Link Budget Calculator System for Satellite Communication

Norsuzila Ya'acob[1,2], Juliana Johari[1], Maizatul Zolkapli[1], Azita Laily Yusof[1,2],Suzi Seroja Sarnin[1] and Nani Fadzlina Naim[1]

[1]Faculty of Electrical Engineering, Universiti Teknologi MARA, 404500 Shah Alam Selangor, Malaysia

[2]Wireless Communication Technology (WiCoT), Faculty of Electrical Engineering, UniversitiTeknologi MARA, 404500 Shah Alam Selangor, Malaysia

norsuzilayaacob@yahoo.com,julia893@salam.uitm.edu.my,maizatul544@salam.uitm.edu.my,azita968@salam.uitm.edu.my, suzis045@salam.uitm.edu.my,nanifadzlina@salam.uitm.edu.my

***Abstract*—Link analysis basically relates transmitted power and received power and shows in detail how the difference between these two is accounted for. To this end the fundamental elements of the communications satellite Radio Frequency (RF) or free space link are employed. Basic transmission parameters, such as antenna gain, beam width, free-space path loss, and the basic link power equation are exploited. The concept of system noise and how it is quantified on the RF link is then developed, and parameters such as noise power, noise temperature, noise figure, and figure of merit are defined. The carrier-to-noise ratio and related parameters used to define communications link design and performance are developed based on the basic link and system noise parameters. Hence, a new system named as Link Budget Calculator is successfully designed to formulate the mathematical of link budget. The system analyzesand calculates basic formulas which are related to link budget by using the MATLAB software.**

***Keywords*—Link Budget, Satellite Communication System,MATLAB program**

I. INTRODUCTION

In telecommunication system, a link budget is the accounting of signal gains and losses travelling through a medium from transmitter to receiver. It accounts for attenuation of transmitted signal due to propagation including antenna gain, feed line and miscellaneous losses.

Link budget analysis system is developed to analyze signal loss factor during propagation and estimate minimum power required for transmissionto overcome noise signal, which usuallyoccur in mobile phones (receiver) [1-2]. The system also calculates and tabulates interfering noise power and useful signal power at the receiver. In general, link budget analysis system calculates and provides information of losses and gains, available power at transmitter, antenna gain, propagation losses and performance losses due to noise and natural interference [3]. The basic elements that are usually found in a link budget are effective isotropic radiated power (EIRP), transmitted and received power, transmitter and receiver gain, flux density, free space path loss and effective aperture [4]. The calculation to determine link budget is rather straightforward.

Nowadays, some researches on link budget calculator have been developed. A simple link budget calculation based on two simulation methods; GPS coordinates and SRTM cartography, are performed in radio simulation software [5]. However, the major drawback on this research is the high cost incurred. In [6], level of power delivered to receiver is determined, alongside fade margin, based on output power capacity of transmitter and summation of system gains and losses. Nevertheless, the calculations herein provide only theoretical approximation and do not account for all the myriad practical variables that can and may affect system performance.

Link budget is all about finding the signal level received from the signal level transmitted. Mastering the skill to accuratelycalculate a link budget is essential for a communications system design engineer as it is the basics of antennas and signal wave propagation. It is substantial to create and calculate link budget in the easiest way possible without incurring expenses. It is also significant to determine which formula is most suitable to be used in the link budget analysis.

In communications, the carrier-to-noise ratio, often written as CNR or C/N, is a measure of the received carrier strength relative to the strength of the received noise. High C/N ratio provides better quality of reception, and higher communications accuracy and reliability in general. Engineers specify the C/N ratio in decibels (dB) between the power in the carrier of the desired signal and the total received noise power [7]. C/N ratio is measured in a manner similar to the way signal-to-noise ratio (S/N) is measured, and both ratiosreflect the quality of a communication channel. While C/N ratio is commonly used in satellite communications systems to point or align the receiving dish; the best dish alignment is indicated by the maximum C/N ratio [8-9], S/N ratio specification is more useful in practical situation.

