# Performance Analysis of Propagation in VHF Military Tactical Communication System

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**Abstract:**

The main challenge of military tactical communication systems is the accessibility of relevant information on the particular operating environment required for the determination of the waveform's ideal use. The existing propagation model focuses mainly on broadcasting and commercial wireless communication with a highs transceiver antenna that is not suitable for numerous military tactical communication systems. This paper presents a study of the path loss model related to radio propagation profile within the suburban in Kuala Lumpur. The experimental path loss modeling for VHF propagation was collected from various suburban settings for the 30-88 MHz frequency range. This experiment was highly affected by ecological factors and existing wave propagation effects such as reflection, diffraction, scattering, and Doppler effect. Radio propagation performance is evaluated by collecting received power at the allocated substation and comparing it against existing propagation models. The existing propagation model also will be tuned close to the measurement value by identifying the best path loss exponent to perform a suitable model for a suburban area. Theoretical assessments and analysis of the initial measurement stage for radio propagation show the extensive contribution of radio field from potential obstacles at lower VHF frequencies for both short and medium ranges around there. The explanation indicates the standard radio propagation prediction models that are generally reasonable for the suburban area. From the general error analysis, it is seen that, the performance of the LDPL with adjusting path loss exponent is the suitable model since it has least value of error metrics.

**Keywords**: Propagation loss, Suburban, Tactical radio, VHF.

**Introduction**:

The nature of the warfighting has radically changed even from a couple of years ago because of quick worldwide urbanization. Based on land tactical communication, the environment significantly attenuates the radio signal. Regarding in real situation, terrain analysis is fundamental to offensive and defensive planning on any battlefield. Regarding real operation, operations in specific environments are operations peculiar with the geography of the operations to be conducted. The geography here covers the nature of the ground or terrain, the climate, the space from the ground upwards or if it involves rivers and the sea, it may cover even the riverbed or seabed. These operations include operations in built-up areas (OBUA), operations in jungle, operations in conditions of limited visibility, and coastal areas' defense. Cities, towns, villages, and industrial facilities are all examples of built-up areas. These areas are growing in number and size across Malaysia, especially in Peninsular Malaysia. As a result, fighting tactics and approaches in densely populated places are becoming increasingly crucial.

For all communications operations, OBUA provides a unique challenge. Built-up environments impede radio wave propagation, and the shortage availability of uncongested communication connections makes moving and installing fixed stations and multichannel systems problematic. Within densely populated places, communication problems are extremely severe. To maintain the line of communication throughout this operation, some key aspect such as path loss serves as a useful reference for communication coverage to keep the

forward and rearward elements for command and control purpose [1]. In this operation, the VHF band is suitable for use because of comprehensive coverage. In order to create coverage regions, an empirical model must be used to estimate path loss at the VHF band in a built-up area. The primary goal estimation path loss model predicts the loss of signal strength or coverage in a particular location. To date, several studies have been conducted on the path loss prediction in VHF and UHF band within the urban environment for commercial equipment [2]. However, the measurement of the characteristics is not valid with the military specification in terms of the frequency range, antenna height and power.

VHF is the radio frequency range from 30-300 MHz. Ordinarily, the VHF range is utilized for TV and FM radio broadcast at 88-108 MHz. VHF is additionally customarily utilized for terrestrial and navigation communication system. Likewise, VHF frequencies' propagation characteristics are perfect for short-distance terrestrial communications [3] VHF ranges are mostly used by the majority of military tactical communication normally at 30 – 88 MHz include Malaysian Armed Forces to maintains communication in combat scenarios. VHF propagation requires a detailed understanding to establish a useful communication link. Based on the majority of classical empirical data or equation-based suburban path loss model, there is an absence of attenuation prediction models in the suburban environment for the frequency range of 30-88 MHz and geometries (antennas 1 – 10 meters above ground) utilize by the prevailing piece of military communications systems [4]. Table 1 shows the existing empirical model to predict the path loss for radio frequency [5].

