits one to measure around curves or corners. Today it is ubiquitous, even appearing in miniature form as a keychain fob, or novelty item. Surveyors use tape measures in lengths of over 100 m.

Fig 3.2: A measuring tape.

3.4 EXPERIMENTAL SETUP

The major aim of this project experiment is to measure the radiation power density that is being emitted from a base station in Uniben using this coordinates 6˚23’46”N, 5˚37’11.6”E (6.396264, 5.619884) To locate the base station and taking it as a major case study in this project work.

After locating the base station, the following steps was taken to determine the power density using the devices listed above.

1. The mobile phone GPS was used to determine the coordinates of the base station.
2. The operator of the base station was determined(MTN)

3. The height of the antenna's tower was determined by measuring it using a self-constructed protractor and using Pythagoras theorem.
4. One of three sectors was selected to measure the radiation power density i.e. the direction where there is no building or any obstruction was selected for the measurement.
5. The GQ EMF-390 Multi-Field/Multi-Function Meter was turned on
6. The EMF meter device unit was setup to mw/m^2 and was set to adjust automatically when the radiation is too low.
7. The device was held at an angle of about 60˚ towards the tower and five different reading was recorded at a particular distance.
8. The same procedure was repeated at distances of 50m interval up to 500m
9. The average of the five readings was calculated to ensure a more accurate reading.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 READINGS OBTAINED.

Location coordinate: 6˚23'46"N, 5˚37'11.6"E (6.396264, 5.619884) opposite Uniben Staff School