978-1-5386-0908-8/17/$31.00 ©2017 IEEE

The scope of the proposedsystem is to create the most effective approachto calculate link budget related to telecommunication system by developing a graphical user interface (GUI) using MATLAB software. Users are required to enter some information prior to calculating specific parameter and result will be displayed at the link budget calculator. Multiple parameters can be calculated according to information given[10]. Some parameters are calculated in the dB while someare calculated in Watt. Calculations are not successful if required information are not complete.

The objective of this research is to formulate a mathematical link budget and to analyze and calculate basic formulas related to link budget using MATLAB software.

II. METHODOLOGY

A. Flowchart

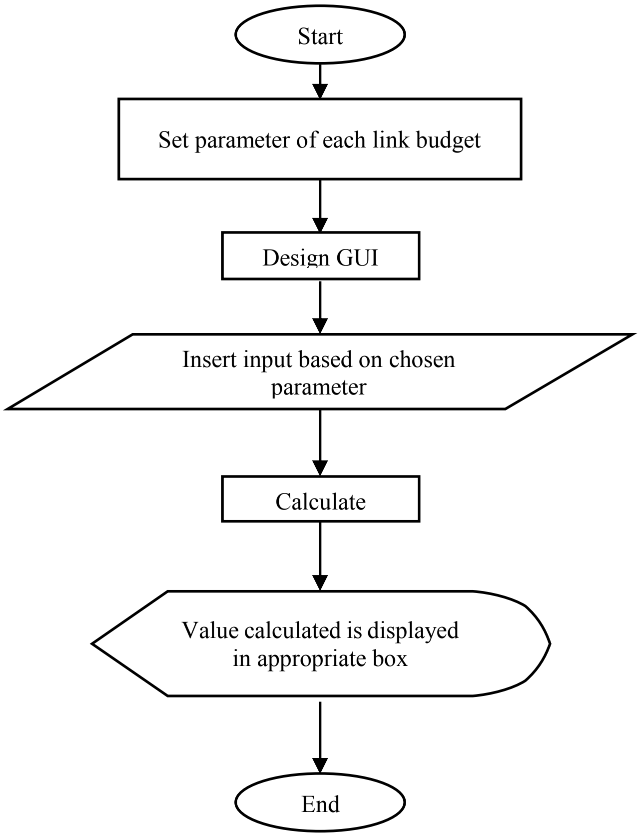

Fig. 1. Link Budget software development flowchart.

Fig. 1 above demonstratesthe process of developingand verifying link budget software calculation in MATLAB program. Once formula and parameter have been identified, the link budget system can be programmed and its GUI can be designed using MATLAB software.

Table 1. Formula for each parameters.

	Parameter	**Formula**
1	Lambda, λ	$=\frac{c}{f}$
2	Effective aperture, *Ae*	$= (\eta)(A_r)$
3	*Ar*	$=\frac{(\pi(D^2))}{4}$
4	Transmitted gain, *Gt*	$=(n)(\frac{(\pi D)^2}{\lambda})$ $=10*\log 10\ (n)(\frac{(\pi D)^2}{\lambda})(dB)$
5	Received gain,*Gr*	$=\frac{4\pi Ae}{\lambda^2}$ $= 10*\log 10\ \frac{4\pi Ae}{\lambda^2}(dB)$
6	Effective Isotropic Radiated Power,*EIRP*	$=P_t G_t$ $= 10*\log 10 P_t G_t(dB)$
7	Received power, *Pr*	$=\frac{P_t G_t A_r}{4\pi R^2}$ $= 10*\log 10\ \frac{P_t G_t A_r}{4\pi R^2}(dB)$
8	Transmitted power, *Pt*	$=\frac{P_r 4\pi R^2}{G_t A_r}$ $= 10*\log 10\ \frac{P_r 4\pi R^2}{G_t A_r}$
9	Flux density, *F*	$=\frac{p_t G_t}{4\pi\ R^2}$
10	Free space path loss (FSPL), *Lp*	$=(\frac{4\pi R}{\lambda})^2$ $= 10*\log 10\ (\frac{4\pi R}{\lambda})^2$
11	Noise power,P_n	$=kTB$
12	Noise power spectral density,N_0	$\frac{p_n}{B}=kT$
13	Carrier to Noise Ratio, $\frac{C}{N}$	$= P_R - P_n\ (in\ dB)$ $= EIRP + (G_R/T_s) - Losses - k - B_n$
14	Figure Of Merit, $\frac{G}{T}$	$= G_R - T_s$
15	Carrier Power to Noise Density,$\frac{C}{N_0}$	$= EIRP + (G_R/T_s) - Losses - k$

