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Modelling of Foliage Effects for Radio Military Application in Tropical Forest

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In recent years, military radio is used for the military communication system in the tropical forest. This military radio is using Very High Frequency (VHF) spectrum which the frequency range is from 30 MHz to 300 MHz and also Ultra High Frequency (UHF) spectrum which the frequency range is from 300 MHz to 3 GHz. This research will be focuses on the vegetation effects that influence the signal strength and signal loss of the radio in the forest and to overcome the problem of radio's signal strength that faced by most of the military. The measurements was conducted in the tropical forest in Malaysia. First of all, simulation of the measurement setup was calculated using a special military HTZ software. Then the measurement was setup and the signal strength was measured from the various distance at foliage area. Then the data was collected and analyzed before proposing a new vegetation model regarding radio military application system in VHF and UHF spectrum. There are three objectives of this research. The first one is to study the communication propagation effects for VHF an UHF bands in tropical forest. The second one is to measure the value of vegetation or foliage loss at tropical forest for VHF and UHF radio and lastly is to develop a model for foliage effect in VHF and UHF frequency. The result of this analysis is very important to the military since this project are collaborating with Science Technology Research Institute for Defense (STRIDE). Besides, other researcher who are doing the same research that meet the condition of this research also can benefit the vegetation model proposed later in this project.

Keywords: UHF, VHF, Foliage effects, forest.

1. Introduction

In Malaysia, military radio is used for the military communication system in the tropical forest. This military radio is in Very High Frequency (VHF) spectrum and Ultra High Frequency (UHF) which the frequency range is from 30 MHz to 300 MHz and 300 MHz to 3GHz respectively, VHF and UHF is two of the most common frequency range that is used nowadays [1]. Besides military application, it is also applied in medical system and FM radio transmission [1]. However, there are some vegetation effects that can influence the data and result of the wireless transmission in the forest thus can lead to a disturbance in the military communication. Malaysian Communications and Multimedia Commission (MCMC) has allocated many range of frequencies for each type of application such as Low Frequency (LF), Medium Frequency (MF), High Frequency (HF) and many more [1]. However, this project just focused on the Very High Frequency (VHF) and Ultra High Frequency (UHF) because military communication system is applied in these two spectrums. There are many types of forest in this world such as temperate deciduous forest, temperate coniferous forest, boreal forest and tropical forest. In this project, our scope is only tropical forest because all forests in Malaysia are tropical [2]. This research is focused on the measurement of the signal strength of VHF and UHF frequency in tropical forest and the value of the fade margin.

2. Methodology

A. Software simulation

Before starting to setup the equipment and undergo the experiment at the forest chosen, the place chosen is simulated using the HTZ warfare software as shown in figure 1 and 2.

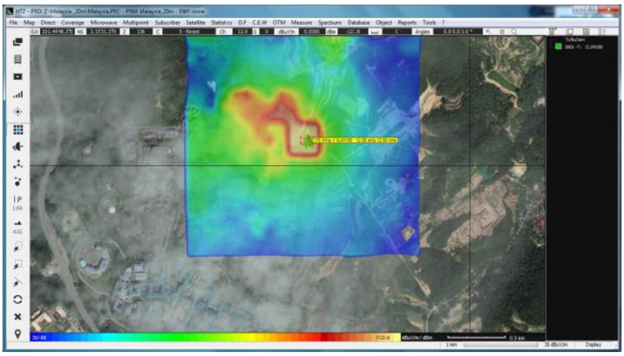

Figure 1: HTZ warfare simulation

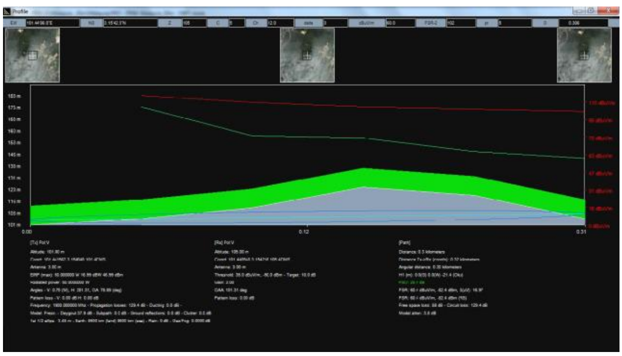

Figure 2 : HTZ warfare simulation's details.

