Investigation of Diurnal Variation of Signal Strength Generated by FM Transmitter

Prince Chigozie Iwuji,
Physics Department, University of Calabar, Calabar, Nigeria
Victor Chukwuagozie Onuabuchi,
Department of Science and Computer Education,
Enugu State University of Science and Technology, Enugu State, Nigeria

Doi: 10.19044/esj.2018.v14n18p235 URL:http://dx.doi.org/10.19044/esj.2018.v14n18p235

Abstract

This paper focuses on the determination of the diurnal variation of signal strength generated by Orient 94.4 FM transmitter along six (6) selected route in Imo State, Nigeria. This was carried out with the aid of a constructed signal strength meter (SSM). Signal strength measurements were collected at different time, on different days, and in different months. The measurement was carried out at a constant distance of 20 Km. Arrangement was made with the management of the base station to ensure that the transmitting parameters were kept constant throughout the period of signal strength measurement. The average results of these measurements were taken. The data obtained from the measurements was plotted in a graph to establish the diurnal variation in signal strength along the different routes of signal strength measurement. It was observed from this research that transmission and reception of signals are dependent on the time of the day. High signal strength was noted between the hours of 8 am and 11 am, while low signal strength was recorded between the hours of 1 pm and 5 pm. Better signal strengths were recorded at night. The result of this study shows that signal strength generated by FM transmitter vary with time of the day and the prevalent weather conditions. Stronger signals are recorded mostly at night along the different routes of the study. The signal strength consequently drops in the afternoon and recovers in the morning hours.

Keywords: Signal strength, Transmitter, Measurement, Variation, Diurnal

Introduction

Radio wave transmission is affected by some atmospheric parameters such as rainfall, temperature, pressure, and relative humidity (Amajama, 2016). Electromagnetic waves are refracted away from the surface of the earth by the shape of the earth and other conditions of the atmosphere. They travel farther at night, but some medium and shortwave like AM radio waves signal travel farther during the day in normal condition. This is due to the interaction of signal with a certain layer of the atmosphere known as the ionosphere, and how this interaction varies from the daytime to night-time (Nor, Atiq, Roslan, Shahirah, Zainol & Wan Zul, 2015). It has been shown from studies that wind direction and speed has a major effect on radio signals as it transmits through the air in the troposphere. Thus, radio signal strength varies from observations directly to the air density taking into cognizant the direction of the wind and speed (Lindsay, Ulrich & Mark, 2011). Radio waves propagated through a wireless network may experience reflection, refraction, absorption, interference, attenuation, diffraction, and diffusion. This is because the wireless network is not in the vacuum but in the atmosphere. Consequently, radio systems undergo certain difficulty compared to the network properties in mobile communication with a well-built antenna. Since the height of the antenna in radio gadget is commonly very small, most of the natural and artificial phenomena in the surrounding of the consumer may have extensive effects on the properties of the transmission channel. The transmission properties vary from one place to another and from time to time as the radio appliance is being moved (Osuagwu, 2014).

A number of factors affect the promulgation of a radio signal in an ideal atmosphere. These factors are; the elliptical curvature of the earth, the atmosphere which is classified into different strata namely troposphere, stratosphere, mesosphere, and ionosphere and the interface with the surrounding objects such as mounting, building, trees, valleys, hills, fogs, etc. The interface with these surrounding objects results in reflection, attenuation, diffraction, refraction, scattering, and interference (Iwuji & Emeruwa, 2018). The existence of water on the peripheral of the arena is the actual cause of variation in the strength of radio signal and not necessary rainfall. This is the reason why radio signal takes time to recover from a rainfall incident as they gradually desiccated with time. Water capacitive plugs into the aerial of the transmitter changes its transmission configuration. In most cases recorded, radio signal strength becomes poorer; nevertheless, poor signal strength can also improve efficiency by equipping the terminal with a device that can control the effect of water (Andrew & Niki, 2014).

Radio signal strength is widely known for being a boisterous signal that is hard to use for an inference based stations. The major problem with radio signal strength interference is that the consequence of attenuating and reflecting substances in the surroundings may have a greater effect on radio signal strength than distance, making it hard to deduce distance from radio signal strength without a complete paradigm of the physical surroundings. This has given radio signal strength the prestige of being erratic for fluctuation assessment (Shang, Ruml, Zhang & Fromherz, 2013). Most radio signal strength based location networks actually uses a method known as radio frequency delineation where the consequence of the objects in the environment such as trees, walls, and others must be figured out before knot can be localized. It is often assumed that radio signal strength can be used for fluctuation determination in outdoor environs that are unrestricted from obstacles such as buildings and trees (Sichitiu, Ramadurai & Peddabachagari, 2003).

