The Impact of a Measurable Antenna in Radio Wave Transmission

Ajaegbu Chigozirim¹, Adesegun Oreoluwa²

¹²Computer Science Department Babcock University

ABSTRACT

Communication is the interaction between two or more entities. Over the years, many communication systems have emerged both in the area of wired and wireless communication. For an effective communication, the components that make up the communication system must be reliable. For a mobile communication to be achieved, radio transmission techniques have to be employed with an idle propagation means. This will enhance the proper movement of radio waves from one point to another. It has been observed that there is a need for telecom firms to propagate signals with a measurable antenna size in respect to the carrier wave being employed. This paper, explores the need for an effective transmission of signals from one point to another and designed a simple calculator for extracting the size of antenna that can be use for any transmission using java programming language.

Keywords: Telecommunication, Transmission, Radio wave, Antenna

1. INTRODUCTION

Communication is the transfer of information from a source (in space and time) to a destination. For communication to take effect, there should be a communication system: a system containing specific elements/components used in driving communication. Many different communication systems exist, but there main purpose is to produce a replica of the source message in the destination. Some communication systems have input and output transducers as shown in Figure 2.

The input transducer is used to convert messages to a time varying electrical quantity (signal) such as voltage or current while an output transducer converts the signal back to message. For example, an input transducer in a voice communication system could be a microphone while an output transducer could be a speaker.

Though, most input signal cannot be sent over far distances as they come from the transducer and thus cannot be sent directly over the channel. In order to make the distance transmission possible, a carrier wave (with the ability to travel over long distances) whose properties suit the transmission medium is been modified to represent the message before it’s been passed to the transmitter. A good example of this process is speech. When a person speaks, the mouth movement takes place at low frequency of 10Hz (Bruce, 1968) and such cannot effectively generate propagating acoustic waves. Transmission of voice through air is accomplished by generating a higher frequency carrier tones in the vocal cords of humans and modifying this tone with the rising and falling actions of the oral cavity thus, what the ear hears as speech is the modified acoustic sound wave (a process called modulation).

Exclusive of transducers, the three basic parts of a communication system are the transmitter, transmission channel (which can be in form of cables, air, vacuum etc) and receiver.

Transmitter: The function of a transmitter is to process the signal from the input transducer to a more suitable transmission signal with respect to the characteristics of the transmission medium. This processing of the input signal...
may at times require a systematic variation of the carrier wave in accordance to the message (modulating signal). Thus, modulation takes place at the transmitter.

Transmission Channel: This is the electrical medium used in bridging the distance between the sender and receiver and can be in the form of wires, coaxial cable, radio wave and sometimes a laser beam. Regardless of the type of transmission channel, all are characterized with attenuation (the fading out of signal power in relation to increase in the distance).

Receiver: This is used to extract the actual message from the transmission channel and deliver it to the output transducer for replication. Thus, its function includes amplification to compensate for the signal lost during transmission, demodulation and sometimes decoding in order to reverse the processed signal performed at the transmitter.

Communication network can exist in the form of a wired network (a network connection that makes use of physical means such as cables to establish communication) or wireless network (a network connection that makes use of radio wave to establish communication).

The scope of this research focuses on the wireless form of communication using cellular phone.

2. Mobile Communication Networks
Mobile network is a network designed in such a way that the “Last mile” (connection to the user) is based on radio transmission techniques. It is a wireless implementation that gives the user the added benefit of mobility in the local area or wider area, depending on the nature of the network.

2.1 Mobile Radio Background
Mobile Radio emerged from wireless communication/transmission – communication that exists through interconnection of network devices without the use of cables or interconnection of network devices using radio waves. This has helped users to overcome a large number of problems, including the size of radio equipment that the user needs to carry around. Mobile radio systems have been in existence since the advent of radio technology and the first installed radio services emerged in 1920s by the police in Detroit [Wakefield, 2007]. The name “Mobile” means that the radio equipment/device is portable enough to be carried around. The early systems of 1920s were designed to offer a one-way radio communication and was improved to a two-way radio as a result of the world wars I and II. Advances in the technology, and radio spectrum management, led to the development of cellular radio networks that support many users and covers a wide area with the help of cell sites (a base station with transmitter and receiver antennas respectively) see Figure 3.