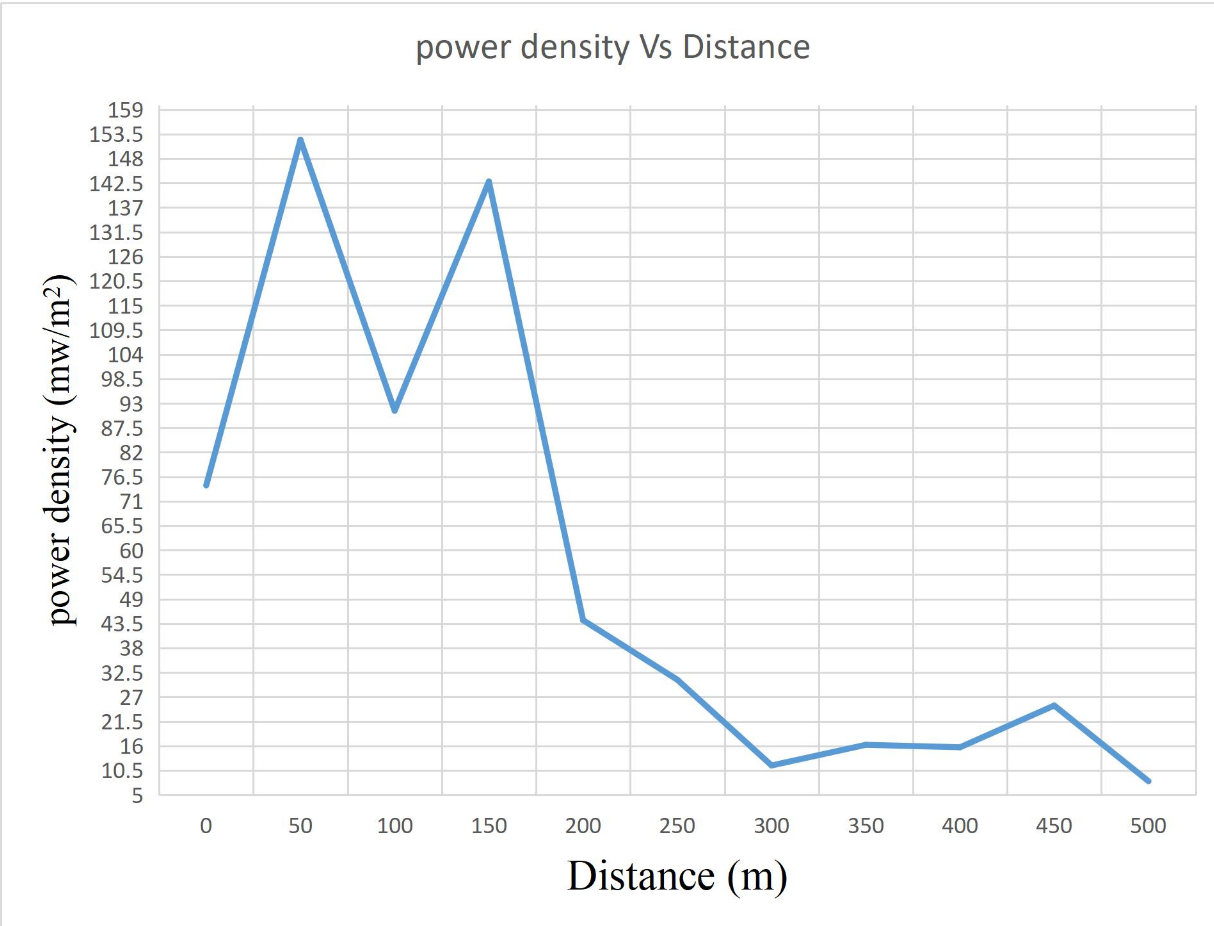
Date: 14-09-19

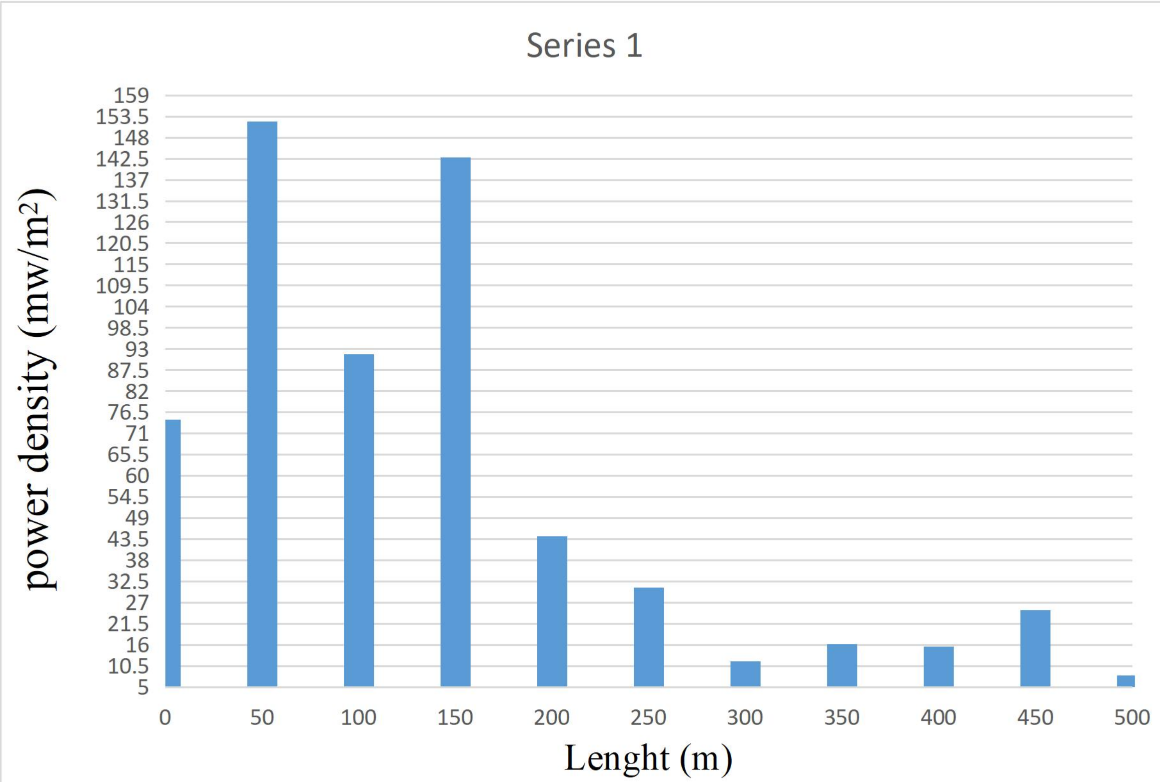
Start time: 05:52pm

Stop time: 06:25pm

Length (m)	Readings (mw/m^2)					Average Values
0	44.69	45.24	101.02	116.50	65.32	74.55
50	161.4	185.2	118.8	185.5	110.4	152.26
100	46.27	134.4	90.10	136.7	49.24	91.34
150	145.9	159.2	158.8	123.5	126.8	142.84
200	52.94	56.80	56.27	27.46	27.82	44.25
250	27.18	36.11	37.09	28.14	25.82	30.87
300	11.23	10.43	10.16	14.01	12.19	11.60
350	17.61	16.94	16.24	14.83	15.58	16.24
400	31.61	21.87	21.40	11.00	10.52	15.69
450	11.80	12.00	11.98	81.90	7.717	25.07
500	5.146	6.589	6.667	11.37	10.56	8.06