**Table 1. The existing Empirical model.**

| Author | Frequency Range (MHz) | Coverage Distance (km) | Transmitter Height, $H_T$ (m) | Receiver Height, $H_R$ (m) |
|---|---|---|---|---|
| Y. Okumura | 15-1920 | 1-100 | 30-1000 | |
| M. Hata | 150-1500 | $\geq 1$ | 30-200 | 1-10 |
| COST 231 | 800-2000 | 0.02-5 | 4-50 | 1-3 |
| H. Xia | 900, 1900 | 0.001-2 | 3.2, 8.7, 13.4 | 1.6 |
| V. Erceg | 1956 | 0.01-0.5 | 3.3, 6.6 | 1.5 |
| D. Har | 900, 1900 | 0.06-2 | 3.2, 8.7, 13.4 | 1.6 |
| A. Kanatas | 1890 | 0.02-0.18 | 4 | 1.7 |
| H. Masui | 3350, 8450, 15750 | 0.02-0.5 | 4 | 2.7 |
| Y. Oda | 457-15450 | $\geq 20$ | - | - |
| T. Rao | 200, 400, 450 | 0.5-10.5 | $\geq 20$ | 3 |
| N. Blaunstein | 902-928 | 7 | 2-3 | - |
| W. Young | 150, 450, 800, 3700 | 0.108-16.3 | 138 | 2 |

This model represents such are a reference for commercial application, which is different in the military specification. Most of the models discuss more on urban scenarios and designed for cellular communication. The frequency, environment and antenna height do not apply to terrestrial military tactical communication specifications.

This paper presents the performance of the experimental path loss modeling for VHF propagation collected from various suburban settings for a 30-88 MHz frequency range. The measured path loss is compared to the expected path loss predicted by empirical models which compensate on reflection, diffraction, scattering, and the Doppler Effect [6]. The performance will give analysis using path loss exponent from log-distance path loss model to assess the model's validity in the frequency range based on comparison and observation [7]. The rest of the paper is organized into five different sections, which are sections for the

theoretical background, survey description, path loss analysis, and conclusion.

## Theoretical Background:
## Propagation Environment

The propagation environment mainly considered for this project is propagation over the ground. There are different types of ecosystems that have been categorized by International Telecommunication Union (ITU), namely: Urban, Suburban, and Rural [8, 9].

## Path Loss Model

For the radio wave propagation, the free space path loss (FSPL) model shown in [10] acts as a lower bound for the estimation of path loss

$$L_{FS,dB} = 32.45 + 20 \log (r) + 20 \log (f) \qquad (1)$$

where f is the frequency in MHz and r is the separated distance between Tx-Rx in meters. The

Plane Earth Path Loss (PEPL) model, rather than the free space model, can better illustrate path loss when the radio wave propagates close to the ground with a line of sight (LoS) condition [7]. The ground reflection effect is included in the plane earth path loss model, which is expressed as

$$PEPL(dB) = 40\log 10(d) - 20\log 10 (h_T) - 20 \log 10(h_R) \tag{2}$$

where d is the separated distance between a station in meters, $h_T$ and $h_R$ are transmit and receive antenna heights in a meter. The assumption in this model is the range separated is much larger than antenna high.

The Friis free space model is enhanced by the Log Distance Path Loss (LDPL) model. It is used to measure propagation loss in a wide range of environments, however it is confined to an unobstructed clear path between the transmitter and the receiver. Because of sign obstruction by slopes, trees, and building structures, the model incorporates irregular shadowing effects. It is additionally alluded as log normal shadowing model [3].

