

The Modelling of Tropical Weather Effects on Ultra-High Frequency (UHF) Radio Signals Using SmartPLS

R Mat^{1,4}, S N Hazmin^{1,5*}, R Umar², S Ahmad³, S N A S Zafar² and M S Marhamah²

¹Advanced Nano Materials (ANoMa) Research Group, School of Fundamental Science, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia

²East Coast Environmental Research Institute (ESERI), Universiti Sultan Zanal Abidin, Kampus Gong Badak, 21300 Kuala Nerus, Terengganu, Malaysia

³School of Informatics and Applied Mathematics, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia

⁴Institut Pendidikan Guru Kampus Sultan Mizan, 22200 Besut, Terengganu, Malaysia

⁵Pusat Islam Sultan Mahmud, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia

Corresponding author email: norhazmin@umt.edu.my

Abstract. The interference occurs in radio signals transmission in many communication technologies are attributed to weather variations as well as other environmental factors. This work evaluates some atmospheric variables that have a dominating impact on temporal signal strength fluctuations. The Received Power Level (RPL) of Ultra High Frequency (UHF) communication signals (1800 MHz and 2160 MHz) and three tropical weather predictors (humidity, temperature and wind) were collected using spectrum analyser (KEYSIGHT N9915A) and weather station (Vantage Pro 2) respectively for 24 hours in rainy days. SmartPLS 3.2.6 was used to determine the strongest predictors influence the RPL for UHF frequency. It has been found that changes in weather conditions have affected the signal in which all weather predictors provide a significant relationship to the signal where R^2 (coefficient of determination) value is 0.314 for frequency 1800 MHz and 0.254 for frequency 2160 MHz. The findings also show that humidity, temperature and wind are anticorrelations to RPL. However, humidity is found to be the strongest predictor influences the RPL of communication signals for frequency 1800 MHz ($\beta = -0.449$, $p = 0.000$). This model may benefit many sectors such as telecommunication service provider, radio and TV transmission, radio astronomy study, Electromagnetic (EM) researcher and satellite broadcasting.

1. Introduction

Nowadays, the use of communication technologies such as smartphone, laptop and computer are increasing day by day in our lives. Most of us depend on these various technologies to achieve certain tasks in our daily activities especially in getting news, making online or banking business and also connecting with social media. According to the Malaysian Communications and Multimedia Commission (MCMC) Internet Users Survey 2014, the smartphone is the most widely-used device to access the Internet at 74.3% [1]. As the numbers indicate, users fully embrace the concept of getting connected everywhere at any time. However, a poor mobile phone signal reception is a dilemma experienced by almost every one of us at some point in



time. A recent survey by MCMC has shown that 48.1% of Malaysian owners experience some form issue due to poor cellular network strength [1]. These can result due to some failures in cell tower and overcrowding etc. However, the weather condition also plays an important role in affecting the cellular signal. Understanding the effects of the weather on radio wave propagation will help to improve the quality of radio signals in communication. Radio waves in Ultra High Frequency (UHF) range, is very widely used in modern technology, particularly in telecommunications. UHF is the part of the electromagnetic spectrum, ranging from 300 to 3000 MHz [2]. When the radio wave is interrupted by the bad weather, the quality of the signal will be reduced. For a tropical weather like Malaysia, environmental factors such as temperature, rainfall, wind and humidity will change, depending on the seasons. The weather of Malaysia has a nearly uniform temperature, high humidity, abundant rainfall and the wind is weak because its location is close to the equator [3].

Several factors that can affect radio wave propagation such as terrain, building, vegetations, CO₂ concentration and weather parameters (such as rain, solar radiation and dust) have been studied by many authors [4-7]. Most of the research and observations were made in another part of the tropical countries had shown some discrepancy which did not apply to Malaysia weather [6-8]. Therefore, more data are required to confirm the effect of weather on radio waves in tropics. Research in radio wave propagation is a new field in Malaysia and only a very few have examined the impact of tropical weather on UHF radio signals. There is only a few direct or indirect measurements of attenuation of weather have been made in Malaysia and they have not looked into the correlation between radio signals and weather parameters so far [9, 10]. In this study, we used statistical analysis to identify the correlation between the variables and finally we used regression to determine the strongest predictor influences the signal. The usage of SmartPLS is a novel idea, and it is a first-hand study of its kind. Findings could be enhanced with the study of using this method. Therefore, this study is hoped to address the above problems.