4.2 GRAPHS AND CHARTS


power density Vs Distance
159
153.5
148
142.5
137
131.5
126
120.5
115
109.5
104
98.5
93
87.5
82
76.5
71
65.5
60
54.5
49
43.5
38
32.5
27
21.5
16
10.5
5
power density (mw/m²)
0
50
100
150
200
250
300
350
400
450
500
Distance (m)



4.3 DISCUSSION

After taking a total of five 5 readings at every distance the average value was calculated and tabled out. A graphical representation of the data was constructed as well as a bar chart. From the graph, it can be seen that the highest value of power density was recorded at 50m radius of the MTN BTS - Base Transceiver Station. The value dropped at 100m and then increased again at 150m from the foot of the base stations. Though this increase might be influenced by other RF emission gadgets like radio transmitters, TV antennas etc. The values dropped at Subsequent distances up to about 450m where there was a very slight increase and then a very sharp decrease at 500m. The Values recorded were minimal and below the ICNIRP set standard. In all cases, the radio frequency radiation emissions from the base stations are below 107µWm-2, the standard limit set by the international commission on non-ionizing radiation protection (ICNIRP). However, values were assumed to be influenced by some known and unknown factors such as EM radiation from FM and TV antennas, satellite dish etc.

4.4 ATTENUATION OF RF AND EMF IN THE ATMOSPHERE

Attenuation is a general term that refers to any reduction in the strength of a signal. Attenuation occurs with any type of signal, whether digital or analog. Sometimes called ***loss***, attenuation is a natural consequence of signal transmission over long distances.

Attenuation can relate to both hard-wired connections and to wireless transmissions.

There are many instances of attenuation in telecommunications and digital network circuitry.

Inherent attenuation can be caused by a number of signaling issues including:

- Transmission medium - All electrical signals transmitted down electrical conductors cause an electromagnetic field around the transmission. This field causes energy loss down the cable and gets worse depending upon the frequency and length of the cable run.
- Crosstalk from adjacent cabling causes attenuation in copper or other conductive metal cabling.
- Conductors and connectors - Attenuation can occur as a signal passes across different conductive mediums and mated connector surfaces.

Repeaters are used in attenuating circuits to boost the signal through amplification (the opposite of attenuation). When using copper conductors, the higher the frequency signal, the more attenuation is caused along a cable length. Modern communications use high frequencies so other mediums which have a flat attenuation across all frequencies, such as fiber optics are used instead of traditional copper circuits.

Different types of attenuation include:

- Deliberate attenuation can occur for example where a volume control is used to lower the sound level on consumer electronics.
- Automatic attenuation is a common feature of televisions and other audio equipment to prevent sound distortion by automatic level sensing that triggers attenuation circuits.
- Environmental attenuation relates to signal power loss due to the transmission medium, whether that be wireless, copper wired or fiber optic connected.

In telecommunication, the **free-space path loss** (**FSPL**) is the attenuation of radio energy between the feed points of two antennas that results from the combination of the receiving antenna's capture area plus the obstacle free, line-of-sight path through free space (usually air).

The free-space path loss (FSPL) formula derives from the Friis transmission formula that states power gain of an antenna system thus.

The FSPL formula expresses a loss value that is the reciprocal of gain and assumes the directivity for the transmit and receive antennas are isotropic and therefore unity. Both modifications simplify the equation to...

$$\text{FPSL} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

Where λ = c/f

Free-space path loss in decibels

A convenient way to express FSPL is in terms of dB:

$$L_{dB} = 10log_{10}\frac{P_t}{P_r} = 20\log\left(\frac{4\pi d}{\lambda}\right)$$

$$\text{FPSL(dB)} = 10log_{10}\left(\left(\frac{4\pi}{c}df\right)^2\right)$$

$$= 20log_{10}\left(\frac{4\pi}{c}df\right)$$

$$= 20log_{10}(d) + 20log_{10}(f) + 20log_{10}\left(\frac{4\pi}{c}\right)$$

$$= 20log_{10}(d) + 20log_{10}(f) - 147.55$$

For other antennas, we must take into account the gain of the antenna, which yields the following free space loss Equation:

$$\frac{P_t}{P_r} = \frac{(4\pi)^2(d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$

Where P_t, P_r, G_t, G_r have their usual meanings

A_t = effective area of transmitting antenna

A_r = effective area of receiving antenna

The third fraction is derived from the second fraction using defined in Equation. Thus, for the same antenna dimensions and separation, the longer the carrier wavelength (lower the carrier frequency), the higher is the free space path loss.