If $PL(d_0)$ is the path loss at a distance $d_0$ meter from the transmitter, then the path loss at any distance $d>d_0$ for separations past $d_f$ in transmitter's far field region is given by

$$[P_L(d) \, dB = [P_L(d_0)]dB + 10n \log \frac{d}{d_0} \quad \text{for} \quad d_f \leq d_0 \leq d \tag{3}$$

as shown in Table III, PL (d) is the LDPL at a distance of d meter, and n is the path loss exponent that varies depending on the type of environment [11]. The reference path loss, also known as close-in reference distance, is PL ($d_0$). The Friis path loss equation or field measurements at d0 can be used to evaluate it. A microcell's $d_0$ is typically 1 to 10 m, while a large cell's $d_0$ is 1 km.

The Path Loss Measure is the radio signal degradation that was calculated from received power measurement and derived from the link budget system [3].

$$P_{RX} = P_{TX} - L_{TX} + G_{TX} - PL_{measured} + G_{RX} - L_{RX}$$
$$PL_{measured} = P_{TX} - L_{TX} + G_{TX} + G_{RX} - L_{RX} - P_{RX} \tag{4}$$

where $P_{TX}$ is the transmit power (dBm), $G_{TX}$ and $G_{RX}$ are transmitted and receive antenna gain (dBi), $L_{TX}$ and $L_{RX}$ are the cable loss for transmit and receive and $P_{RX}$ is the mean measured received power (dBm).

## Survey Description:
## Measurement Sites

The measurement sites dependent on the suburban environment are painstakingly chosen. During measurement, the area of the transmitting antenna is fixed on 10 meters push up lightweight tactical telescopic communications mast (PU Mast). So, the coverage should cover over the rooftop every building in this measuring area and for the others substation, will be provided with 2 meters from the ground antenna to communicate with the base station. Measurement environments incorporate low-rise houses, grid roads, multiple vehicles, auxiliary facilities and some zone across high voltage overhead transmission lines. When working locally in a small town with regular grid roads aside from some roadblocks, there are two types of radio connections. The first is a line-of-sight (LoS) connection, and the second is a non-line-of-sight (NLoS) connection [12]. The NLoS connect occurs when Rx is shielded by homes or impediments and the transmit antenna of Tx is not visible at the Rx location. Measurement was carried out in a suburban area, as shown in Figure 1.

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**Figure 1. Measurement site.**

## Measurement Setup

The transmitter and receiver ware located at 6 Substation which is the base station located at Radio Lab with 10m monopole antenna from ground and the others Substation is mounted at mobile communication vehicle with 2m antenna. The following equipment ware used throughout this project:

1) A pair of Transceiver VHF military tactical man pack radio, each with a handset and monopole military antenna.
2) Field Fox Handheld Analyzers with real-time spectrum analyzer that can detect low-level signals as short as 22 ns.
3) Aero flex 3550R with complete RF Receiver Testing down to -125 dBm.

The initial phase in the field was the determination of the test frequency of spectrum accessibility and return loss response of the antenna. Since the timetable was tight, the number of frequency was restricted to three in range of 30MHz-88 MHz band. For explicit frequency ranges are recorded as follows [13]: Low Band: 30 MHz – 47.4 MHz, Mid Band: 47.4 MHz – 67.3 MHz and High Band: 67.3 MHz – 88 MHz. The measurement frequency was a multiband channel sounder operating at center frequency 35.7, 55.3 and 72.9 MHz were chosen. Both transmit and receive antenna had gains approximately -5 dBi, -3 dBi, and -2dBi at 35.7, 55.3 and 72.9 MHz with type of monopole omnidirectional antenna. Coaxial cable used in this measurement form type RG-58, 50-Ohm. The total cable/connector loss was found to be about 2.7 dB at 35.7 Mhz, 3.8dB at 55.3 MHz and 4.8 dB at 72.9 MHz [14].

The work plan might be summed up as follows. Two colleagues stayed in a position within in Radio Lab at Base station and the other pair are at the mobile group. The mobile group will contact to base station to perform the measurement procedure. After getting the radio contact from base station, the mobile group will analyze the signal strength utilize over the air signal quality spectrum analyzer. This procedure will be continued utilizing diverse chosen frequency and different power transmitting which is 0.5 W, 5 W and 10 W. The test signal transmission was done with the handset close to the mouth of operator, who just presses the Push To Talk (PTT) button and addressing affirm the correspondence communication level. Generally, the measurement was transmitted 1220 H until 1515 H at different Substation.