B. Hardware measurement

As displayed in figure 3, in the left hand side (LHS) is the device that used to transmit the signal, which are the Fujian Quanzhou antenna, VHF dual band mobile transceiver, portable generator and portable spectrum analyzer. At the right hand side (RHS) is the devices that will be carried deep into the forest to receive the signal which are Rohde & Schwarz R&SHE400VHF antenna, portable spectrum analyzer and Yaesu portable radio

Figure 3: Measurement setup at the Bukit Beruang Forest

After done with the setup the experiment, the data is collected. First of all, we walked into the forest and stop for each 100m, this means it have five checkpoints which are 100m, 200m, 300m, 400m and the last one is 500m deep in the forest. The important information that been measured are the distance, latitude and longitude using the GPS reader. Then in each checkpoint, the temperature and humidity of the forest will be measured using Humidity meter. Next, the signal strength is measured by using the radio, antenna and read the result from the spectrum analyzer for each 100m.

For the data analysis of this project, the received power of the signal or signal strength has been collected using spectrum analyzer. The data collected is then analyzed in terms of signal strength and distance, theoretical and calculated path loss and then the new vegetation model for VHF and UHF that suitable for this kind of distance and type of forest is proposed.

3. Results and Discussion

Table 1 & 2 shows the results of the HTZ simulation at certain distance and location. As displayed in table 1 and 2, there are some important information that can be extracted from the simulation. Besides the exact distance, the simulation also informs about the exact latitude and longitude of the test point. Next important information is the Equivalent Isotropically Radiated Power (EIRP) which basically is the sum of the transmit power and transmit gain. The simulation also displayed the propagation or path loss which is one of the most important information in this project. Path loss is the total loss or attenuation of the signal strength through the project [9]. Last important information displayed is the free space loss, free space loss is basically the loss or attenuation of the signal strength when it travel through free space [9]. After these information are considered, the foliage or vegetation loss can be calculated as using the formula that will be shown.

Table 1:Simulation Result of HTZ in VHF (149.95MHz)

Distance (km)	Latitude	EIRP (dBW)	Received Power (dBW)	Path Loss (dB)	Free Space Loss (dB)
0.10	3º 14.599’ N 101º 44.286’ E	21.99	-59.51	81.50	55.00

0.20	3º 14.549'E 101º 44.263'	21.99	-71.31	93.30	61.00
0.30	3º 14.533' E 101º 44.195' N	21.99	-98.51	120.50	66.00
0.40	3º 14.483' E 101º 44.170' N	21.99	-104.11	126.10	69.00
0.50	3º 14.431' N 101º 44.158' E	21.99	-104.91	126.90	70.00

Table 2: Simulation Result of HTZ in UHF (450MHz)

Distance (km)	Latitude	EIRP (dBW)	Received Power (dBW)	Path Loss (dB)	Free Space Loss (dB)
0.10	3º 14.599' N 101º 44.286' E	21.99	-52.01	74.00	64.00
0.20	3º 14.549' N 101º 44.263' E	21.99	-71.31	93.30	70.00
0.30	3º 14.533' N 101º 44.195' E	21.99	-103.21	125.20	75.00
0.40	101º 44.170' E	21.99	-108.91	130.90	78.00
0.50	3º 14.431' N 101º 44.158' E	21.99	-109.61	131.60	79.00

Table 3 that shows the data collection of measurement for UHF and VHF spectrum.

Table 3: Measurement at UHF frequency

Distance (km)	Latitude	Received Power (dB) Low Medium High Pt=5.30 dB Pt=18.30 dB Pt=25.50 dB	Free Space Loss (dB)
0.10	3º 14.599' N 101º 44.286' E	-75.50 -69.80 -67.50	55.97
0.20	101º 44.263' E	-95.40 -90.80 -88.20	61.99
0.30	3º 14.533' N 101º 44.195' E	-99.30 -94.40 -92.20	65.51
0.40	3º 14.483' N 101º 44.170' E	-110.30 -105.20 -102.80	68.01
0.50	3º 14.431' N 101º 44.158' E	-118.40 -114.70 -111.40	69.95

