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Optimum Parameter Analysis of Microwave Link Design in Tripoli

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Abstract: The development in communications science is considered one of the most technological developments in the modern era, and microwave wireless communications receives wide attention from communications site designers because of its strong and direct impact on the quality of communications. This development not only led to good performance, but also caused some optimization problems because some standards of several world regions were used jointly without sufficient investigations in sufficiently specific models or regions. In Libya these common standards related to microwave links have not yet been improved, as Libya is calculated according to the classification or division of the countries of the world by the International Telecommunication Union (ITU) with in one region symbolized by the symbol D, which creates or generates some mathematical problems for the rain attenuation, therefor errors in microwave link budget. This research presents how to adjust the design the design parameters of microwave links based on the analysis and actual readings recorded by Al-Madar Al-Jadeed Company on the microwave link in Tripoli as practical example of conducting these analysis. This analysis supported by actual results and within of the specific climate and geographical region, helps predict the performance of microwave links in communications systems and other systems in the future. In fact, this study can be referred to as a reference for making the necessary changes in the standard values currently in effect in design procedures and taken from (ITU), and thus achieving optimal performance effectively.

Keywords: (International Telecommunication Union (ITU), Link budget, Rain attenuation, receiver signal level (RSL))

Introduction

Microwave links are considered an essential pillar of the communications system, wireless data transmission systems, and many applications. To maintain the performance of the communications system network, the performance of the microwave links must be maintained and their performance improved continuously. This research aims primarily to establish a preliminary reference for future applications and specifically in communications systems under similar circumstances in Libya, through analysing a real link theoretically and practically. Therefore, a microwave link was taken from the links that operate within the telecommunications network in Libya and in Tripoli specifically, and the link between the two towers of the telecommunications network, with a distance of 5.58 km and a frequency of 15 GHz, as a real example of controlling the system's performance comparing the standard values and the actual values of the analysis results. Figure (1) shows the topological location of the site according to the Ellipse software used by Al-Madar Al-Jadeed Company.

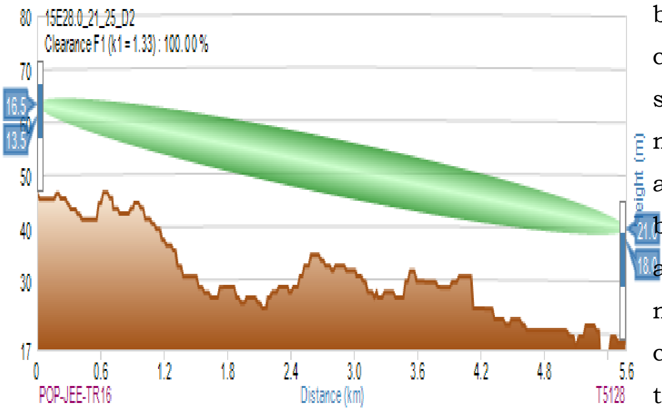

Fig 1: Topology location of T5128 link

This research covers the following main objectives:

- Applying mathematical and computer models to solve problems in communications engineering.
- Theoretical formulas for signal propagation.
- Losing track and calculating the link budget.
- Calculating the fade margin.

1. Methodology

First, a general analysis of microwave communications is performed theoretically. Secondly, the actual correlation was analyzed to verify the expected results. Finally, the practical results were compared with each other to reach conclusions.

2. Theoretical Analysis

Microwave describes the contemporary current signals between 300 MHz to 300 GHz frequency ranges, microwaves have a resultant wavelength among $\lambda = \frac{c}{f}$ =1m and λ =1mm respectively [1]. These are ideal for transmission of information from point to point or to multipoint other because power of microwave can penetrate smog, rainfall, and snow.

Microwave waves are considered one of the best linking mediums between communications systems, where they transmit signals across the radio band via progression microwave towers, where it is required to achieve a line of sight (LOS) to avoid obstacles between the transmitting and receiving towers and for ensure arrive the signals at both ends., microwave communications is the most commonly used transmission technique for telecommunication services era. The choice for microwave when it comes with data communications is because of several advantages over other communication mediums (Infrared, optical fibre cables and etc.) [2].

- Microwave link is possible to deploy in a day.
- Microwave radio link is flexible in the capacity that can be increase at negligible cost. Moreover, microwave radio link can be reinstalled depending on the customer requirement or if network demands changes. Therefore, losing client does not make a sense that assets are lost as in case of fifer optic.
- Microwave radio infrastructure is already available for various networks in the rooftops, cellular poles and residing towers of microwave radio transmission.
- Microwave radio has few and simple breakdown, does not require a long time to repair compared optical fibres, whose interruption causes disastrous breakdown and requires a long time that may reach Days to repair it.

On the other hands, the following problems may have to be faced:

- It is affected by rain attenuation it may cause of breakdown of microwave link.
- Line of sight is strictly required.
- The length of the link is limited to the frequency band used.

