OPTIMUM PARAMETER ANALYSIS OF MICROAVE LINK DESIGN IN SRI LANKA

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ABSTRACT

Among the technological developments in the recent past, microwave wireless communication takes the main attention nowadays. Development of technology has not led only to good performance, but also to a series of new optimization problems due to complexity of interconnected theories and standards used worldwide in common without sufficient feasibility studies on specific empirical models. In Sri Lanka, the interest in feasibility studies on microwave empirical links is yet to be improved as the whole island is counted under one specific ITU (International Telecommunication Union) region, and the factors that directly affect the performance of the channel because of variations in climate and geography within the country are often neglected. This particular research gives an overall idea about tuning parameter values of microwave link designs based on an analysis, with reference to the microwave communication system at Upper Kotmale Hydropower Project. The study mainly focuses on link performance in mountainous area with low humidity, frequent rainy conditions and across water paths. This analysis with comparison to actual results under the special climate and geographical area helps to predict the link performance in other system designs in similar conditions in the future. In fact, this could be referred to make necessary changes in current standard values in design procedure, i.e. constants depending on the ITU region, and then, to achieve optimum performance effectively.

***Key words*:** Microwave link, Wireless communication, Link optimization, Parameter tuning, Line of sight.

1. INTRODUCTION

Microwave communication links are becoming increasingly popular among wireless data transmission systems in broadcasting/ unicasting/ multicasting applications whose extracting predictable performance is notoriously hard. In process of optimization, there are many uncertain factors to be focused on, depending on the specific geographical area and climate. To keep the link in good condition and or to have betterment in future implementations or replacements, optimization has to be performed continually and frequently. To reach the maximum performance, parameters that affect the link must be tuned till it reaches the optimum result, considering and comparing each and every parameter with one another. References could be used to make decisions in initial planning and designing as well.

The main objective of this research is to make an initial reference for future implementations under similar and also rare conditions in the island by analyzing a real link theoretically and practically. For that, the communication link in Upper Kotmale Hydropower Project was considered which is used to communicate between the power station site (Upper Kotmale) and the dam site (Talawakelle), approximately 13km apart from distance how line of sight is gained via a passive repeater (Gongalla) because the actual displacement has been obstructed by mountains.

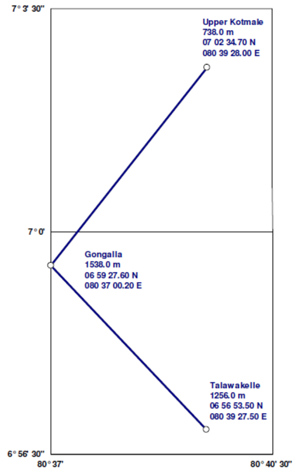

Figure 1: Network topology of UKHP's link [1]

The research covers the key objectives,

- Application of mathematical and computer based models for solving problems in communication engineering;
  - Theoretical formulas of signal propagation
  - Tower height analysis
  - Path loss and power budget calculation
  - Fade margin calculation
- Assessment of limitations of particular cases;
  - BER (Bit Error Rate) analysis with sudden climate changes
  - Transmitter power limitations
  - Transmitter and receiver gain limitations
  - Line of sight issues
  - Diversity analysis with combining methods
- Understanding of concepts from outside engineering disciplines and effective application;
  - Path loss variations with rainfall pattern and climate changes

In fact, the link was designed to work in duplex mode. The frequencies used for the two directions are [2],

- Direction A (8363MHz);

From Upper Kotmale (power station) to Gongalla (repeater) to Talawakelle (dam)

- Direction B (8482MHz);

From Talawakelle (dam) to Gongalla (repeater) to Upper Kotmale (power station)

Table 1: Frequency allocation of the link

Item	Frequency
Band	8GHz
Transmitter - receiver spacing	119MHz
Bandwidth	7MHz

2. METHODOLOGY

Firstly a general analysis in microwave communication took place theoretically. Secondly the actual link was analyzed to check the expected results. At last, practical results were compared with each other to come to conclusions.

2.1. Theoretical Analysis

The microwave spectrum consists frequencies from 30GHz to 300GHz. In general, frequencies between 3GHz to 60GHz are mostly taken for typical microwave communications. These links are used in terrestrial point to point communication mostly though points to multi point networks also exist.
The choice for microwave when it comes with data communication is because of several advantages over other communication mediums (Infrared, optical fibre cables and etc.) [3];

- Travels longer distances compared to other available mediums.
- Installation is easier (single point installation).
- Simple to maintain.
- High data rates are possible.
- Less affected by natural calamities.
- Less prone to accidental damage.
- Single point security.
- Links across mountains and rivers are more economically feasible.