1.1 Literature review

Weather factors such as rain, wind, temperature and humidity are one of the Radio Frequency Interference (RFI) sources that disturb the propagating signal and cause loss of data which have been studied by many authors. [11] investigated the influence of air temperature, relative humidity and atmospheric moisture on the UHF radio propagation in South Western Nigeria. The results showed that air temperature, relative humidity and liquid water density of the cloud relative (LWDC) have a significant influence on UHF signal propagation within the troposphere region of southwest Nigeria. They observed that as the air temperature increases, relative humidity decreases, hence a proportional decrease in UHF path loss while the received signal strength (RSS) shows a proportional increase. [12] found that an inverse relationship between the path loss and the relative humidity was obtained from their results. That is, a decrease in relative humidity brings about a slight increase in path loss. Another finding research from Nigeria, [13] also indicated that radio signal strength is inversely proportional to atmospheric temperature, pressure and humidity; provided that for any of the giving components, others were observed constant, including the wind speed and direction, since it has been erected that wind has a marked effect on a radio signal. The correlation of the signal strength and atmospheric temperature, pressure and humidity were respectively $r = -0.94$, -0.99 and -0.93 and the equation $S = K(\alpha)/TPH$ constant wind speed and direction was postulated, where S , T , P , H and K are Signal strength, Atmospheric temperature, Atmospheric pressure, Relative humidity and constant respectively. [14] studied the effects of temperature and humidity on radio signal strength in outdoor wireless sensor and also showed that changes in weather conditions affect received signal strength in western Finland. However, they found that temperature seems to have a significant negative influence on signal strength in general, while high relative humidity may have some effect on it, particularly below 0°C. Same as [8] also have found that a linear relationship between passive UHF Radio Frequency IDentification (RFID) tags' resonant frequency and temperature at relative humidity (RH) of 50% and 80% in their study. They also found that there is no significant change in the resonant frequency was observed as a result of humidity variation at a temperature ranging from 20°C to 80°C. Analysis using regression was also used in previous studies. [15] has conducted a study on the impact of the weather conditions on the wireless link quality. Mathematical models extracted fit different transmission problems over a link IEEE 802.11b/g as a function of different meteorological variables. This research has been carried out by symbolic regressions since it is a powerful and reliable method to analyse difficult hidden relations among variables. Results show that grouping weather

conditions entail a significant increment in the correlation coefficients in comparison with previous studies.

1.2 Objectives and hypothesis

The study aims to examine and evaluate the impact of three tropical weather factors (temperature, humidity and wind) in predicting the Received Power Level (RPL) of telecommunication signals transmission in the UHF band (Peak3=1800 MHz and Peak4=2160 MHz). The main objective of this research is to identify the strongest weather predictor influences the signal in the UHF band for Peak3 and Peak4.

Past researches [9-15] has shown that weather influences signal directly. Thus, we hypothesize that:

H1: Humidity will have an effect on RPL signals of Peak3

H2: Temperature will have an effect on RPL signals of Peak3

H3: Wind will have an effect on RPL signals of Peak3

H4: Humidity will have an effect on RPL signals of Peak4

H5: Temperature will have an effect on RPL signals of Peak4

H6: Wind will have an effect on RPL signals of Peak4

2. Methodology

2.1 Site description

The data measurement was conducted at Balai Cerap KUSZA (BCK), Universiti Sultan Zainal Abidin, Terengganu. BCK is located in Merang ($5^{\circ} 32' 10''$ N and longitude $102^{\circ} 56' 55''$ E), a coastal area of East Coast Peninsular Malaysia which is 28 km away from the main city of Kuala Terengganu. BCK is near the Merang beach located on top of Merang Hill, 160 m above sea level (Figure 1). This observatory has a tropical climate with uniform temperature, high humidity and constant moist with no dry and cold [16]. It is very suitable for the study because the Radio Frequency Interference (RFI) due to other factors are low because it is located in rural areas, far from the commercial and residential area, top of the hill so it receives a direct signal from base station transmission (reduced blockage) [17].