Table 4: Measurement at VHF frequency

Distance (km)	Latitude	Received Power (dB) Low Medium High Pt=5.30 dB Pt=18.30 dB Pt=25.50 dB	Free Space Loss (dB)
0.10	3º 14.599' N 101º 44.286' E	-84.80 -79.30 -75.80	65.51
0.20	101º 44.263' E	-109.80 -99.40 -91.70	71.53
0.30	3º 14.533' N 101º 44.195' E	-113.40 -106.10 -102.90	75.06
0.40	3º 14.483' N 101º 44.170' E	-120.20 -113.30 -109.30	77.56
0.50	3º 14.431' N 101º 44.158' E	-133.50 -125.60 –122.50	79.49

As displayed in Table 3 and 4, the important data that have been collected and needed to do the modelling is the received power within three level which are low transmit power, medium transmit power and high transmit power. However, later in the comparison and modelling the one that used is just the low transmit power model to ensure incase if the minimum power use in real environment. Table 4.5 and 4.6 displayed all the losses that involved in this project for VHF and UHF respectively. The losses involved are path or propagation loss, free space loss and foliage loss. For measurement and calculation, the value of path loss, free space loss and foliage loss was calculated by using this formula;

Path loss: $Pl = Pt + G - Pr$ (1)

Free space loss: $FSl = 32.45 + 20 log 10 d + 20 log 10 f$ (2)

Foliage loss: $Fl = Pl - FSl$ (3)

Where;

Pl = Path Loss in dB

G = Gains in dB

Pt = Transmit Power in dB

Pr = Received Power in dB

Fl = Foliage Loss in dB

FSl = Free Space Loss in dB

d = Distance in km

f = Frequency in MHz

Table 5 : Loss analysis for VHF (149.95MHz)

Distance (km)	Path Loss (dB)		Free Space Loss (dB)		Foliage Loss (dB)	
	Measure	Simu	Measure	Simu	Measure	Simu
0.1	80.80	81.50	55.97	55.00	24.83	26.50
0.2	100.70	93.30	61.99	61.00	38.71	32.30
0.3	104.60	120.50	65.51	66.00	39.09	54.50
0.4	115.60	126.10	68.01	69.00	47.59	57.10
0.5	123.70	126.90	69.95	70.00	53.75	56.90

Table 6: Loss analysis for UHF (450MHz)

Distance (km)	Pat Loss (dB)		Free Space Loss (dB)		Foliage Loss (dB)	
	Measure	Simulation	Measurement	Simulation	Measurement	Simulation
0.1	90.10	74.00	65.51	64.00	24.59	10.00
0.2	115.10	93.30	71.53	70.00	43.57	23.30
0.3	118.70	125.20	75.06	75.00	43.64	50.20
0.4	125.50	130.90	77.56	78.00	47.94	52.90
0.5	138.80	131.60	79.49	79.00	59.31	52.60

This subsection will compare this project's measurement and simulation path loss with the other three foliage model's path loss which are Weissberger, COST235 and Joshi model. As displayed in table 7 and 8 are the path loss for all the models involved for VHF and UHF respectively. The formula used for the calculation are:

Model	Expression
Weissberger[10]	$L(dB)=1.33f0.284df0.588$ (4)
COST235 Model[9]	$L(dB)=26.6f-0.2df0.5$ $(With\ foliage)$ (**5**) $L(dB)=15.6f-0.009df0.26$ $(Without\ foliage)$ (6)
Joshi Model [13]	$L(dB)=2.7+45.4\log10d$ (VHF) (7) $L(dB)=-86.5+95.4\log10d$ (UHF) (8) $L(dB)=-33.2+81.2\log10d$ $(UHF\ Wet\ Foliage)$ (9)

Table 7: Path Loss model comparison for VHF(149.95MHz)

Distance (km)	Measurement (dB)	Simulation (dB)	Weissberger (dB)	COST235 (dB)	Joshi (dB)
0.1	80.80	81.50	82.76	97.65	93.50

0.2	100.70	93.30	124.40	138.10	107.17
0.3	104.60	120.50	157.89	169.14	115.16
0.4	115.60	126.10	187.00	195.31	120.83
0.5	123.70	126.90	213.21	218.36	125.23

Table 8: Path Loss model comparison for UHF (450MHz)

Distance (km)	Measurement (dB)	Simulation (dB)	Weissberger (dB)	COST235 (dB)	Joshi (dB)
0.1	90.10	74.00	113.07	78.39	104.30
0.2	115.10	93.30	154.00	110.85	133.02
0.3	118.70	125.20	183.73	135.77	149.82
0.4	125.50	130.90	204.49	156.77	161.74
0.5	138.80	131.60	211.31	175.28	170.98

Figure 4 and 5 shows the graph of distance vs path loss for VHF and UHF respectively. As displayed, for all models, the path loss is increasing with the increase of the distance. This proved this project's statement which is the longer the distance, the higher the path loss which makes the received power becomes lower. This is based on the path loss formula that already been showed at the early part of this section. The trend for all models is quite equal but the value is different due to the condition of the forest that being experimented.