Figure 2: Cellular Radio Network

Cellular is attributed only to the technique of using available radio spectrum and also makes use of radio wave propagation for its transmission.

3. Electromagnetic Spectrum
The term spectrum is used to define the entire range of electromagnetic wave arranged in order of their frequencies. Electromagnetic spectrum consists of Radio waves, infrared wave, visible light, ultra-violet light etc. The uniqueness of each of these electromagnetic waves lies in frequency (f)/wavelength (λ) (see Figure 4) and both parameters are connected with by the speed (c) of light (f = c/λ), indicating that the higher the frequency, the shorter the wavelength and the longer the signal can travel. It is long established that electromagnetic spectrum travels at the speed with that of light.
Just as Electromagnetic spectrum is classified into different regions, the radio regions of this spectrum are also classified into regions called “bands”. This is in accordance to their different points of electromagnetic emission (occurs when charge particles such as electrons changes direction/speed/acceleration) observed by scientist. The most common radio band names and their respective wavelength and frequencies are as shown in Table 2.

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-band</td>
<td>90 cm</td>
<td>327 MHz</td>
</tr>
<tr>
<td>L-band</td>
<td>20 cm</td>
<td>1.4 GHz</td>
</tr>
<tr>
<td>C-band</td>
<td>6.0 cm</td>
<td>5.0 GHz</td>
</tr>
<tr>
<td>X-band</td>
<td>3.6 cm</td>
<td>8.5 GHz</td>
</tr>
<tr>
<td>U-band</td>
<td>2.0 cm</td>
<td>15 GHz</td>
</tr>
<tr>
<td>K-band</td>
<td>1.3 cm</td>
<td>23 GHz</td>
</tr>
<tr>
<td>Q-band</td>
<td>6 mm</td>
<td>45 Hz</td>
</tr>
</tbody>
</table>

4. Electromagnetic Waves Propagation
Radio waves are electromagnetic energies radiated from antenna as shown in Figure 5. This wave radiates around the surface of the earth and up the sky at different angles to the earth surface.

For proper understanding of radio wave propagation, the following terms should be understood with respect to Figure 6 and 7.
(a) Wave: Waves are disturbances (sound, light, radio waves) which travel through a medium.
(b) Wave motion: Wave motion is a continuous reoccurrence of a disturbance as it travels with or without a physical medium through space e.g. the continuous disturbance we generate when using a microphone system and the analogy illustrating the movement of wave when a stone is dropped into water as shown in Figure 6. Situation ‘A’ marks the initial point of dropping the stone, situation ‘B’ shows the generation of the wave when the stone is dropped into the water causing an up and down movement, situation ‘C’ shows the stone moving deeper into the water and pushing the disturbance out to the surface of the water while situation ‘D’ shows point of origin of the wave with respective crest and troughs when the stone had finally dropped.
(c) Wavelength: A wavelength is the distance travelled by a radio wave cycle (i.e. one up and down movement of a graphical representation) in space at specific period or in a simplified way the distance between one point of the wave crest to the other point of the crest traveled in a period of time to complete a cycle (see Figure 7).

(d) Wave Train: Wave train is a continuous production of wave having the same amplitude (the strength of the transmitting wave) and wavelength.

(e) Wave Train Frequency: The number of cycles contained in a particular wave train at a given time and is measured in hertz (cycles per seconds).

![Figure 5: GENERATION OF WAVES ON THE SURFACE OF WATER. (Principles of radio wave propagation, US Army Signal center and fort Gordon, Edition B)](image)

Radio communication is established between two distance communication points when radio waves leaving a conductor of suitable length known as a transmitting antenna and is picked up by another conductor with suitable length know as receiving antenna.