Figure 1. Location of Balai Cerap KUSZA

2.2 Data collection and data analysis

The procedure framework for statistical modelling of meteorological factors on UHF communication signals transmission is as illustrated in Figure 2. To determine the impact of the weathers on a radio signal, the study begins with instrument testing and calibration using the measurement setup as shown in Figure 3. The observation started with a preliminary study to get the overall view of the study. Then the real data measurement takes place for a selected date in the presence of rain. Finally, the data

obtained was analysed and the statistical model was developed. The instrument set up was illustrated in Figure 3. This method has been adapted from [5, 18-20] that this study has been using a discone antenna. The RPL at frequencies (namely Peak3-1800 MHz and Peak4-2160 MHz) and tropical weather variation (humidity, temperature and wind) were collected using spectrum analyser (KEYSIGHT N9915A) and weather station (Vantage Pro 2) respectively for 24 hours in rainy days during January - December 2017 (selected date). The description of Peak3 and Peak4 and their allocations were illustrated in Table 1 which are owned by cellular phone.

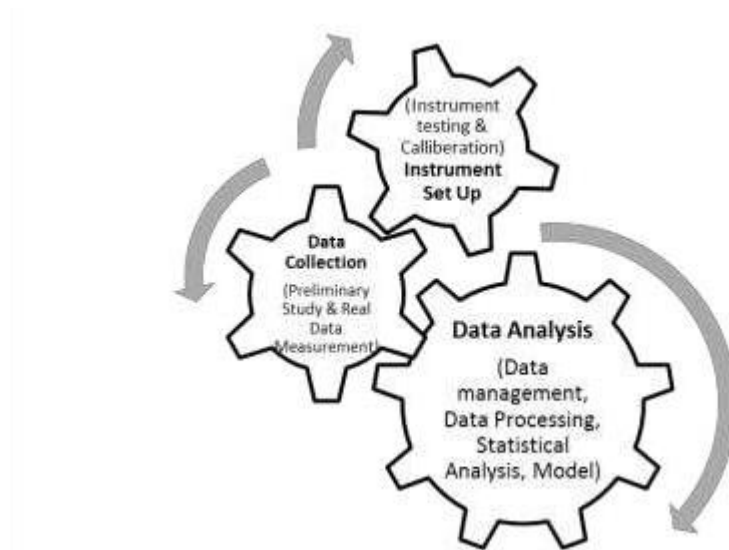


Figure 2. The procedure framework of Modelling of Tropical Weather effects on UHF Signals.



Figure 3. The instruments set up for observation work [5, 18-20]

Table 1. The description of Peaks and its allocation

Frequency MHz	Peaks	Malaysia Allocation	Sources
1800	Peak3	FIXED	Cellular mobile services [EGSM/GSM]/ [IMT]
		MOBILE 5.384A 5.388A MLA53	
		MLA89 MLA91 MLA92 MLA99	
		5.149 5.341 5.385 5.386	
2160	Peak4	MLA3 MLA81 MLA90	Cellular mobile services IMT
		FIXED	
		MOBILE 5.388A MLA53 MLA92	
		5.388	

Based on the data obtained from both a spectrum analyzer and weather station, data is then analyzed to investigate the relationship between signal and weather factors. We applied linear regression to explore the magnitude of these effects using PLS-SEM. The partial least squares path modelling (PLS-SEM) method to structural equation modelling allows estimating complex cause-effect relationship models with latent variables. It is a component-based estimation approach that differs from the covariance-based structural equation modelling. We used the Partial Least Squares (PLS) technique using the SmartPLS 3.2.6 software to analyze the research model and determine the strongest weather predictor influences the signal [21]. Following the recommended two-stage analytical procedures by [22], we tested the measurement model (validity and reliability of the measures) and followed by an examination of the structural model in order to test the hypothesized relationship [23-26]. Besides, to test the significance of the path coefficients and the loadings a bootstrapping method (5000 resamples) was used [23].