The strength of radio signals received by radio receivers is always not exposed to humanoid regulation. The transmission of the radio signal in the Megahertz band is extremely affected by the rate of rainfall, and drop size dust particle proportion in relations to depletion, eruption, depolarization, and noise. For frequencies above 10 GHz, the scattering and absorption by rain result to a drop in the propagated signal strength thus resulting to decrease in the reliability, availability, and performance on the transmission network (Roslan, Shahirah, Atiq, Zainol, Wan Zul & Nor, 2015). Also, stellar emissions and other astrophysical activities influence the entire electromagnetic content of the ionosphere and also alter different radio frequencies used in broadcastings (Fidelis, 2015). To this end, this study becomes necessary as it will help radio broadcasting stations to know the best period of the day to disseminate vital information. The chief aim of this study is to determine the diurnal variation of signal strength generated by Imo State Broadcasting Corporation (Orient 94.4 FM) frequency modulated (FM) transmitter.

This research to study the variation of signal strength was carried out in Imo State, Nigeria along six selected routes. Imo state is a state in the eastern part of Nigeria. It is located within longitude 6°50'E and 7°25’E and latitudes 4°44'N and 7°14'N. It has a boundary with Anambra State, Abia State, Delta State, Rivers State and River Niger (Fidelis, 2015). Imo state is the home of Heartland FM which is a Federal Government owned radio broadcasting corporation and Orient FM and TV which belongs to the Imo State Government. The broadcasting station of interest is the Orient 94.4 FM which is located at Chief Achike Udenwa Avenue, New Owerri, Owerri Municipal Council, Imo State, Nigeria. Orient FM is currently transmitting on a 4.2 kW transmitter and has an antenna which is about 1000 feet high.

Literature Review

Radio signal broadcasting has become an inert service whose major interest is mainly on the reception of radio waves signals which naturally occurs. The intensity of the radio waves signal cannot be controlled by the humanoid as the frequencies are naturally fixed (Fidelis, 2015). The efficiency of radio transmission networks depends on the medium of propagation (the atmosphere) which mainly occurs between the transmitter and receiver. The natural features of the atmosphere like rainfall, temperature, relative humidity, and pressure are depended on the radio links making the radio links to be very arbitrary (Iwuji & Emeruwa, 2018). Also, the transmitting signal wave itself is influenced by polarization and its wavelength when traveling through the atmosphere. As the effect of the atmospheric features on radio wave signal increases, the frequency of the radio signal also increases. The assimilation and diffusion of the radio waves signal by drops of water will result to signal attenuation. The resonance of the waves with individual molecules of water is involved in the assimilation of the signal, while the diffusion will scatter the signal (Fidelis, 2015). As the atmospheric temperature increases, the molecular energy is increased by the assimilation which will lead to the attenuation of radio signal strength (Amajama, 2016).

The D-region which is the lowest part of the ionosphere is a significant reflecting surface for the long wave navigation and propagation systems (Suli'c, Sre´ckovi´c, & Mihajlov, 2016). The Low Frequency {(LF) about 30-300 kHz} and Very Low Frequency {(VLF) about 3-30 kHz} bands are beneath the significant frequencies of the D-region. These radio waves frequency from transmitters are transmitted via transmission line confined by the surface of the D-region and Earth. This transmission has constant amplitude and phase and also has comparatively little attenuation (Goodman, 2005). The LF/VLF emissions are reflected from electron densities at an elevation of about 80-90 km during nighttime and 70-75 km during the daytime. These frequency emissions are also reflected by the conducting surface of the Earth. This means that the radio waves frequencies transmit over Earth confined between the ionosphere and the ground (Suli'c, Sre´ckovi´c, & Mihajlov, 2016). The actual reflection elevation relies on the ionization levels of the D-region. The lowest region of the ionosphere which is less than 90 Km high is experienced in unobtrusive environments mainly by the activity of solar Lyman-α radiation (121.6 nm) on nitric oxide. During the day, electron density in this place is less than or equal to Ne $\sim 10^8$ m^{-3}. At night, the ionization percentage decreases and adjoining processes sustain. Notwithstanding, at night, there is adequate ionization in the D-region of the ionosphere to affect the Very Low-Frequency and Low-Frequency radio signals (Kelley, 2009). A variety of active phenomena occur in the D-region resulting in seasonal and diurnal variations in linking with solar action.