Since link budget calculation consist ofmany formulas, some formulas and parameterswhich are commonly used has been selected to run the link budget calculation in MATLAB software as shown in Table 1 above.

Design of the GUI consists of two parts.The upper part of the interfaceis made up of initial input data and the lower part shows specific parameter calculated. More details will be shown in the conclusion and discussion part.Moreover, the value can display more than one parameter at one time according to the input inserted. For some parameter that usually calculated in dB, such as power receive (*Pr*), power transmit (*Pt*), effective isotropic radiated power (*EIRP*) and antenna gain (*Gt/Gr*), there will be two value calculated, which are in dB and in Watt. However, if there are not enough input inserted, the parameter cannot be calculated.

978-1-5386-0908-8/17/$31.00 ©2017 IEEE

III. RESULT AND DISCUSSION

Link budget analysis system is developed to evaluate signal loss factor during propagation as well asapproximatethe power thresholdrequired by transmitter to overcome the noise of mobile phone (receiver). Certain constraints such as small received flux density, limited electrical power and limited dimensions are applicable in designing a transmission system.Therefore, link budget calculation is frequently used to determine viability of the design to surpass these constraints and meet required specifications.

The interface of the designed link budget calculator system using MATLAB softwareis shown in Fig. 2. Formula of each parameter has been set and users are only needed to enterinitial data prior to clicking on 'compute' or 'convert' buttonto obtain result. Computed resultsare displayed in appropriate boxes. Examples on calculating wavelength, antenna aperture, effective aperture, flux density and free space path loss are shown in Fig. 3, 4, 5, 6, and 7, respectively. Some parameters such as receiver gain (Fig. 8), received power (Fig. 9), transmitted power (Fig. 10) and EIRP (Fig. 11) are displayed in two types of unit measure. Calculation of figure of merit and carrier to noise ration are reflected in Fig. 12 and 13, respectively. Additional calculation is included to convert power level from unit watt or unit gain ratio into unit decibel, dB as demonstrated in Fig. 14.

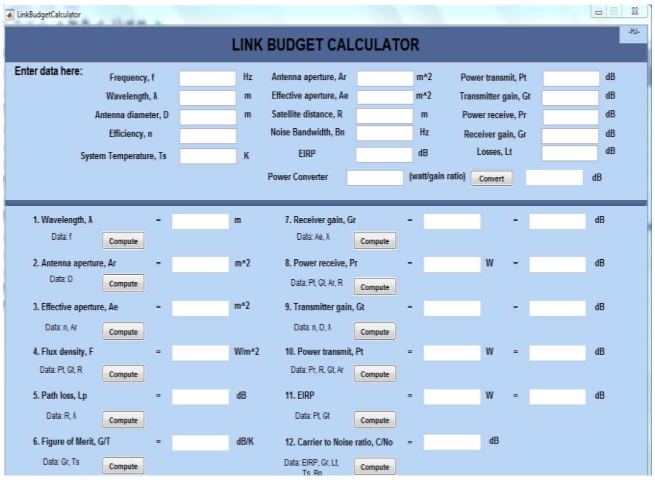

Fig. 2. GUI of Link Budget Calculator.