## Path Profile

The measurements have been conducted in suburban area in Kuala Lumpur. The data terrains were collected from 6 substation perform by mobile group will communicate with base station. Before this group will be deployed, a simple analysis on path profile of the every location had to be performed. Path profile will shows signal path by ecosystem or other man made obstacle that can degrade the signal quality by causing phenomena effects of the wave propagation. A path profile provides data of elevation signal form 1 point to another point that interference might occur and tool for selecting a suitable antenna height. This analysis can show clearly the position estimate signal path to facilitate measurement. A brief description of substation and elevation map are provided below.

1) Substation 1 and 2: This is LOS scenario when both Tx and Rx are located near to the base station. For the Substation 1, the distance is 0.7 m and located 50 m from high voltage overhead transmission lines. This station also consists

low–rise building, open field, rifle range and some forest area. While Substation 2 is in hilly ground around 25 m above base station. This station is usually used for relay station because it can give good coverage for this area.

2) Substation 3, 4, 5 and 6: This is NLOS scenario. The Substation usually have their own terrain's characteristic with low rise building, some high rise apartment, open filed, light foliage, some forested area and a few small hill that can be obstacle for radio propagation.

**Path Loss Analysis:**
**Data Processing**

Received Power measurement were taken with spectrum analyzer. The transmitter and receiver consisting of manpack military tactical radio with analog fixed frequency to select the selecting frequency for testing. RF power output for this man pack version is 0.5W, 5W and 10W with sensitivity >22dB for 113 dBm RF Signal. The receiver power was collected for about 30s at every recipient position, with the normal over completely estimated power utilized in path loss calculation.

The location of receiver marks as per path profile before which is the range 0.721 to 3.22 km. The received power spectrum record using spectrum analyzer and reading for each frequency and power

at every location. Overall, for each frequency, power and 6 location data were accessible. Path loss was picked as the analysis parameter and the estimation path loss can be acquired by utilizing count of path loss measure formulae.

The chosen analytical approach comprised a comparison of path losses derived from measurements with path losses determined using an empirical model, which included free space path loss, plane earth path loss, and log periodic path loss with exponent adjustments.

**Measurement Result**

From the result taken, the received power value increases proportional to the distance. There are differences in location substation 1 and 2 which is LOS to the base station. The measurements are quiet difference cause by environment and man-made obstacle such as building and high voltage overhead transmission lines that cause interference in wave propagation. Power received also proportional to the power transmit from 0.5 to 10 W. Increment of power transmission will make higher signal strength. For analysis result, power transmit of 10 W will be used for comparison with empirical model. The summarize received power at the substation are provided in table 2:

**Table 2. Summarize received power.**

| Substation | Received Power (dBm) | | |
|---|---|---|---|
| | Frequency : 35.7 MHz | Frequency: 55.3 MHz | Frequency: 72.9 MHz |
| 1 | -91.59 | -74.95 | -67.11 |
| 2 | -75.84 | -51.98 | -59.88 |
| 3 | -99.62 | -89.11 | -79.98 |
| 4 | -103.37 | -100.97 | -106.67 |
| 5 | -102.5 | -87.72 | -87.44 |
| 6 | -102.27 | -103.40 | -101.14 |

From the result, the frequency band likewise impact with wave propagation. As should be obvious, the higher VHF gives high received power compare to lower VHF. Due to the propagation phenomena effect, the extreme signal is not stable, with signal drop off that is generally seen at higher frequencies being greatly decreased to lower VHF bands. However, at higher frequencies, where the immediate path loss is extremely low, the multipath effect is the primary source of connectivity between a transmitter and a receiver in a certain condition of environment [15, 16].