4.5 EFFECTS OF BTS ANTENNA ON THE ENVIRONMENT

BTS are radio transmitters mounted on either free-standing masts or on buildings. Radio signals are fed through cables to the antennas and then launched as radio waves into the area, or cell, around the base station. At position where people are exposed to the radio waves from BTS, the level of exposure is much more constant over whole body than when they are exposed to a mobile phone. Depending on the location of the base stations and the level of mobile phone usage to be handled, base stations may be anything from only a few hundred meters apart in major cities to several kilometers apart in the concentrate.

Though there is no concrete evidence of health damage related to radio frequency (RF) radiation from BTS. However, internationally acknowledged experts in the field of RF research have shown that RF (of certain range) of the type used in digital cellular antennas and phones can have critical effects on cell cultures, animals and people in laboratories and have also found epidemiological evidence (studies in communities, not in the laboratory) of serious health effects at ‘non-thermal levels’, where the intensity of radiation was too low to cause heating. It has been found in different studies that RF can double the rate of lymphoma in mice, changes in and increase in tumor growth in rats, and increased breaks in double and single stranded DNA (genetic material). RF has also caused leukemia in children, headache, and Neurological changes, loss of memory, increased blood pressure and damage to eye cells when combined with commonly used glaucoma medications.

In Pakistan, The Ministry of Environment raised the issue of health hazards from BTS and requested Pakistan Nuclear Regulatory Authority (PNRA) in 2005 to investigate the matter. PNRA, in response, informed that it had conducted a radiation survey of areas around boosters/ antennas of assorted telecommunication companies, within public domain and found negligible radiation level for below that of natural background level. According to PNRA, the frequency of RF fields is of short range and does not cause significant stochastic or deterministic health effects to human beings.

In conclusion, it is suggested that cellular phone BTS antenna should not be sited closer than 300 m to populations to minimize exposure of neighbors.

4.6 NON-IONIZING ELETROMAGNETIC RADIATION

Non-ionizing radiation is the term given to radiation in the part of the electromagnetic spectrum where there is insufficient energy to cause ionization. It includes electric and magnetic fields, radio waves, microwaves, infrared, ultraviolet, and visible radiation. OR

Non-ionizing radiation refers to any type of electromagnetic radiation that does not carry enough energy per quantum (photon energy) to ionize atoms or molecules that is, to completely remove an electron from an atom or molecule.

Instead of producing charged ions when passing through matter, non-ionizing electromagnetic radiation has sufficient energy only for excitation, the movement of an electron to a higher energy state.

Non-ionizing radiations (NIR) encompass the long wavelength (> 100 nm), low photon energy (<12.4 eV) portion of the electromagnetic spectrum, from 1 Hz to 3 x 10^{15} Hz. Except for the narrow visible region, NIR cannot be perceived by any of the human senses unless its intensity is so great that it is felt as heat. The ability of NIR to penetrate the human body, the sites of absorption, and the subsequent health effects are very much frequency dependent.

The region at which radiation becomes considered as "ionizing" is not well defined, since different molecules and atoms ionize at different energies. The usual definitions have suggested that radiation with particle or photon energies less than 10 electronvolts (eV) be considered non-ionizing. Another suggested threshold is 33 electronvolts, which is the energy needed to ionize water molecules. The light from the Sun that reaches the earth is largely composed of non-ionizing radiation, since the ionizing far-ultraviolet rays have been filtered out by the gases in the atmosphere, particularly oxygen. The remaining ultraviolet radiation from the Sun causes molecular damage (for example, sunburn) by photochemical and free-radical-producing means.