On the other hand, the following problems may have to be faced;

- Seriously affected by rain (fading of the link increases and there would be a possibility for total loss of the link).
- Line of sight is strictly required.
- Difficult to use within areas where climate is rapidly changed.
- The link may lose due to duct.
- Length of the link is also limited with the frequency band used.

In addition, bandwidth assignment which is closely related to network capacity planning is a highly specified task as it plays a critical role to avoid interference within one's own network and between other operators' networks. For that, TRC (Telecommunications Regulatory Commission) specifies ranges for a particular company or sector.

Basically a typical microwave system consists of main three parts such as IDU (InDoor Unit), ODU (OutDoor Unit) and antenna [3]. However, because of reflection, refraction and diffraction issues, sometimes transmitted power may not be detected sufficiently at the receiver end.There are several terminologies used for design of a specific link. Some of those are;

- Link power budget

$$P_{RX} = P_{TX} - L_{TX} + G_{TX} - L_{PL} + G_{RX} - L_{RX} \quad (1)$$

Where,

P_{RX} - Received signal level (dBm)

P_{TX} - Transmitter output power (dBm)

L_{TX} - Transmitter losses (dB)

G_{TX} - Transmitter antenna gain (dBi)

L_{PL} - Total path loss (dB)

G_{RX} - Receiver antenna gain (dBi)

L_{RX} - Receiver losses (dB)

- Free space loss

$$L_{FSPL} = 92.4 + 20log_{10}f + 20log_{10}d \quad (2)$$

- Fresnel zones
- Modulation scheme
- Diversity
- Antenna gain
- Tower height
- Fading probability

$$P_r = K\, Q\, \frac{W}{W_0}\, f^B\, d^C \quad (3)$$

Where,

P_r - Fading probability

K, B, C- Constants depend on ITU regions

Q - Terrain factor

f - Frequency (GHz)

d - Path length (km)

W - Received power in fading condition

W_0 - Received power in non-fading condition

- Path reliability

$$PR = \frac{P_r}{f_d'} \quad (4)$$

Where,

PR - Path reliability

f_d' - Fade margin (W)

- Fade margin

$$f_d = Link\ budget - Threshold\ level \quad (5)$$

- Path unavailability
- Required SNR (Signal to Noise Ratio)
- Other losses connected with the system
- Line loss, connector loss and etc.

2.2. Actual Link Analysis

There were assumptions made by the contractors for link budget calculations and path profile analysis such that [1];

- An average annual temperature of 30^0C.
- Rain attenuation based on ITU region P.
- 60% of 1st Fresnel zone, 100% of 2nd Fresnel zone.
- Heights of self supports are 15m.
- Frequency is the middle between transmit and receive frequencies.

Table 2: Calculation results by UKHP contractors

Parameter	Value		Unit
	Direction A	**Direction B**	
Noise figure	6	6	dB
Noise bandwidth	3.6	3.6	MHz
T_X output power	23	23	dBm
T_X branching loss	3	3	dB
T_X feeder & losses	0.5	0.5	dB
T_X antenna gain	45.5	45.5	dB
FSPL in hop #1	128.1374636	128.260187	dB
Repeater gain	90.43	90.43	dB
FSPL in hop #2	127.1720679	127.2947914	dB
R_X antenna gain	45.5	45.5	dB
R_X feeder & losses	0.5	0.5	dB
R_X branching loss	3	3	dB
R_X input level	(-57.87953149)	(-58.12497835)	dBm
P_m	(-102.436975)	(-102.436975)	dBm
P_r	1.07E-02	1.09E-02	
C/N thermal:1E-03	16.6	16.6	dB
Threshold: 1E-03	(-85.83697499)	(-85.83697499)	dBm
Fade margin: 1E-03	27.9574435	27.71199665	dB
Path reliability: 1E-03	1.71E-05	1.84E-05	
C/N thermal: 1E-06	20	20	dB
Threshold: 1E-06	(-82.43697499)	(-82.43697499)	dBm
Fade margin: 1E-06	24.5574435	24.31199665	dB
Path reliability: 1E-06	3.75E-05	4.03E-05	

In the analysis, it was found that W/W_0 ratio for calculations has been taken as 1 by the contractors. According to (3), the ratio can never become 1 practically as it is a comparison between fading and non-fading conditions' values. Thus this neglected condition had already added an error in calculation process.

What is more, the tower height used here is 15m that is normally used for long distance transmission according to ITU specifications [4], i.e.32km. Since one line of sight in UKHP belongs to short distance propagation which does not exceed 7km, it would probably have been enough with considerably a lower height.