3. Results and Discussion

Figure 4 shows the validity of the Measurement Model Results. To assess the measurement model two types of validity were being examined, first the convergent validity and the discriminant validity. All the values passed as suggested in the literature (see Figure 4) indicating that the converging validity and discriminant validity of this model have been ascertained. The SRMR value was 0.000 (< 0.08) and NFI was 1.000 (> 0.90) indicating the data fit the model well. The SRMR is defined as the difference between the observed correlation and the model implied correlation matrix whereby values less than 0.08 [27] are considered a good fit. [28] introduced the SRMR as a goodness of fit measure for PLS-SEM that can be used to avoid model misspecification. The second fit index is a normed fit index (NFI) an incremental fit measure which computes the Chi-square value of the proposed model and compares it against a meaningful benchmark [29]. NFI values above 0.9 usually represent acceptable fit.

Figure 5 illustrates the bootstrapping results of the model and Table 2 shows the results of the hypothesis testing, to assess the structural model, [21] suggested looking at the R^2 , beta (β) and the corresponding t-values via a bootstrapping procedure with a resample of 5,000. R^2 indicates how well all weather factors explain RPL of Peak3 and Peak4. For example, a value of 0.314 indicates that 31.4% of the variance in the RPL of Peak3 is explained by the weather factors (humidity, temperature, wind). Accordingly, our primary way to compare the strength of relationships is looking at the path coefficients, β . Furthermore, we could calculate the effect strength f^2 for each predictor, which indicates to which extent this predictor contributes to the explanation of a RPL. Based on Table 2, we found that for Peak3 (1800 MHz) predictors, humidity ($\beta = -0.449$, $t = 40.337$, $p < 0.01$, $f^2 = 0.2818$), temperature ($\beta = -0.375$, $t = 34.018$, $p < 0.01$, $f^2 = 0.1920$) and wind ($\beta = -0.096$, $t = 8.125$, $p < 0.01$, $f^2 = 0.0123$) negatively influenced by 31.4 % of the radio signal strength of Peak3. This supports H1. H2 and H3. Next we looked at the weather predictors on the Peak4 (2160 MHz), humidity ($\beta = -0.370$, $t = 30.586$, $p < 0.01$, $f^2 = 0.1757$), temperature ($\beta = -0.370$, $t = 33.908$, $p < 0.01$, $f^2 = 0.1718$) and wind ($\beta = -0.089$, $t =$

7.402 $p < 0.05$, $f^2 = 0.096$) were significant and giving 25.4 % contribution to this signal. The findings also support H4, H5 and H6.