**Modelling Result**

The path loss values obtained are reproduced in table 3-6 for the frequency of 35.7 MHz, 55.3 MHz and 72.9 MHz respectively. The objective is to make the path loss model

approximate as possible to the measurement path loss. LDPL model is represented to adjust or tuned as close as measured path loss with minimum, average and maximum value It is required to recognize the best path loss exponent, so it tends to be tuned to accomplish least error with the measured data. The path loss exponents calculating for the LDPL models of the 3 frequencies band are tabulated in table 3-5. It is observed that adjusted path loss exponent by LDPL model close to the measured path loss, compared to others models. The FSPL model and PEPL model overestimate the path loss. Comparative outcomes are observed for other frequency band.

1) At frequency 35.7 MHz, all data were within min and max interval for path loss exponent from 3.8 to 4.0. Except for point at 1.09 km

which is at substation 2. The station is on the hilly ground around 25 m higher from base station. This substation and the base station are LOS cause the measure in high signal strength. This Substation 2 modelling shows close to the plane earth path loss model for every frequency that are using for this testing. Compare to Substation 1, even though this station as we can

see on path profile is LOS and the shortest distance 0.721m from base station, but this substation is located about 50m from high voltage transmission line which is probably will give RF interference. Other substations are NLOS and represent average behavior with respect to path loss exponent.

**Table 3. Comparison for various path loss model for frequency 35.7 MHz.**

| station/km | PL measured (dB) | FSPL (dB) | PEPL (dB) | LDPL n=3.8 (dB) | LDPL n=3.9 (dB) | LDPL n=4.0 (dB) |
|---|---|---|---|---|---|---|
| 1/0.72 | 118.89 | 60.65 | 88.30 | 117.80 | 120.97 | 124.13 |
| 5/0.86 | 129.80 | 62.22 | 91.44 | 119.37 | 122.55 | 125.72 |
| 2/1.09 | 103.14 | 64.24 | 95.48 | 121.39 | 124.57 | 127.74 |
| 6/1.70 | 129.57 | 68.10 | 103.20 | 125.25 | 128.42 | 131.60 |
| 3/1.77 | 126.92 | 68.45 | 103.90 | 125.60 | 128.78 | 131.95 |
| 4/3.22 | 130.67 | 73.65 | 114.29 | 130.80 | 133.97 | 137.15 |

2) At frequency 55.3 MHz, all the data were within min and max interval for path loss exponent from 3.4 to 3.6. This frequency band much better from 35.7 MHz with good signal strength and good voice quality at the same distance. Form the Graph, substation 2 also show drop curve due to LOS and terrain effect. Other substations are NLOS and represent average behavior with respect

to path loss exponent. Besides that, the area in substation 3 to 6 is 70 % generally cover by bush and tree canopies about 5-7 meter. It tends to be inferred that the ground reflected exists when the signal going through this region. It is discovered the thought of secondary jungle reflection could lessen total path loss by around to 20-30 dB base on path loss measure.

**Table 4. Comparison for various path loss model for frequency 55.3 MHz.**

| Station/km | PL measured (dB) | FSPL (dB) | PEPL (dB) | LDPL n=3.4 (dB) | LDPL n=3.5 (dB) | LDPL n=3.6 (dB) |
|---|---|---|---|---|---|---|
| 1/0.72 | 105.15 | 64.453 | 88.30 | 111.54 | 114.90 | 118.26 |
| 5/0.86 | 117.92 | 66.025 | 91.44 | 113.11 | 116.47 | 119.83 |
| 2/1.09 | 82.18 | 68.043 | 95.48 | 115.13 | 118.49 | 121.85 |
| 6/1.70 | 133.60 | 71.90 | 103.20 | 118.99 | 122.35 | 125.72 |
| 3/1.77 | 119.31 | 72.26 | 103.90 | 119.34 | 122.70 | 126.06 |
| 4/3.22 | 131.17 | 77.45 | 114.30 | 124.53 | 127.90 | 131.26 |

3) At frequency 72.9 MHz, all the data were within min and max interval for path loss exponent from 3.4 to 3.6. This frequency band much better from 35.7 MHz with good signal strength and good voice quality at the same distance lowers than frequency 55.3 MHz. Form the Graph, substation 2 also show drop curve due to LOS and terrain effect. Other substations are NLOS and represent average behavior with respect to path loss exponent. Besides that, the area in substation 3 to 6 is 60 % generally cover by bush and tree canopies about 5-7 meter. It tends to be inferred that the ground reflected exists when the signal going through this region. It is discovered the thought of secondary jungle reflection could lessen total

path loss by around to 20-30 dB base on path loss measure.