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

a- Free space loss:

$$L_{fspl} = 92.4 + 20log_{10} f + 20log_{10} d \quad (1)$$

Where:

f Is frequency in (Ghz) and d is distance in (km)

b- Link budget:

$$P_{RX} = P_{TX} - L_{TX} + G_{TX} - L_{PL} + G_{RX} - L_{RX}$$

(2)

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)

c- Rain attenuation:

$$A_{0.01} = A * d * r \quad (3)$$

$$A = aR^b \quad (4)$$

$$r = \frac{1}{1+d/d0} \quad (5)$$

$$d_0 = 35e^{(-0.015*R)} \quad (6)$$

Where:

$A_{0.01}$ – rain attenuation rain attenuation at 0.01 from the time the signal unavailable.

A - the specific attenuation

r - reduction factor

d_0 - the rain cell

d -the path length in (km)

d- Measured rain attenuation:

$$MRA = RSL(clear\ sky) - RSL(rain\ sky)$$

(8)

e- Fade margin:

$$f_d = link\ budget - threshold\ leve$$

(9)

And some of the parameters that are taken into consideration when designing a microwave link, such as:

Fresnel zone

Antenna gain

Tower height

Diversity

Path unavailability

Required SNR (Signal to Noise Ratio)

Other losses connected with the system.

3. Actual Link Analysis

There are assumptions made by microwave link designers for link budget calculations and path profile analysis to achieve quality coverage at a lower cost in transmission power.

In the practical analysis of the calculations, it was found that the measured attenuation differs from that calculated theoretically, and there was also a difference in the value of the fade margin, which in turn will affect the rest of the parameters that are used in designing the microwave link, such as the link budget, the level of transmitting and receiving power, which will cause large losses in communication and reduce Path reliability. On the other hand, it will increase the cost and difficulties that link designers in telecommunications companies will face. Therefore, the recalculation was performed using actual (recorded) data from Al-Madar Company regarding the basic parameters in Table 1 using the formulas given in Section 2.

TABLE (1): Calculation Results of T5128 Link

Parameter	Value				Unit
	Direction A		Direction B		
Site	POP-JEE-TR16		T5128		
Distance	5.58				km
Frequency	14963		14543		MHz
Tower coordinate (long/lat)	13.007	32.775	13.012	32.825	deg
Polarization	V		V		
TX height on tower	16.5		21		m
TX azimuth	5.14		185.14		deg
TX antenna	Ml150.6m HPX		Ml150.6m HPX		
TX power	9		9		dBm
RX level	-54.79		-54.53		dBm
Threshold	-65		-65		dBm
Fade Margin	10.21		10.47		dB
Rain Model	P530				
Rain Model Region	Rain Region, ITU Region				
Region	D				
R 0.01(mm/h)	19				

4. Results

For optimization, new values got in recalculation process and a comparison was made between the actual values and the theoretical values.

First and foremost, the measured rain attenuation (MRA) was calculated by recording receiver signal level (RSL) values during rainy sky and clear sky periodically every five minutes a day for four links Includes study link, to ensure more accuracy in the results.

TABLE (2): Receive Level in Rain and Clear Sky of T5128 Link

Data date	at hour	Level R_X (rain sky)	Level R_X (clear sky)
29/12/2022	23:37PM	-59.8	-52.2
29/12/2022	23:42PM	-59.5	-52.2
29/12/2022	23:47PM	-63.3	-52.1
29/12/2022	23:52PM	-63.1	-52.6
29/12/2022	23:57PM	-62	-55.1
29/12/2022	00:02AM	-62.3	-54.9
29/12/2022	00:07AM	-61.4	**-56.4**
30/12/2022	00:12AM	-61.2	-56.2
30/12/2022	00:17AM	-61.4	-55.3
30/12/2022	00:22AM	-60.7	-56.9
30/12/2022	00:27AM	-60.3	-56.3
30/12/2022	00:32AM	-62.1	-53.1
30/12/2022	00:37AM	-63.6	-54.7
30/12/2022	00:42AM	**-64.2**	-54.5

Then (MRA) is calculated by finding the difference between the RSL values in the two different periods. Then taken the difference between the rain attenuation calculated by ITU model as shown equation (7) and the measured rain attenuation from Al-Madar Al-Jadeed Company.

$$MRA = (-56.4) - (-64.2) = 7.8\,dB$$

TABLE (3): Summary of Calculated and Measured Rain Attenuation for Four Links

Name	Freq. (MH)	Distance (km)	Attenuation (dB)	
			ITU model calculation	Links measurement
TRP10	14711	1.37	1.875	4.210
T5128	14543	5.58	6.591	7.8
TOK1	14781	7.44	8.286	9.000
ABY2	14725	9.96	10.297	11.695