However, recalculation was done regarding each parameter in the table 2 with the use of formulas in section 2.1 while considering above mentioned ignored conditions and situations.

3. RESULTS

For optimization, new values got in recalculation process and test results obtained by test equipment were used to make comparisons.

First and foremost, values for W/W_0 ratios were calculated considering the receiver level and threshold level in fading conditions for both directions. As example;

Direction A,

$$\frac{W}{W_0} = \frac{-85.836975}{-57.8795315}$$

Thus the values became 1.4830 and 1.4768 respectively in each use case instead of 1.000.

In Fresnel zones and free space losses calculations, there was no any significant issue other than slight variations in decimal points, but there were several effects on other parameters such as fade margin, fading probability, path reliability, link budget, transmit power and receive level due to arithmetic errors in design process and test results not satisfying the expected results under real environment and climate conditions.

For fade margin, both (4) and (5) formulas can be used. However there were 2.372W to 9.437W differences in calculations when compared to each other under both BERs for both directions due to the neglected real W/W_0 ratio, thus path reliability value has been dramatically affected and in chain manner other parameters have been affected.

The *test data* was recorded *during mid-July in 2012*. MatLab software was used to plot test values versus specific parameters in a range of values.

The graphs shown below title followed by Figure 2 are in accordance to practical data. Although linearity is expected theoretically (Figure 3), slight variations can be seen in real conditions.

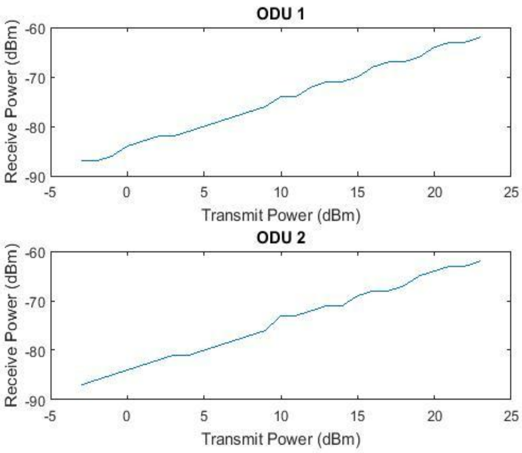

Figure 2: Transmit and receive power in practical

The comparison could be made with regard to specified transmit value, how receive value would have been theoretically and practically with the use of Figure 2 and Figure 3.

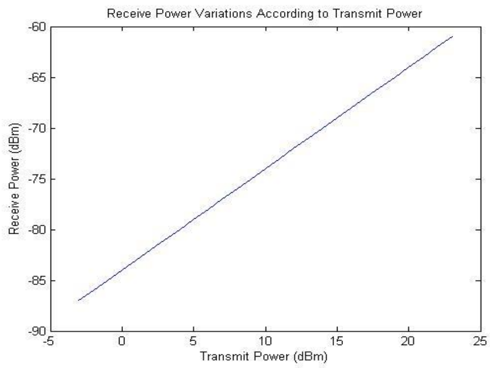

Figure 3: Expected transmit power and receive power

The same way like in Figure 4, the receiver level in Talawakelle was plotted.

On the other hand, the minimum receive level is (-68)dBm and the maximum is (-61dBm) according to test data.

Thus, $f_{d_{actual}} = (-61) - (-68)$

$$= 7\ dB$$

Table 3: Receive level in Upper Kotmale site

Date at 00:00:00h	R_X Maximum (dBm)	R_X Minimum (dBm)
16-07-2012	-61	-64
17-07-2012	-61	-64
18-07-2012	-61	-64
19-07-2012	-62	-64
20-07-2012	-61	-64
21-07-2012	-61	-64
22-07-2012	-62	-64
23-07-2012	-62	-66
24-07-2012	-62	-68
25-07-2012	-62	-66
26-07-2012	-62	-68
27-07-2012	-62	-65
28-07-2012	-62	-64
29-07-2012	-61	-64
30-07-2012	-61	-64
31-07-2012	-61	-64

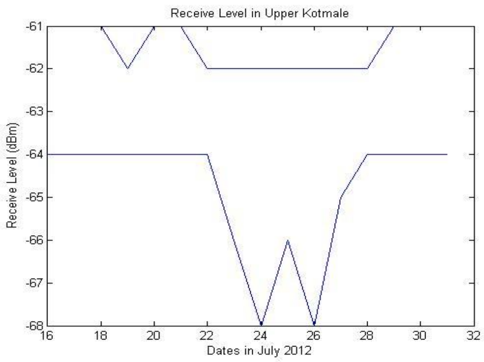

Figure 4: Receive level in Upper Kotmale site

As the actual fade margin in practical is very less than expected values, there is a clue that the transmit power can be further reduced.