**Table 5. Comparison various path loss model for frequency 72.9 MHz.**

| Station/km | PL measured (dB) | FSPL (dB) | PEPL (dB) | LDPL n=3.4 (dB) | LDPL n=3.5 (dB) | LDPL n=3.6 (dB) |
|---|---|---|---|---|---|---|
| 1/0.72 | 98.31 | 66.85 | 88.30 | 115.64 | 119.13 | 122.61 |
| 5/0.86 | 118.64 | 68.43 | 91.44 | 117.21 | 120.70 | 124.18 |
| 2/1.09 | 91.08 | 70.44 | 95.48 | 119.23 | 122.71 | 126.20 |
| 6/1.70 | 132.34 | 74.30 | 103.20 | 123.09 | 126.58 | 130.06 |
| 3/1.77 | 111.18 | 74.65 | 103.90 | 123.44 | 126.93 | 130.41 |
| 4/3.22 | 137.87 | 79.85 | 114.29 | 128.64 | 132.13 | 135.61 |

**Performance Metrics to Validate the Tuned Results**

The performance of the improved model is assessed by error analysis. The two error metrics measurements utilized are, Mean Square Error (MSE) and Root Mean Square Error (RMSE). The mathematical expressions of these metrics are given by Eq [17, 18].

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left|PL_i^m - PL_i^p\right|$$

(5)

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(PL_i^m - PL_i^p)^2}$$

(6)

where $PL^m$ = measured Path loss (dB), $PL^p$ = Predicted Path loss (dB) and n = Number of measured data points

The measured path losses are difference with the FSPL, PEPL and prediction LDPL models. By comparing the measured with theoretical path loss from FSPL, PEPL and path loss exponents using LDPL that found to be the most appropriate expectation model. In order to have better prediction exactness, the parameters of this model are balanced close to measure path loss. The results of error metrics are calculated in Tables 6.

**Table 6. Error Matrics table.**

| f (MHz) | Model | MSE (dB) | RMSE (dB) |
|---|---|---|---|
| 35.7 | FSPL | 56.94 | 57.62 |
| | PEPL | 23.73 | 25.69 |
| | LDPL n:3.8 | 5.92 | 8.79 |
| | LDPL n:3.9 | 6.18 | 9.41 |
| | LDPL n:4.0 | 7.91 | 10.96 |
| | Average LDPL | 6.67 | 9.72 |
| | | | |
| 55.3 | FSPL | 44.87 | 47.36 |
| | PEPL | 15.45 | 20.85 |
| | LDPL n:3.4 | 10.90 | 15.31 |
| | LDPL n:3.5 | 10.90 | 16.15 |
| | LDPL n:3.6 | 11.57 | 17.59 |
| | Average LDPL | 11.1263 | 16.35 |
| | | | |
| 72.9 | FSPL | 42.48 | 44.73 |
| | PEPL | 15.47 | 19.65 |
| | LDPL n:3.4 | 12.94 | 15.36 |
| | LDPL n 3.5 | 13.63 | 17.09 |
| | LDPL n 3.6 | 14.79 | 19.30 |
| | Average LDPL | 13.79 | 17.25 |

The results show the least value indicate for the tuned path loss exponent from LDPL compared to other models. From the table 5, it is clear that tuned path loss exponent from LDPL has the best performance in dedicated frequency in range of suburban path loss exponent as it has the least MSE and RSME, followed by PEPL. From the curve of graph xyz, PEPL is suitable for LOS short distance communication the curve has minimum error to measure path loss. Overall, customized path loss from LDPL is the best estimation method for better signal quality since it has the least average MSE and RSME of each frequency band, which is the least among other empirical models for the selected suburban region.