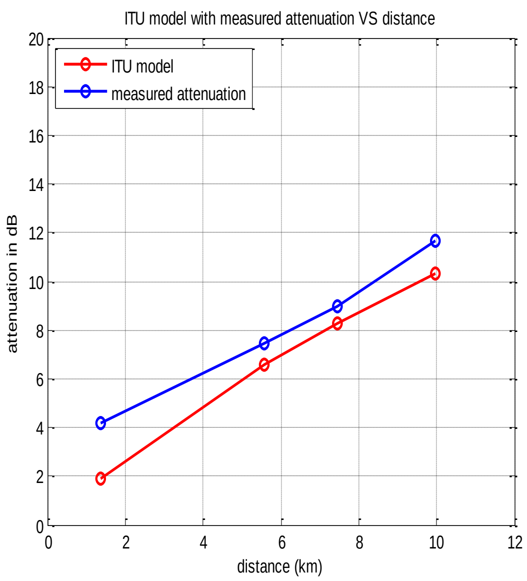

Fig 2: Calculated and measured rain attenuation

On the other hand, readings of the received signal level were taken in another period and the climate was moderate. It was found that the minimum reception level was (-58.3 dBm) and the maximum was (-52.2 dBm) according to the recording data that shown in table 4.

TABLE (4): Recorded Receive Level of Site

Data date	at hour	LevelR_X	Notes
28/10/2022	10:15AM	-54.8	
28/10/2022	10:30AM	-52.2	R_X Maximum
28/10/2022	10:45AM	-55.1	
28/10/2022	11:00AM	-53.9	
28/10/2022	11:15AM	-55.5	
28/10/2022	11:30AM	-56.1	
28/10/2022	11:45AM	-56.4	
29/10/2022	10:00AM	-54.2	
29/10/2022	10:15AM	-55.8	
29/10/2022	10:30AM	-58.3	R_X Minimum
29/10/2022	10:45AM	-57.3	
29/10/2022	11:00AM	-55.1	
29/10/2022	11:15AM	-56.1	
29/10/2022	11:30AM	-55.2	

Thus, $f_{d\ actual} = -52.2 - (-58.3) = 6.1\,dB$

Since the actual fade margin is in practice very less than expected values, there the new value of the threshold becomes:

$$R_X' = -65 - (-6.1) = -58.9\ dBm$$

Because the maximum receive level practically got is (-52.2) dBm, there is a clue that the transmit power can be further reduced as:

$$T_X' = 9 - [(-52.2) - (-58.9)] = 2.3\ dBm$$

This gives 6dB or 7dB reduction of used transmits power.

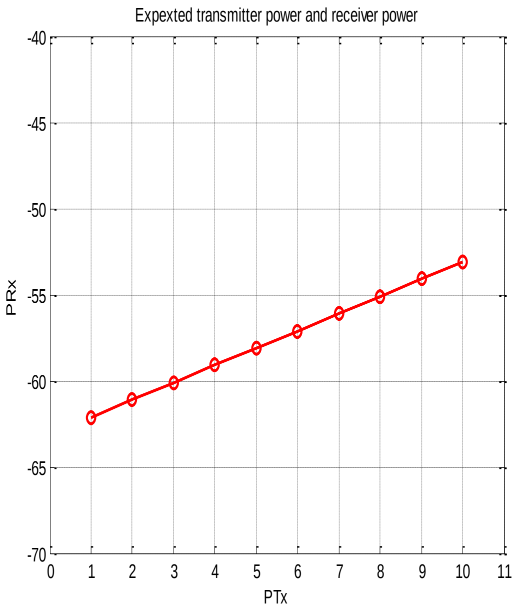

Fig 3: Expected transmit power and receive power

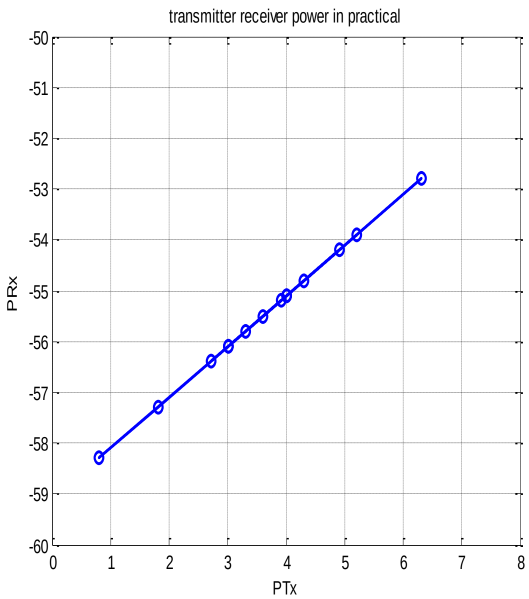

Fig 4: Transmit and receive power in practical

5. 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 that has affected path reliability, where considering ITU region D by the designers for Fresnel zone calculations, in addition rain attenuation specifically in the same area though Libya belongs to N as it exists in ITU maps world regions.

In addition, when it comes with recorded readings data for fade margin, it proved that practically required fade margin is almost 4 dB less than the expected values obtained by calculation. Moreover, sufficient receive level would have been kept lower, thus it leads to a decreased transmit power that reduces the operational cost.

Furthermore, figures included in section 4 could be used to find the relationships between parameter values within the given range.

This particular feasibility study concludes how theoretical sides of microwave wireless communication different in real environment depending on weather, climate, geography and unique challenges. And how enhancement performance of microwave link leads to more economically feasible and highly accurate performances in operation.

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