Non-Ionizing radiation originates from various sources: Natural origin (such as sunlight or lightning discharges etc.) and man-made (seen in wireless communications, industrial, scientific and medical applications). Near ultraviolet, visible light, Black Body radiation, infrared, microwave, radio waves, and low-frequency radio frequency (long wave) are all examples of non-ionizing radiation. Visible and near ultraviolet electromagnetic radiation may induce photochemical reactions, or accelerate radical reactions, such as photochemical aging of varnishes or the breakdown of flavoring compounds in beer to produce the "light-struck". Near ultraviolet radiation, although technically non-ionizing, may still excite and cause photochemical reactions in some molecules. This happens because at ultraviolet photon energies, molecules may become electronically excited or promoted to free-radical form, even without ionization taking place.

4.7 SOURCES OF NIR

Non-Ionizing radiation originates from various sources: Natural origin (such as sunlight or lightning discharges etc.) and manmade (seen in wireless communications, industrial, scientific and medical applications). The NIR spectrum is divided into two main regions: optical radiations and electromagnetic fields.

4.7.1 Optical Radiations

The optical radiations are centered on visible light; those with higher energies are termed UV radiation and those with lower energies IR radiation. Sources of UV radiation are the sun, arc welding, oxy-gas welding, sun lamps, lasers (UV), sterilization (germicidal) lamps, low pressure gas discharge lamps, high pressure discharge lamps. Sources of IR radiation are from hot processes such as steelmaking, glassmaking, welding, and also lasers (IR). The application of laser as a coherent light source is increasing rapidly.

Medical applications include UV and neonatal phototherapy, surgical and therapy lasers, physiotherapy heat lamps.

4.7.2 Electromagnetic Fields

Microwaves are used in telecommunications, radar/satellite links, mobile phones, microwave ovens, TV transmitters. RF is used in radio communications,

visual display units, television sets. Extremely low-frequency (ELF) electric and magnetic fields (EMFs) surround electrical machinery, home appliances, electric wiring, and high-voltage electrical transmission lines and transformers.
Medical applications include: microwave hyperthermia, therapeutic and surgical diathermy, and magnetic resonance imaging (MRI).

The NIR part of the electromagnetic spectrum is divided into four approximate regions:

- static electric and magnetic fields, 0 Hz;
- extremely low frequency (ELF) fields, >0 Hz to 300 Hz;
- radiofrequency (RF) and microwave (MW) radiation, 300 Hz to 300 GHz;
- optical radiations: infrared (IR) 760 – 10^6 nm visible 400 - 760 nm ultraviolet (UV) 100 - 400 nm

(On the other hand, ionizing radiations, with wavelengths less than 100 nm, constitute the high photon energy portion of the electromagnetic spectrum.)

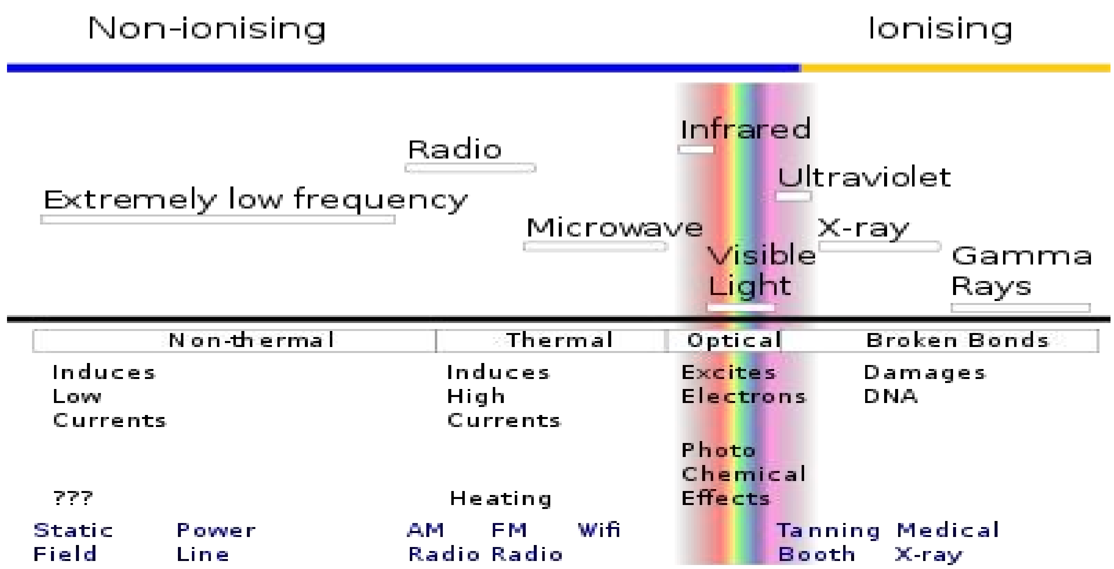


Fig 4.1a The electromagnetic wave spectrum for ionizing and non-ionizing radiation