## Conclusion:

In this paper, the performance is obtained from different path loss model with measured data for the best suited path loss model. The path loss exponent for LDPL for frequency band 35.7 MHz, 55.3 MHz and 72.9 MHz are the best performance compare to other models in the suburban region. The experimentally result collected from received power and predicted by empirical model such as FSPL model, LDPL model and PEPL model. The comparison between the models are discussed to identify the suitable model. LDPL model is observed as the suitable model with tuned the path loss exponent in suburban environment. The tuned model is compared with others empirical model in terms of MSE and RSME. From the general error analysis, it is seen that, the performance of the LDPL with adjusting path loss exponent is the suitable model since it has least value of error metrics. Model LDPL with adjusting path loss exponent is more accurate for estimation method than other models for better signal quality, according to this study. This model will be able to manage the VHF communication problem throughout the operation, starting with initial mapping to estimate range before the actual deployment. Analysis for quasi-simultaneous mobility in digital modulation can be done in the future.

## Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- The author has signed an animal welfare statement.
- Ethical Clearance: The project was approved by the local ethical committee in University of Teknologi MARA Shah Alam.

## Authors' contributions:

Hafizi Halim and Azita Laily Yusof did conception, design, acquisition of data, analysis, interpretation and drafting the MS while revision and proofreading done by Norsuzila Ya'acob and Nur Haidah Mohd Hanapiah to the writing of the manuscript.

## References:

1. M. C. S. Forbes, F. Leavenworth, M. Christopher, S. Forbes, and U. S. Army, "In Order to Win , Learn How to Fight : The US Army in Urban Operations A Monograph by School of Advanced Military Studies."
2. N. Faruk, S. I. Popoola, and N. T. Surajudeen-bakinde, "Path Loss Predictions in the VHF and UHF Bands Within Urban Environments : Experimental Investigation of Empirical , Heuristics and Geospatial Models," IEEE Access, vol. 7, pp. 77293–77307, 2019.
3. J. Andrusenko, R. L. Miller, J. A. Abrahamson, N. M. Merheb Emanuelli, R. S. Pattay, and R. M. Shuford, "VHF general urban path loss model for short range ground-to-ground communications," IEEE Trans. Antennas Propag., vol. 56, no. 10, pp. 3302–3310, 2008.
4. P. K. Sharma and R. K. Singh, "A Modified Approach to Calculate the Path Loss in Urban Area," vol. 4, no. 4, pp. 453–460, 2011.
5. M. Suchanski, P. Kaniewski, R. Matyszkiel, and P. Gajewski, "Prediction of VHF and UHF wave attenuation in urban environment," 2012 19th Int. Conf. Microwaves, Radar Wirel. Commun. MIKON 2012, vol. 1, pp. 60–65, 2012.
6. Y. Zakaria and L. Ivanek, "Propagation Modelling of Path Loss Models for Wireless Communication in Urban and Rural Environments at 1800 GSM Frequency Band Models," pp. 139–144, 2016.
7. Y. S. Meng, Y. H. Lee, and B. C. Ng, "Empirical near ground path loss modeling in a forest at VHF and UHF bands," IEEE Trans. Antennas Propag., vol. 57, no. 5, pp. 1461–1468, 2009.
8. L. Alberto and R. Ramirez, "Analysis of ITU-R VHF / UHF propagation prediction methods performance on irregular terrains covered by forest," vol. 12, pp. 1450–1455, 2018.
9. F. A. Almalki and P. Sciences, "Optimisation of a Propagation Model for Last Mile Connectivity with Low Altitude Platforms using Machine Learning," no. December, 2017.
10. W. Debus, "RF Path Loss & Transmission Distance Calculations By Director of Engineering," 2006.
11. H. Abdullah et al., "An efficient algorithm for larg-scale RFID network planning," no. September, 2019.
12. E. Bedeer, J. Pugh, C. Brown, and H. Yanikomeroglu, "Measurement-Based Path Loss and Delay Spread Propagation Models in VHF / UHF Bands for IoT Communications," pp. 5–9, 2017.
13. P. J. Vigneron and J. A. Pugh, "PROPAGATION MODELS FOR MOBILE TERRESTRIAL VHF COMMUNICATIONS," 2008.
14. J. Andrusenko, "Operations methods," 2004.
15. F. T. Dagefu, J. Choi, M. Sheikhsofla, B. M. Sadler, and K. Sarabandi, "Performance assessment of lower VHF band for short-range communication and geolocation applications," Radio Sci., vol. 50, no. 5,