These radio waves have number of ways through which they travel from the transmitting antenna to the receiving antenna and they are as follows:

- Ground wave propagation
- Sky wave propagation
- Space wave propagation

4.1 Ground Wave Propagation

Ground waves travel from transmitting antenna to receiving antenna along the surface of the earth (see figure 8). It has a limited range of coverage and this is as a result of the absorption of the wave by the earth, buildings, trees etc. The absorption of energy depends on the frequency of the ground wave and the absorption properties of the earth surface.

![Figure 7: GROUND WAVE PROPAGATION (http://www.ustudy.in/node/5139)](image)
4.2 Sky Wave Propagation
In sky wave propagation, the transmitting antenna sends out radio waves in all directions (see Figure 9). As this wave travels, some parts of it travels towards the sky and enters the upper region of the atmosphere known as the ionosphere – a region made up of electrically charged particles called ions. The ionosphere acts as a huge mirror to the earth that reflects back a high radio wave frequency to the earth like a ray of light reflected from a mirror. Thus, this reflected radio wave from the ionosphere is what is known as a sky wave. The ionosphere consists of four distinct layers namely: D, E, F1, F2 arranged in their order of increasing height and intensity. These layers are all present during the day when the rays of sun are directed towards their direction in the atmosphere but layers D and E tends to fade out during the night while layers F1 and F2 are merged into one layer as layer F. The actual number of layers, their height above the earth and their respective intensities varies from hour to hour, day to day, season to season and year to year. Sky wave propagation ranges from 300 kHz to 300MHz and are used for AM radio, Citizens band (CB), ship/aircraft communication, VHF TV and FM radios.

![Figure 8: SKY WAVE PROPAGATION](http://www.fas.org/man/dod-101/navy/docs/es310/propagat/Propagat.htm)

4.3 Space Wave Propagation
These waves operate at frequencies above 30MHz and cannot travel more than a few hundred feet along the surface of the earth due to heavy absorption by the earth and so are not reflected by the ionosphere. The space by which this wave travels is known as the “troposphere” and tends to be 15km above the surface of the earth as it travels from the transmitting antenna to the receiving antenna. These waves travelling through the troposphere are known as “space waves”.

Space waves comprises of at least two transmission component (see Figure 10)
- **Direct/line-of-sight wave:** this involves the travelling of the wave from transmitting antenna to receiving antenna thus, establishing communication within the optical range or line-of-sight distance only.
- **Reflected wave:** This wave reaches the receiving antenna through reflection from the surface of the earth as it is been radiated from the transmitting antenna. For effective communication and coverage of greater distance, the transmitting and receiving antennas have to be raised as high as possible [Sharma, 2003].

![Figure 9: Space Wave Propagation](http://www.rfcafe.com/references/electrical/NEETS%20Modules/NEETS-Module-10-2-11-2-20.htm)

Radio waves at these high frequencies are called microwaves and are used to established links between two telephone communication points. This is also made possible through the help of communication satellites, which can be located at suitable distance above the earth. These microwaves are also used for long distance television broadcasts and other radio communication channels extending over thousands of miles.

6. Cellular Telephone Antennas
In order to radiate the high frequency generated from the power amplifier circuit of the transmitter tank, into free space as radio wave, the modulated radio frequency signal must be fed into a structured conductive component/element called “antenna”.
The aim of the antenna is to radiate into space the strongest possible radio waves generated by the power amplifier circuit of the transmitter. In order words, propagation of radio waves cannot solely be achieved without the aid of antennas and this is achieved through the use of transmitting lines (connecting wires from the output point of the transmitter to the antenna). Cellular telephone antennas are typically $\lambda/4$ in size (Bernard, 2003) and are of two categories namely:

- **Transmitting antenna**: its function is to convert the radio frequency energy into radio waves which travels in space with a velocity of light.
- **Receiving antenna**: This receives or picks up these radio waves and converts them into the suitable band frequency, which is transferred to radio receivers by means of transmission lines. Thus an antenna is a conductor that either radiates or collects electromagnetic waves and is associated with two fields; induction and radiation fields.