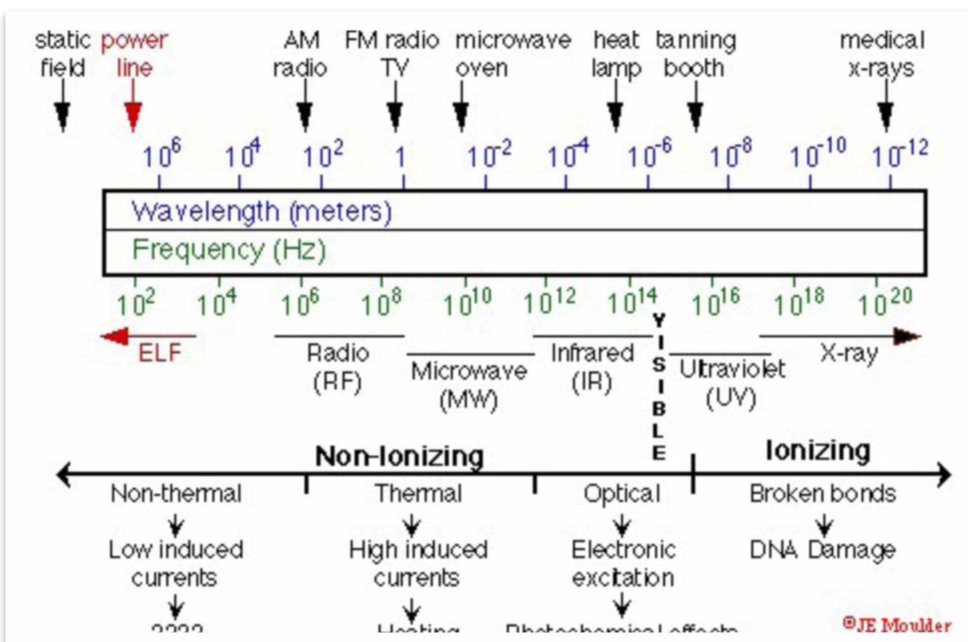


Fig 4.1b Electromagnetic Spectrum and associated Biological Effects

CHAPTER FIVE

CONCLUSION

In conclusion, this study focuses on measurement and evaluation of Electromagnetic Radiation (w/m2) radiated from Base Transceiver Stations (BTS) in University of Benin. Although measurements were influenced by unavoidable factors, values were found to be below the standard limit (4.5W/m2 for 900MHz and 9W/m2 for 18000MHz) set by the International Commission on Non-ionizing Radiation Protection (ICNIRP) and other regulatory agencies.

These measurements were carried out using the GQ EMF-390 multi-field/multi-function meter. Maximum radiation values were measured from (BTS) of the selected sites in Uniben and the results were compared because there is need to carry out practical measurements around the BTSs in Uniben in order to determine whether the radiations comply with the standard provided by the International Commission on Non-Ionizing Radiation Protection, and to assess the risk they pose to the people, particularly the young and elderly and a good agreement was obtained (standard exposure not exceeded). Therefore, these BTS are safe for use.

REFERENCES

1. Nigerian Communications Commission, (2009), http://www.ncc.gov.ng/aboutis.htm

2. Electromagnetic Fields (up to 300 GHz), ICNIRP GUIDELINES (1998), Vol.74, No.4, Pp.494- 522, International Commission on Non-Ionizing Radiation Protection,

3. Tell R.A, (1972)"Broadcast Radiation How Safe is Safe", IEEE Spectrum, vol, 38, no.5, Pp, 128-133.

4. Bernardi, P., Pisa. S and Puizzi E.,(2000), "Specific Absorption Rate and Temperature Increases in the Head of a Cellular-Phone User," IEEETransactions on Microwave Theory andTechniques, Vol. 48, no. 7, pp. 1118-1126.