pp. 443–452, 2015.

16. X. Zhang, S. Member, T. W. Burress, K. B. Albers, and B. William, "Propagation Comparisons at VHF and UHF Frequencies," pp. 245–248, 2009.

17. B. Sridhar, M. Zafar, and A. Khan, "RMSE comparison of Path Loss Models for UHF / VHF bands in India," pp. 330–335, 2014.

18. W. Channel and P. Characteristics, "Wireless Channel Propagation Characteristics and Modeling Research in Rice Field Sensor Networks," pp. 1–17, 2018.

## تحليل أداء الانتشار في نظام الاتصالات التكتيكية العسكرية VHF

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كلية الهندسة الكهربائية ، كلية الهندسة اونيزرسيتي تيكنولوڬي مارا شاه عالم، سيلانجور، ماليزيا

**الخلاصة:**

يتمثل التحدي الرئيسي لأنظمة الاتصالات التكتيكية العسكرية في إمكانية الوصول إلى المعلومات ذات الصلة حول بيئة التشغيل الخاصة المطلوبة لتحديد الاستخدام المثالي لشكل الموجة. يركز نموذج الانتشار الحالي بشكل أساسي على البث والاتصالات اللاسلكية التجارية باستخدام هوائي جهاز إرسال واستقبال عالي الارتفاع غير مناسب للعديد من أنظمة الاتصالات التكتيكية العسكرية. تقدم هذه الورقة دراسة لنموذج خسارة المسير المتعلق بمظهر الانتشار الراديوي داخل الضواحي في كوالالمبور. تم جمع نمذجة خسارة المسير التجريبية لانتشار الموجات المترية (VHF) من إعدادات الضواحي المختلفة لمدى التردد 88-30 MHz. تأثرت هذه التجربة بشدة بالعوامل البيئية وتأثيرات انتشار الموجات الحالية مثل الانعكاس والحيود والتشتت وتأثير دوبلر. يتم تقييم أداء الانتشار الراديوي من خلال جمع القدرة المستلمة في المحطة الفرعية المخصصة ومقارنتها مع نماذج الانتشار الحالية. كما سيتم ضبط نموذج الانتشار الحالي بالقرب من قيمة القياس عن طريق تحديد الأس الأفضل لخسارة المسير لتنفيذ نموذج مناسب لمنطقة الضواحي. تُظهر التقييمات والتحليلات النظرية لمرحلة القياس الأولية للانتشار الراديوي المساهمة الواسعة للمجال الراديوي من العوائق المحتملة عند ترددات VHF المنخفضة لكل من النطاقات القصيرة والمتوسطة هناك. يشير التفسير إلى نماذج التنبؤ بالانتشار الراديوي القياسية المعقولة عمومًا لمنطقة الضواحي. من تحليل الخطأ العام ، يتضح أن أداء LDPL مع تعديل أس خسارة المسار هو النموذج المناسب لأنه يحتوي على أقل قيمة لمقاييس الخطأ.

**الكلمات المفتاحية:** خسارة الانتشار ، الضواحي، الراديو التكتيكي، VHF.