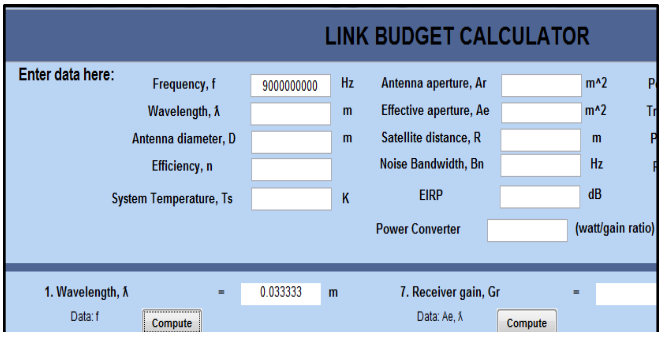

Fig.3. Wavelength Calculation.

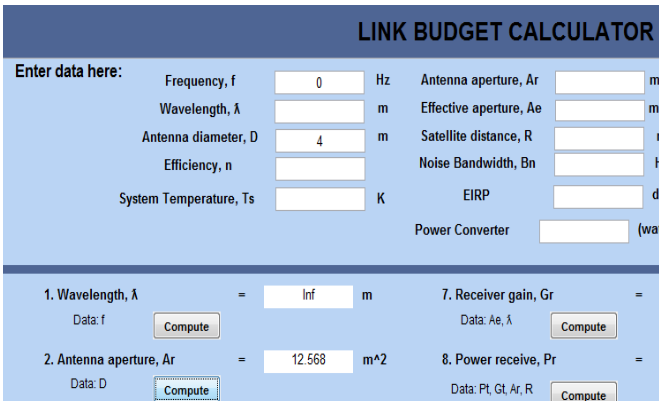

Fig. 4. Antenna Aperture Calculation.

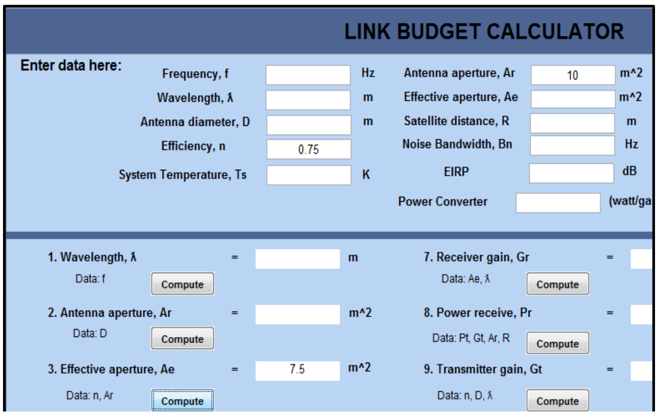

Fig. 5. Effective Aperture Calculation.

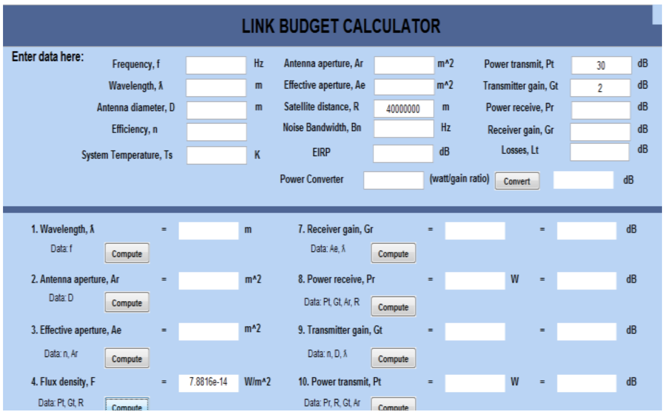

Fig. 6. Flux Density Calculation.