For BER 1E-3,

$$R_X' = (-85.836975) - (-7)$$
$$= (-78.836975)dBm$$

Because the maximum receive level practically got is (-61)dBm;

$$T_X' = 23 - [(-61) - (-78.836975)]$$
$$= 5.163\ dBm$$

This gives 18dB or 17dB reduction of used transmits power.

Moreover, it is sensitive enough to detect the minimum power of (-102.436975)dB at receiver end. Also, it is possible to receive until (-85.836975)dBm without any failure and sufficient receive level is (-78.836975)dBm as well. Therefore it reduces approximately 20.96dBm.

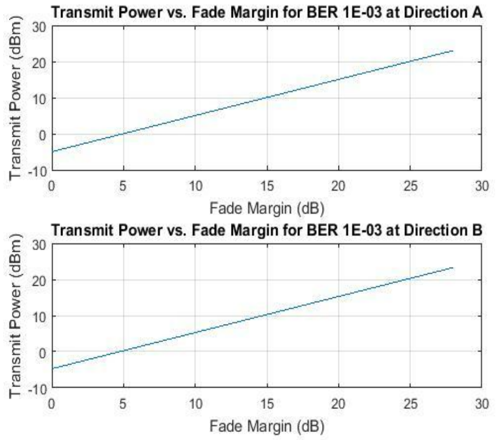

Figure 5: Transmit power vs. fade margin for BER 1E-3

Similar shaped curve like in Figure 5 could have been seen for BER 1E-06 as well.

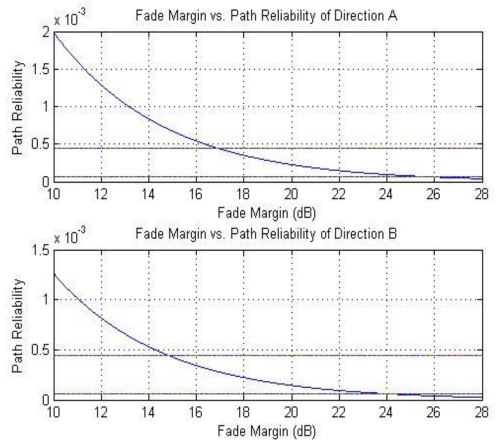

Figure 6: Fade margin vs. path reliability

4. CONCLUSION

For link optimization, analysis of theories, actual link and practical results were a combination in this research.

In design process, significant calculation errors were found due to ignorance of actual W/W0 ratio that has affected fading probability and path reliability straightaway. However it proved neglecting some factors without a proper reason would cause to false results and thus it has huge risk of link failures and incorrect messages to be transmitted. On the other hand, it is a progress in history that ITU region P has been considered by the contractors for Fresnel zone calculations considering rain attenuation specifically in the area though Sri Lanka belongs to ITU region N as whole.

When it comes with practical data for fade margin, it proved that practically required fade margin is almost 20dB less than the expected values gained via calculation. Moreover, sufficient receive level would have been kept lower, thus it leads to a decreased transmit power that reduces the operational cost for the license. Furthermore, figures included in section 3 could be used to find the relationships between parameter values within the given range.

Generally path reliability analysis provides critical verifications that the link budget parameters are sufficient to support the intended communications. When fade margin is high, path reliability is often low. As here the fade margin is significantly low in practical, the actual path reliability would have been taken to a higher value in such use cases.

In addition, also with concern of the height of trees and obstructions in the environment, the tower height could have been kept minimum around 10m which would have saved a huge amount of money for constructions of civil work in three towers as 15m of towers are too much for short distance line of sight communications.

This particular feasibility study concludes how theoretical aspects of microwave wireless communication vary in real environment depending on weather, climate, geography and unique challenges. The UKHP microwave communication link design in hilly countryside where line of sight issues have to be overcome via repeaters and often affected by rain but low humidity throughout the day designed according to internationally standardized theories proved;

- How arithmetic errors affect design process and how to re-correct through better assumptions rather than ignorance (section 2).
- How much theoretically obtained values vary under real environmental conditions and thus to refer the results in future implementations in similar conditions (section 3).
- How different values of a specific parameter in a needed range relate to other parameter values practically and therefore those to be referred when and where variations have to be considered.
- How optimization of microwave link results in more economically feasible and highly accurate performances in operation.

5. REFERENCES

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