The ionosphere consists of so many gases such as oxygen, nitrogen etc. The ultraviolet radiation from the solar system interacts with the atoms present at this zone. This radiation intercepts the oxygen atoms, thereby partially absorbing the ultraviolet waves and ionizing the oxygen atoms (Sharma & More, 2017). The layer of the ionosphere ionizes always apart from the D layer. The D layer is close to the earth and disappears at night as a result of inadequate neutral density below 200 Km. Thus, this takes place within few hours (More, Sharma, Bhonsle & Kenneth, 2010). The ionization of the E layer decreases a little at night. At this particular time, the D layer reappears because of the rising of the sun at the D layers elevation (Sharma & More, 2017). The ionosphere reflects the radio wave signals allowing it to travel around the ground. That is why these waves or radiations are used for transmission all over the world and can also be used for observing the behavior of the ionosphere. The radio frequency wave is reflected from the ionosphere. This explains the reason why radio frequency wave is being affected whenever there is a change in the atmosphere (Kumar & Kumar, 2007). Solar radiation affects ionosphere during magnetic storms and solar flares (Sharma & More, 2017). Galactic emission constantly affects ionosphere. Although the energy of galactic emission is not strong, they continuously affect the ionosphere. The solar radiation has the same effect on ionosphere as with diurnal during magnetic storms and solar flares (Kumar & Kumar, 2007). Thus, the solar flare occurs separately during the daytime alone. At night, the radio frequency wave travels to about 90 Km of the E layers in the ionosphere and it's then reflected to the earth. The D layer partially ionizes during the day resulting to a loss in energy through the channel as the radio frequency travels through the D layer. The signal strength of the radio frequency waves is stronger at night than at daytime. The radio frequency wave reacts differently when subjected to different solar intervention. It has been proven that the strength of radio frequency wave signals is affected by the disturbances happening at the ionosphere, and these disturbances may as well affect the human body (More, Sharma, Bhonsle & Kenneth, 2010).

Methodology

The investigation to determine the variation of signal strength generated by the Orient 94.4 FM transmitter with time was carried out along six (6) different routes in Imo State, Nigeria with the aid of a constructed Signal Strength Meter (SSM). The signal strength meter used for this study houses signal strength monitor, RF stage, IF stage and LCD, and power amp. The block diagram of the constructed SSM is as shown in Figure 1 below.

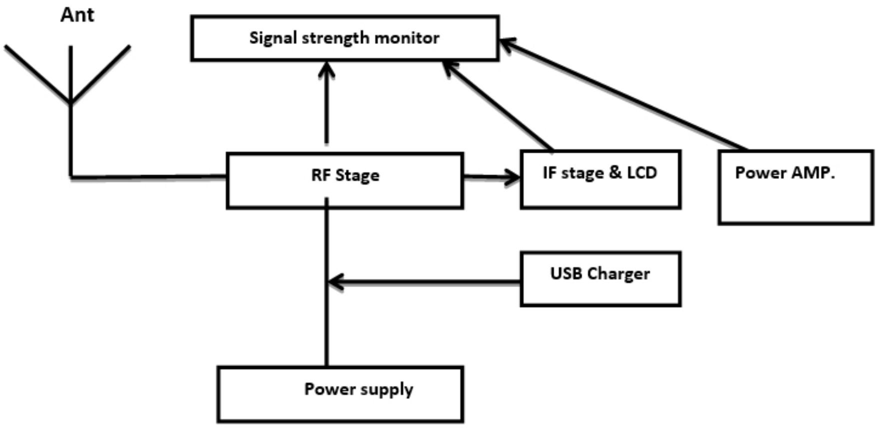

Figure 1. Block diagram of the constructed signal strength meter

The radio frequency phases take in the information from the aerial, tunes the desired signal, boost it, and move it to the IF stage. Voltage, noise, carrier and the audio signal from the antenna are received at this stage, but the voltages and noise are wasted at this stage. However, the carrier and the audio signal moves to the converter hence increasing the sensitivity and selectivity and also improving the automatic volume control (AVC) action. The detector is found in the IF stage. This detector found in the IF stage serves as a demodulator which separates the carrier from the main signal. It is a common frequency that radio signals are converted before the demodulation stage. It accepts the intermediate frequency from the converter, amplifies it, and passes it on to the next detector stage. The liquid crystal display (LCD) is the displayer that shows the particular radio frequency or radio channel that is tuned by the receiver. The power amplifier stage was designed to amplify the signal that is being received and amplified by the other stages of the receiver. The signal strength monitor is a meter attached to all the stages so as to calculate the signal per stage and give out a particular value for the strength in decibel. The meter displays the relative strength of the signal on the channel tuned. It is used as a basis for signal comparison and in the monitoring network.