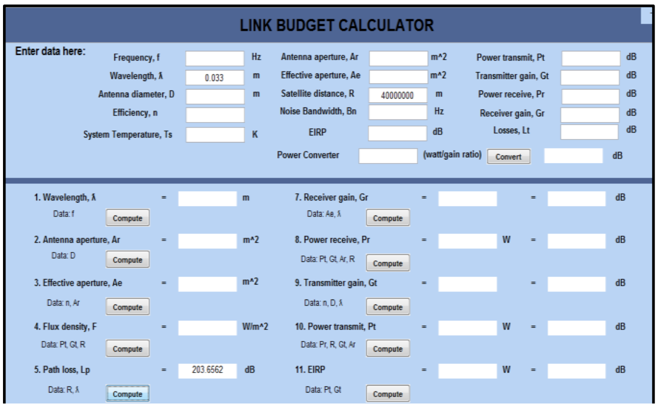

Fig. 7. Free Space Path Loss Calculation.

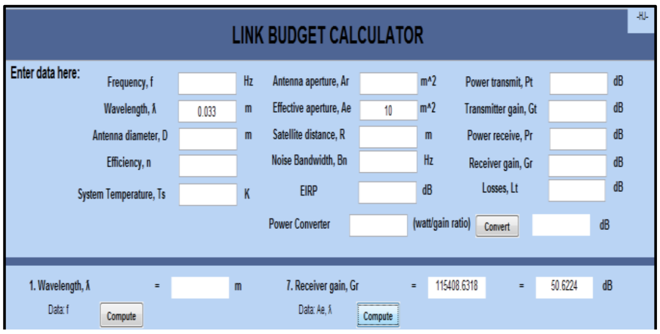

Fig. 8. Receiver gain calculation.

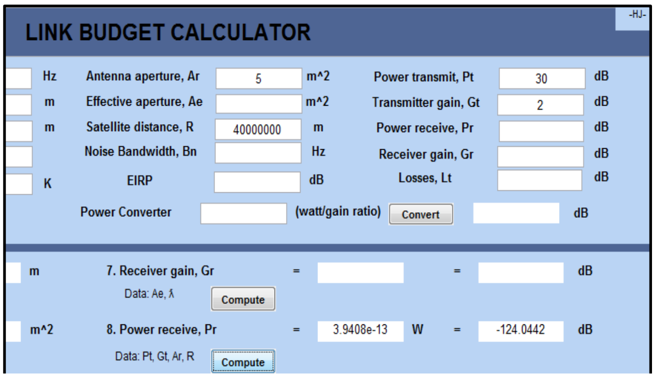

Fig. 9. Received Power Calculation.

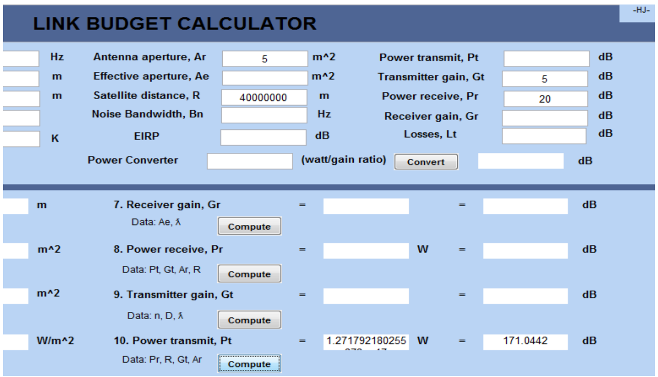

Fig. 10. Transmitted Power Calculation.

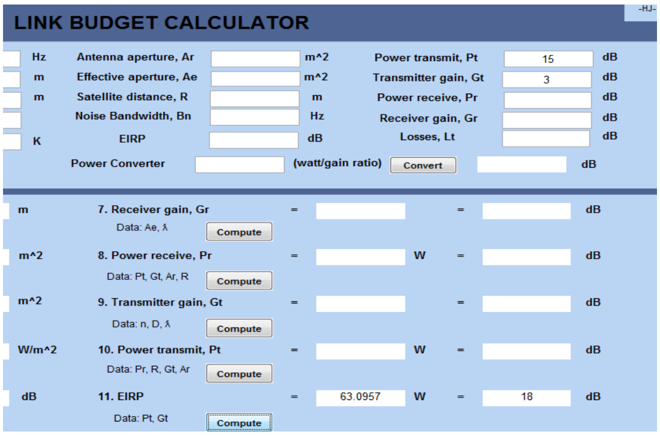

Fig. 11. EIRP Calculation.