**Induction Field**: This field is local to an antenna and is associated with the energy it receives. As an antenna radiates electromagnetic wave, a magnetic field exists round it and that is the reason when a particular radio receiver pass a high voltage transmission line, interference occurs due to the magnetic transmission lines field acting on the radio receiver. This induction field does not contribute to the transmission of electromagnetic waves.

**Radiation Field**: This field is solely responsible to the radiation of electromagnetic wave by the antenna. As the distance between the antenna increases, the field decreases and thus the signal strength reduces or transmission will be very difficult to comprehend.

### 7. Conclusion

Transmission Signal is a mixture of Message and Carrier. In other words:

Transmission Signal = Message + Carrier, Where, Message = Low frequency signal and Carrier = High frequency signal.

Transmission channels are designed using the Carrier signal frequency only (Message frequency is not considered at all).

Ability for a signal to travel a long distance, is obtained from this equation $c = \lambda f$ or $\lambda = c/f$. where, $c =$ velocity of light (transmission signal).

- $\lambda =$ wavelength of transmission signal
- $f =$ frequency of transmission signal.

The condition for a long-distance capability of a signal is that the frequency must be HIGH. Since the frequency of the Message is normally low, it becomes important to employ a technique where a high-frequency signal is used to carry the Message.

Therefore, the distance travelled by Message is given by

$$\text{Message} = \text{Velocity of Message} \times \text{Time of travel} = \frac{\text{Velocity of Carrier}}{\text{Frequency of Carrier}}$$

Where Time of travel, $t = \frac{1}{\text{Frequency}}$

Therefore, the higher the frequency of Carrier, the longer the distance the Message can go and the smaller the antenna dimension.

### 8. Appendix

Java Program showing the calculation of antenna size using the global bench mark.

```java
package Antenna;

/** This part of the program calculates the antenna size from the frequency range of operation adopted by any telecommunication firm with a fixed speed of light.
 * @author MAJOR */

public class AntennaeClass {
    double wave, freq;
    double myWavelength(double a, double b){
        double aa = a;
        double bb = b;
        wave = aa/bb;
    }
```
double AntennaeSize(double a, double b) {
    double wave1, aa1 = a, bb1 = b;
    wave1 = aa1/bb1;
    double wave2 = (1 * (wave1/4));
    double Antennae = wave2/1609.344;
    //double Antennae2 = Double.longBitsToDouble(Antennae);
    return Antennae;
}

package Antenna1;

/** This part calculates the wavelength for each transmission
 * @author MAJOR
 */
public class AntennaeClass2 {

double wave, freq;

double myWavelength(double a, double b) {
    double aa = a;
    double bb = b;
    wave = aa/bb;
    return wave;
}

double AntennaeSize(double a, double b) {
    double wave1, aa1 = a, bb1 = b;
    wave1 = aa1/bb1;
    double wave2 = wave1/4;
    return wave2;
}

double DistanceCovered(double a, double b) {
    double wave3, aa2 = a, bb2 = b;
    wave3 = (aa2/bb2)/4;
    // double Antennae = (1* wave3)/1000;
    //double Antennae2 = Double.longBitsToDouble(Antennae);
    return wave3;
}

References


AUTHOR

Ajaegbu Chigozirim received his B.Sc degree in Computer Technology. M.Sc degree in Computer Science (Networking and Telecommunication) from Babcock University, Nigeria. He has also written and passed some professional certifications like CCNA and Security+. He is currently a PhD student and an assistance Lecturer in Babcock University. His research interests are in the areas of Networking and Telecommunication and Signal Processing (Adaptive filters).

Adesegun Oreoluwa A. received his B.Sc degree in Computer Science from Valley View University Ghana and is currently on his M.Sc degree in Computer Science (Networking and Telecommunication) from Babcock University, Nigeria. He has also written and passed some professional certifications like CCNA and CCENT. He is a Graduate Assistance Lecturer in Babcock University. His research interests are in the areas of Networking Security and Cloud computing.