Signal strength measurements were collected at the different time of the day, on different days, in different months. The measurement was carried out at a constant distance of 20 Km and at a constant temperature of about 26^{o}C. We also ensured that the transmitting parameters were kept constant throughout the period of signal strength measurement by making appropriate arrangement with the management of the base station. The average results of these measurements were taken and the data obtained from the measurements were plotted in a graph to establish the diurnal variation in signal strength along the different routes where the signal strength was measured. The characteristics of the propagating transmitter are as shown in Table 1.

Table 1. Characteristics of the investigated station

Serial No.	Characteristics	Description
1	Investigation position of station	Long. 7.04˚& Lat.5.45˚
2	Base station's transmitting power	4.2 KW
3	Base station frequency (MHz)	94.4 MHz
4	Transmitter in use	ZHC 10 KW
5	Height of transmitting mask	304.8 m
6	Elevation of propagating aerial	15.24 m
7	Propagating aerial gain	30.02 m
8	Height of receiving antenna	Inbuilt

Table 2. Routes definition used for the study

Routes	Routes Description
A	Owerri – Onitsha Road
B	Owerri– Orlu Road
C	Owerri–Okigwe Road
D	Owerri – Aba Road
E	Owerri – Port Harcourt Road
F	Owerri – Nekede

Result and Analysis

The study to discover the diurnal variation of signal strength generated by the Orient 94.4 FM transmitter in Imo State was carried out with the aid of a constructed signal strength meter. The data obtained during the field strength measurement were tabulated and subsequently plotted to establish the variation of signal strength with time. Table 3 shows the Signal strength variation with time along route D, E and F at a distance of 20km from the transmitter. However, Table 4 shows signal strength variation with time along route A, B, and C at a distance of 20km from the transmitter.

Table 3. Signal strength variation with time along route D, E, and F at a distance of 20km from the transmitter

Time (Hours)	Signal Strength (dB)		
	Route D	Route E	Route F
0800	30	20	20
1100	20	10	18
1300	20	10	5
1500	10	0	0
1700	20	8	5
2000	20	12	5

Table 4. Signal strength variation with time along route A, B, and C at a distance of 20km from the transmitter

Time (Hours)	Signal Strength (dB) Route A	Route B	Route C
0800	70	40	40
1100	70	40	38
1300	60	20	32
1500	60	20	20
1700	60	42	20
2000	68	45	30

Analysis of Data Obtained from Field Measurement

Data obtained during the period of the research were plotted to show the diurnal variation of signal strength. Figure 2 below shows the graph of Signal strength variation with time along route A, B, and C at a distance of 20km from the transmitter. The graph of signal strength variation with time along route D, E, and F at a distance of 20km from the transmitter is as shown in Figure 3.

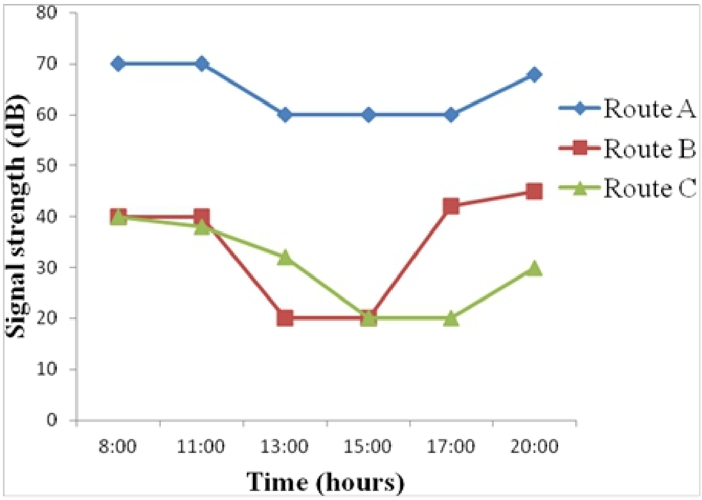

Figure 2. A graph of Signal strength variation with time along route A, B, and C at a distance of 20km from the transmitter