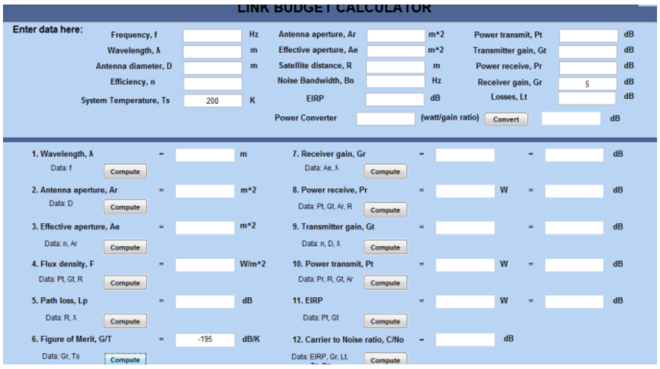

Fig. 12. Figure of Merit Calculation.

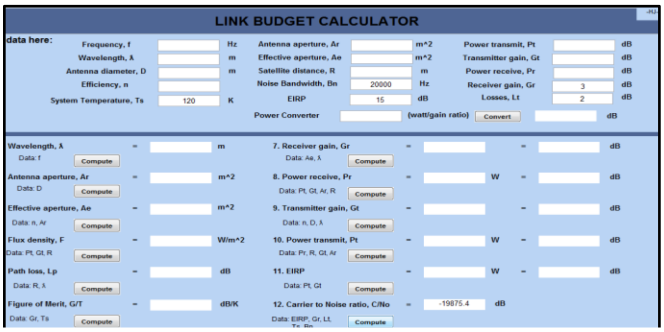

Fig. 13. Carrier to Noise Ratio Calculation.

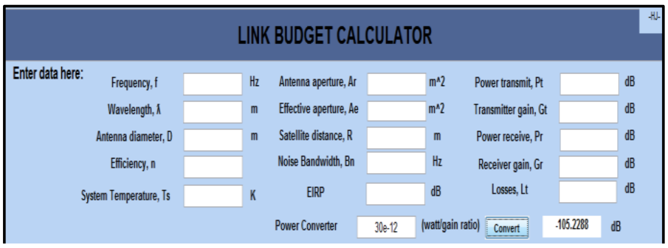

Fig. 14. Power Converter Calculation.

Performing link budget calculationprior to designing a satellite communication system is crucial as it is used to determine viability of system design to meet requirements. Some of the constraints involved in designing a communication system is the limited electrical power of satellite, which is between 1 to 200 Watts. Another limitation is that antenna on satellite has restricted dimension, where its size has to be less than 3 meter and "unfurled" should not exceed 10 meter. In addition to that, received flux density (F) must be minimal. All the constraints mentioned is lead to this link budget calculation. Link budget calculation will determine whether system design proposed is suitable or viable enough to overcome or at least reduce the problems faced.

Link design for satellite involves basic transmission theories, which includes the EIRP, antenna or gain and link budget equations, and system noise. However, this MATLAB program accounts for basic transmission theories only. The first part of the link budget is the basic transmission theories where basic parameters need to be calculated before proceed to the second part, which is system noise. The basic transmission theories include all parameters shown previously such as power receive, power transmit, antenna gain, flux density and path loss.

The link budget equation is the basic link equation which is typically too simplistic. Basically, the formula demonstrated in this program assumes ideal cases. For example, the program calculates free space path loss (Lp) as spherical spreading only, when there are other additional losses in the link, practically. However, these losses, such as loss due to the atmospheric attenuation, feeder loss and polarization mismatch, are included in the second part later on in the system noise.