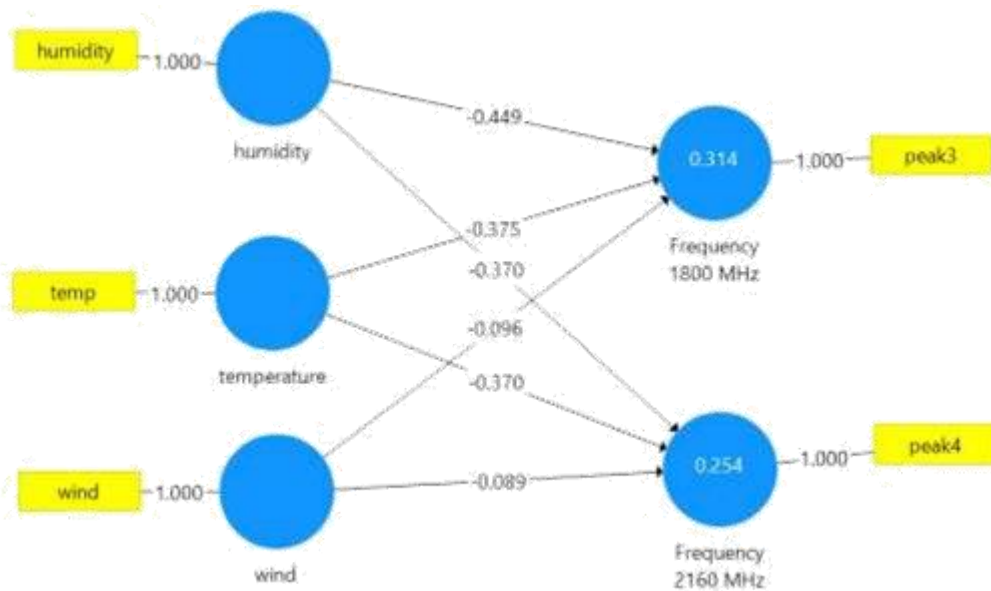


Figure 4. The Measurement Model Results

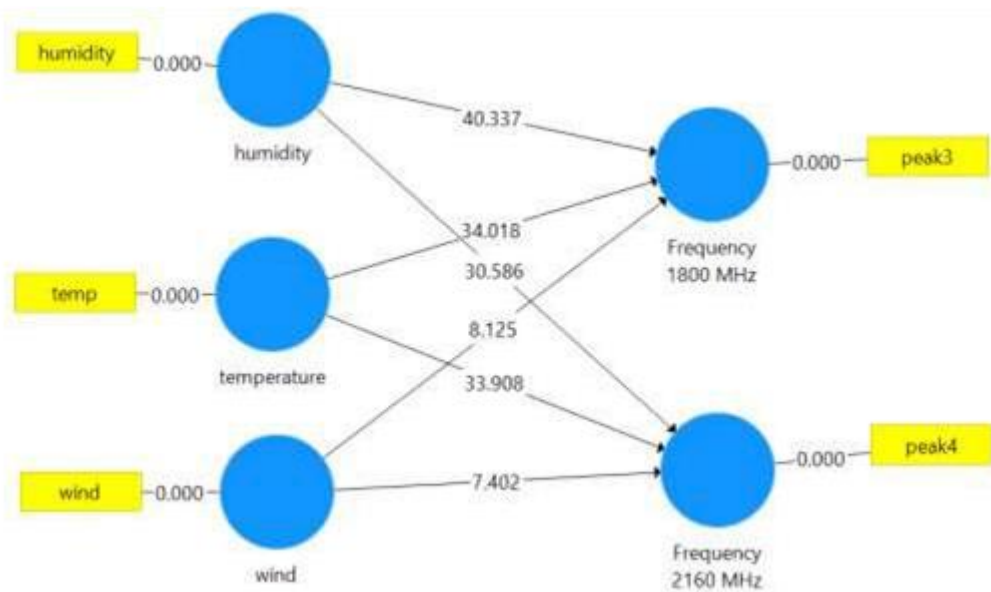


Figure 5. Bootstrapping Result

Table 2. The results of the hypothesis testing

Hypothesis	Relationship	Std beta, β	p-value	T value	Decision	f^2	R^2
H ₁	Humidity -> Peak3	-0.449	0.000	40.337	supported	0.2818	0.314
H ₂	Temp-> Peak3	-0.375	0.000	34.018	supported	0.1920	
H ₃	Wind -> Peak3	-0.096	0.000	8.125	supported	0.0123	
H ₄	Humidity -> Peak4	-0.370	0.000	30.586	supported	0.1757	0.254
H ₅	Temp> Peak4	-0.370	0.000	33.908	supported	0.1718	
H ₆	Wind -> Peak4	-0.089	0.000	7.402	supported	0.0096	

4. Conclusions

From the results of the hypothesis testing and bootstrapping, we can conclude that weather factors (temperature, humidity and wind) play a pivotal role in UHF radio wave propagation. It is found that the change in weather conditions affects the RPL where R^2 was 0.314 for Peak3 and 0.254 for Peak4 (Table 2). Peak3 at frequency 1800 MHz was affected the most due to tropical weather variation with contribution 31.4% whereas weather factors contribute 25.4% to Peak4 (2160 MHz). This confirms our prediction that weather factors (humidity, temperature and wind) are important in UHF radio signal. Humidity is found to be the strongest predictors influence the RPL of communication signals especially for frequency 1800 MHz ($\beta=-0.449$, $p=0.000$). The model of the potential impact of weather factors on radio frequency interference may benefit telecommunication service provider and makes it possible to propose alternative solutions to assure the better service suitable for all weather condition.

5. References

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