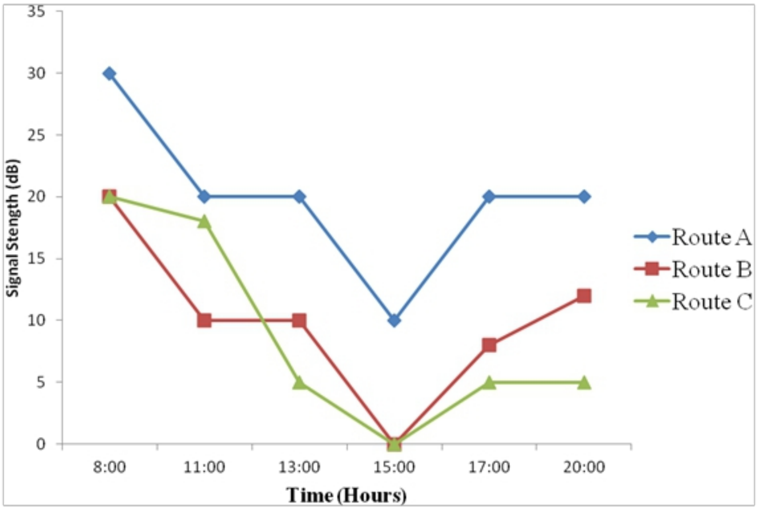

Figure 3. A graph of signal strength variation with time along route D, E, and F at a distance of 20km from the transmitter

Figure 2 and Figure 3 show that time of broadcast affects the signal strength received along the different routes. It was observed from this work that signal strength are stronger during the early hours of the day and late in the night than in the afternoon. During the day, especially in the afternoon, a lot of human activities and use of machines that generate electromagnetic waves interfere greatly with the radio signal thereby resulting to drop in signal strength. From the study, the signal strength at about 0800 hours for a constant distance of 20 km from the transmitter along route A, B and C were 70 dB, 40 dB, and 40 dB respectively. At about 1300 hours, the signal strength along route A dropped to 60 dB, along route B was 20 dB, and the signal strength along route C was 32 dB. At routes D, E and F, the signal strength measured using a distance of 20 km at about 0800 hours was 30 dB, 20 dB and 20dB respectively. At about 1300 hours, the signal strength measured at a distance of 20 Km was 20 dB along route D, 10 dB along route E, while 5 dB was measured along route F. This shows that signal strength is moderate or relatively high between the hours of 0800 hours and 1100 hours in the morning. This is caused by the reduced temperature at that time and may also be as a result of early morning dews. Morning dews, because of its water content, are conductors and thus aid in the propagation of signal. The drop in signal strength at noon is most time probably due to traffics, increase in temperature, interfering ionosphere, presence, and movement of people or probably due to a large number of customers tuning in the channel.

Summary, Conclusion and Recommendation

Summary

The research to investigate the diurnal variation of signal strength generated by Orient 94.4 FM was carried out along six major routes in Imo state with the use of a constructed signal strength meter. The measurement was carried out at the different time of the day, on different days, and in different months. The measurement was carried out at a constant distance of 20 Km and at a constant temperature of about 26^{o}C. Many factors such as solar radiation, some atmospheric parameters, human activities and usage of machines that generate electromagnetic waves etc. have been observed to interfere greatly on the signal generated by the frequency modulated transmitter resulting to drop in signal strength especially in the afternoon. The research shows that the transmission and reception are dependent on the time of the day. Also, high signal strength was noted between the hours of 8 am and 11 am, while low signal strength was recorded between the hours of 1 pm and 5 pm. Better signal strengths were recorded at night.

Conclusion

It was shown from this study that the signals generated from the transmitter of Orient 94.4 FM vary with time of the day and the prevalent weather conditions. Stronger signals are recorded mostly at night at along the different routes of the study when the weather was calm. The signal strength consequently drops in the afternoon and regain in the morning hours.

Recommendation

It is recommended from the result of this research that the management of Orient 94.4 FM should consider increasing the output power of their transmitter presently at 10 kW to about 30 kW. However, this would help boost the signal propagated within the state. Radio users or consumers should obtain an Adaptive and Smart antenna in order to overcome the challenges posed by poor signal quality being experienced in some part of the state. The management of Orient FM should endeavor to broadcast vital information at night or early hour of the morning when signal strength is a lot better.