Some of the parameters such as received power (Pr) and transmitted power (Pt) has more than one formula, however, only one commonly used formula is utilized in this program. Some of the initial values entered need to be in unit watt following formula set in the MATLAB program. If the value is entered incorrectly (for example: different unit mesure), the output data would be inaccurate as different formula is used.

IV. CONCLUSIONS

A Link Budget Calculator system using MATLAB software is successfully designed. This system is created to formulatethe mathematical of link budget and to analyze and calculate basic formulas which are related to link budget. The link budget is a significant tool as it investigates all the areas, gain and losses that may occur between transmitter and receiver of a satellite communication system.

V. FUTURE WORK

For this project, some recommendations that can be proposedfor further improvement. First of all, the *MATLAB* calculation program can involve overall of the link design including system noise. Any input given can be calculated when the formula for certain parameter such as received power and transmitted power be set more than one formula. This project only involves free space path loss, however, other losses such as feeder losses, atmospheric attenuation, polarization, antenna mismatch and others can be added into the *MATLAB* calculation. After adding all the necessary information for the link budget calculation, the total system carrier to noise ratio can be calculated and the viability of the system can be determined directly. Finally, the *GUI* can be improved to be more user friendly. For an example, additional function could be included to allow usersto select more than one interface.

ACKNOWLEDGMENTS

The authors would like to thank Faculty of Electrical Engineering, UniversitiTeknologi MARA (UiTM) for their valuable support. This research is partly funded by the Malaysian Government through UiTM under 600-RMI/DANA5/3/ARAS (0042/2016).

REFERENCES

[1] Andrea Cagliero; Assunta De Vita; RossellaGaffoglio; Bruno Sacco"A New Approach to the Link Budget Concept for an OAM Communication Link", vol. 15, IEEE Antennas and Wireless Propagation Letters, 2016, pp. 568-571.

[2] R.kumar, P.saveeda, "Coverage and Link Budget Calculation for GSM Cellular System using various Parameters", IJCNAC, Vol 2, Feb 2014.

[3] D. Nalineswari and N. Rakesh, "Link budget analysis on various terrains using IEEE 802.16 WIMAX standard for 3.5 GHz frequency," *2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)*, Coimbatore, 2015, pp. 1-5.

[4] Minghui Tao; Lei Zhou; Huaiyu Zeng; Shengping Li; Xiang Liu"50-Gb/s/λ TDM-PON based on 10G DML and 10G APD supporting PR10 linkloss budget after 20-km downstream transmission in the O-band", Optical Fiber Communications Conference and Exhibition (OFC), 2017.

[5] Louise Berthilson and Alberto EscuderoPascual. "Link Budgets and Software Simulations for Wman@Fez", 2008.

[6] S. Berrezzoug, F. T. Bendimerad and A. Boudjemai, "Communication satellite link budget optimization using gravitational search algorithm," *2015 3rd International Conference on Control, Engineering & Information Technology (CEIT)*, Tlemcen, 2015, pp. 1-7.

[7] Ali Nauman; MoazamMaqsood"System design and performance evaluation of high altitude platform: Linkbudget and power budget", 19th International Conference on Advanced Communication Technology (ICACT), 2017.

[8] Andrea Cagliero; Assunta De Vita; RossellaGaffoglio; Bruno Sacco"A New Approach to the Link Budget Concept for an OAM Communication Link", vol. 15, IEEE Antennas and Wireless Propagation Letters, 2016, pp. 568-571.

[9] B. Jeffrey; J. Wout; P. David "Comparison of the Link Budget with Experimental Performance of a WiMAX System", EURASIP Journal on Wireless Communications and Networking, 2009.

[10] N.Shkelzen; M. Artan"Link budget analysis in the network designed mobile WiMAX technology in the territory of the urban area of the city of Gjakova" IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 5, No 2, September 2012.