5. Ahlbom A, Feychting M. Electromagnetic radiation. British Medical Bulletin 2003;68:157-165.

6. Cooper TG, Mann SM, Khalid M, Blackwell RP. Exposure of the general public to radio waves near microcell and Picocell base stations for mobile telecommunications. NRPB Report, September 2010.

7. Cooper TG, Mann SM, Khalid M, Blackwell RP. Public exposure to radio waves near GSM Microcell and Pico cell base stations. J. Radiol Prot 2006; 26:199-211.

8. Henderson SI, Bangay MJ. Survey of RF exposure levels from mobile telephone base stations in Australia. Bioelectromagnetic2006;27:73-76.

9. Solutions Paper: Alternative Power for Mobile Telephony Base Stations, Motorola Inc. 2007, p. 8 Available at: http://www.motorola.com/web/Business/Solutions/Technologies/WiMax/

10. Global Mobile Market Shares. Available at: http://www.3gamericas.org/index.cfm?fuseaction=page&pageid=565

11. National Radiological Protection Board Health effects from radiofrequency electromagnetic fields. Chilton: National Radiological Protection Board, 2003, 107–10 (Documents of the NRPB, Vol 14, No 2)

12. Chia S-E, Chia H-P, Tan J-S. Prevalence of headache among handheld cellular telephone users in Singapore: a community study. Environ Health Perspect 20001081059–1062. [PMC free article] [PubMed] [Google Scholar]

13. Sandström M, Wilén J, Oftedal G. et al Mobile phone use and subjective symptoms. Comparison of symptoms reported by users of analogue and digital mobile phones. Occup Med 20015125–35. [PubMed] [Google Scholar]

14. Santini R, Seigne M, Bonhomme-Faivre L. et al Symptômes rapportés par des utilasateurs de téléphones mobiles cellulaires. Pathol Biol (Paris) 200149222–226. [PubMed] [Google Scholar]

15. Friis Equation - (aka Friis Transmission Formula) http://www.antenna-theory.com/basics/friis.php

16. Electromagnetic wave equation - Wikipedia https://en.wikipedia.org/wiki/Electromagnetic_wave_equation

17. Investigation of the Main Lobe Distance of Transmitted Power Density from GSM Transceiver Base Stations in South-South Nigeria-International Journal of Biophysics 2017, 7(2): 17-23 DOI: 10.5923/j.biophysics.20170702.01

18. Measurement of Electromagnetic Waves Radiated from Base Transceiver Stations (BTS) for Assessing Exposure Limit in Kaduna State---The International Journal Of Engineering And Science (IJES) || Volume || 3 || Issue || 8 || Pages || 28-34 || 2014 || ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

19. WCECS2017 the history of communications in nigeria http://www.iaeng.org/publication/WCECS2017/WCECS2017_pp80-84.pdf

20. Telecommunications in Nigeria - Wikipedia https://en.wikipedia.org/wiki/Telecommunications_in_Nigeria

21. Telecommunication In Nigeria - HG.org https://www.hg.org/legal-articles/telecommunication-in-nigeria-32349

22. How Wireless Communication Works - Science Journal - Medium https://medium.com/science-journal/how-wireless-communication-works a839fc5d41f7

23. What is Electromagnetic Waves? Definition of Electromagnetic Waves, Electromagnetic Waves Meaning - The Economic Times https://economictimes.indiatimes.com/definition/electromagnetic-waves

24. Electromagnetic spectrum - Wikipedia https://en.wikipedia.org/wiki/Electromagnetic_spectrum

25. 9 Steps Involved In The Process Of Communication within Your Organisation http://www.shareyouressays.com/knowledge/9-steps-involved-in-the process-of-communication-within-your-organisation/94720

26. What is a Base Transceiver Station (BTS)? - Definition from Techopedia https://www.techopedia.com/definition/2927/base-transceiver-station-bts

27. Cell Phone Tower Types and Information | Steel in the Air https://www.steelintheair.com/cell-phone-tower/

28. How does GPS work on my phone? | Android Central https://www.androidcentral.com/how-does-gps-work-my-phone

29. Development of base transceiver station https://www.ajol.info/index.php/njt/article/download/122386/111866

30. The effect of Base Transceiver Station waves on some immunological and hematological factors in exposed persons. - PubMed - NCBI https://www.ncbi.nlm.nih.gov/pubmed/27911288