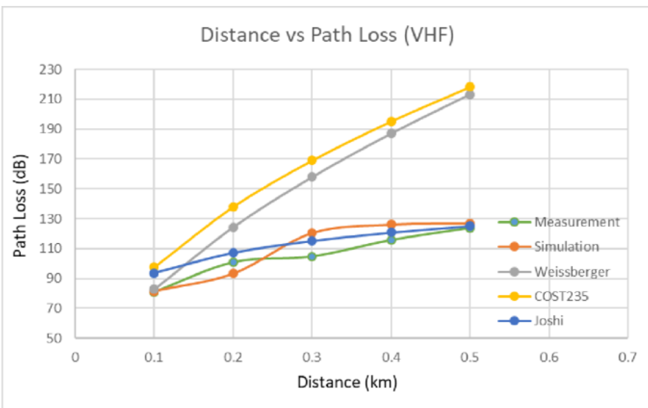

Figure 4: Comparison with other models Foliage Effects at VHF

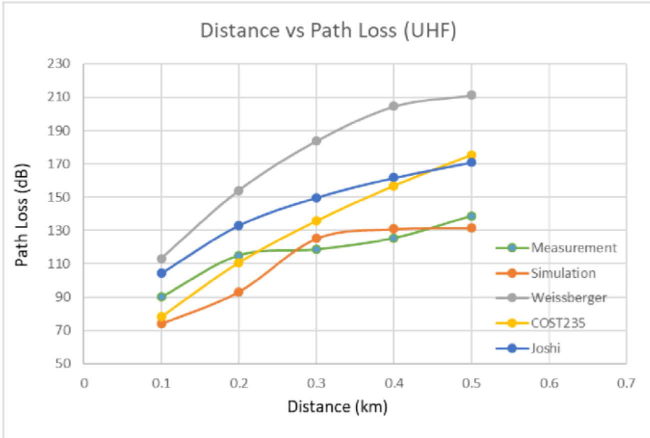

Figure 5: Comparison with other models Foliage Effects at UHF

4. Propose Foliage Model

For a detail explanation, the value of the foliage loss is gradually increase when the distance increase for both VHF and UHF as displayed in table 5 & 6 and Figure 4 & 5. This is merely because they are more vegetation depth when the experiment is implemented deep in the forest. In the other words, the longer the distance, the higher the depth vegetation hence automatically the higher the vegetation loss. In the case of frequency, the foliage loss for UHF (450 MHz) is slightly higher that the foliage loss for VHF (149.95 MHz). This is because the higher the frequency of the signal, the smaller the wavelength because the frequency and wavelength of a signal is inversely proportional. The relation is gain from formula

$\lambda = c/f$ [14],

which λ is the signal wavelength in meter, f is the signal frequency in Hz and c is the constant speed of light which is 299 792 458 m/s[14]. Hence, signal in UHF have lower wavelength compared to signal in VHF. The lower signal wavelength will make it hard to pass through the trees and leaves thus resulting in higher foliage loss compared to signal in VHF. In the end of this research, new model was proposed as a vegetation or foliage model in the tropical forest, which is the formulation is:

$$Fl = 2.7489 \ln(f) + 27.016 \quad (10)$$

Fl = Foliage Loss in dB

f = Frequency in MHz

By using this new proposed vegetation model, data of the new foliage loss can be collected in any range of spectrum or frequency. However, this model is only valid in the tropical forest due to the different condition trees and leaves in the different types of forest.

5. Conclusion

The communication propagation effects for VHF and UHF at tropical forest have been studied and the new vegetation model for the tropical forest have been proposed after thorough research and comparison were implemented between this project (simulation and measurement) with the other vegetation models such as Joshi, COST235, Weissberger and others.

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