Acknowledgment

We wish to thank the management of Orient 94.4 FM for making available necessary information needed to successfully carry out this research and also for keeping the transmitters parameters constant throughout the period of this study. We also want to sincerely thank our colleagues at the University of Calabar, Calabar, Nigeria for their encouragement.

References:

1. Amajama, J. (2016). Impact of Weather Components on (UHF) Radio Signal. International Journal of Engineering Research and General Science. 4(3), 481-494.
2. Andrew, M. & Niki, T. (2014). Effect of Rainfall on Link Quality in an Outdoor Forest Deployment. Stephen Ellwood Wildlife Conservation Research Unit, Oxford University, UK stephen.ellwood@zoo.ox.ac.uk
3. Fidelis, C. O. (2015). *Analysis of 30 Years Rainfall Variation in Imo State of Southeastern Nigeria. Hydrological Sciences and Water Security: Past, Present and Future*. Proceedings of the 11th Kovacs Colloquium, Paris, France, June 2014. IAHS Publ. 366.
4. Goodman, J. M. (2005). Space Weather & Telecommunications. Springer Science & Business Media.
5. Iwuji, P. C. & Emeruwa, C. (2018). Investigation of Signal Strength-Level Generated by Orient 94.4 FM Transmitter in Imo State, Nigeria. International Journal of Science and Research 7(5): 1089 - 1094.
6. Kelley, M. C. (2009). The Earth’s Ionosphere: Plasma Physics & Electrodynamics. Vol. 96. Academic press.
7. Kumar, S. & Kumar, A. (2007). Diurnal Variation of 19.8 KHz Signal, Propagation over Long Path to Suva. The South Pacific Journal of Natural Science. 11; 67 – 1169.
8. Lindsay, M. P., Ulrich, G. R., & Mark, A. P. (2011). Factors Influencing Radio Wave Transmission and Reception: Use of Radiotelemetry in Large River Systems. North American Journal of Fisheries Management 28(1): 301-307.
9. More, C. T., Sharma, A. K., Bhonsle, R. V., & Kenneth, J. W. L. (2010). Field Strength Measurement of VLF Radio Wave Propagation at 19.8 KHz Between Australia and India. 10th Australian Space Science Conference Proceedings. Pg 249 – 262.
10. Nor, H. S., Atiq, W. A., Roslan, U., Shahirah, S. S., Zainol, A. I., & Wan Zul Adli, W. M. (2015). The Effect of Solar Radiation on Radio Signal for Radio Astronomy Purpose. Malaysian Journal of Analytical Sciences 19(6): 1374 – 1381.
11. Osuagwu, F. (2014). Radio Propagation in Outdoor Sub-Urban Environment: Effect on Gsm Signal Strength. The International Journal of Engineering and Science 3(9): 73-79
12. Roslan, U., Shahirah, S. S., Atiq, W. A., Zainol, A. I., Wan Zul, A.W., & Nor, H. S. (2015). Radio Frequency Interference: The Study of Rain Effect on Radio Signal Attenuation. Malaysian Journal of Analytical Sciences. Pg 1093 – 1098.

13. Shang, Y., Ruml, W., Zhang, Y., & Fromherz, M. P. J. (2013). Localization from mere connectivity. In Fourth ACM International Symposium on Mobile Ad-Hoc Networking and Computing (MobiHoc).
14. Sharma, A. K. & More, C. T. (2017). Diurnal Variation of VLF Radio wave Signal Strength at 19.8 and 24 KHz Received at Khatav India ($16^0$46'N, $75^0$53'E). Research & Reviews: Journal of Space Science & Technology. 6(2); 1 – 12.
15. Sichitiu, M. L., Ramadurai, V., & Peddabachagari, P. (2003). Simple algorithm for outdoor localization of wireless sensor networks with inaccurate range measurements. In International Conference on Wireless Networks 2003, pages 300– 305.
16. Suli'c, D. M., Sre´ckovi´c, V. A., & Mihajlov, A. A. (2016). A study of VLF signals variations associated with the changes of ionization level in the D-region in consequence of solar conditions. Retrived on April 23rd, 2018 from https://arxiv.org/pdf/1603.07300.pdf