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A Development of Satellite Communication Link Analysis Tool

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In a Satellite communication system, a link budget analysis is the detailed investigation of signal gains and losses moving through a channel from a sender to receiver. It inspects the fading of passed on data signal waves due to the process of spreading or propagation, including transmitter and receiver antenna gains, feeder cables, and related losses. The extent of the proposed tool is to make an effective, efficient, and user-friendly approach to calculate link budget analysis. It is also related to the satellite communication correlation framework by building up a graphical interface link analysis tool utilizing STK® software with the interface of C# programming. It provides better kinds of graphical display techniques, exporting and importing data files, printing link information, access data, azimuth-elevation-range (AER), and simulation is also possible at once. The components of the link budget analysis tool include transmitter gain, effective isotropic radiated power (EIRP), free space loss, propagation loss, frequency Doppler shift, flux density, link margin, elevation plot, etc. This tool can be useful for amateur users (e.g., CubeSat developers in the universities) or nanosat developers who may not know about the RF communication system of the satellite and the orbital mechanics (e.g., orbit propagators) principle used in the satellite link analysis.

Keywords: satellite communication, link budget, data access, graphical user interface (GUI), nanosatellite

1. INTRODUCTION

A link or connection budget investigation is an analysis of all the information signal wave gains and misfortunes or fading that a correspondence signal encounters in a satellite communication system, from a sender or transmitter, through a medium of free space to the receiver. It represents the weakening of the passed-on data signal waves because of the spreading (propagation), including the antenna gains, cables, and other related losses (Table 1). The amplification (low noise amplifier, LNA) of the signal as it goes through the receiver also considered. A link budget is a design-assist calculated during the analysis of a communication system to determine the received signal strength, to ensure that the signal obtained is with a satisfactory signal to noise ratio. Randomly changing channel gains, such as fading, are considered by including some edge limit (link margin) depending on the predicted quality of its components.

Link budget analysis framework created is to inspect signal losses factor during spreading (propagation) and approximate least energy required for transmission to defeat unwanted noisy signals, which mainly happens in cell phones recipient (Cagliero et al. 2016). The link analysis likewise also computes and organizes interfering unwanted noisy energy and valuable signal power at the receiver end. The link budget analysis framework ascertains and gives details of misfortunes (losses) and gains, accessible energy at the transmitter, receiving antenna gain, causes of losses and propagation losses (Nalineswari & Rakesh 2014). The essential components found in a link budget analysis are effective isotropic power (EIRP), transmitted and received power, transmitter and recipient gain of a signal, motion thickness (flux density), free space channel losses, and aperture efficiency (Tao et al. 2017). The computation to determine the link budget analysis is somewhat direct.

In (Joseph & Martens 2006), link budget analysis (which

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Table 1. Major losses in satellite communication link budget analysis

Free space losses				
Transmission losses			Ionospheric effects	Faraday rotation& scintillation effects
	Propagation losses	Atmospheric losses	Tropospheric effects	Attenuation
				Rain attenuation
				Gas absorption
				Depolarization
				Sky noise
			Local effects	
		Pointing losses		
	Local losses	Equipment losses	Feeder losses	
			etc.	
		Environment losses		

are coverage estimations) was analyzed using different path loss model platforms. In any case, these inclusion estimations have not been sealed or approved by the exhibition tests. Hypothetical examinations and recreations of the demonstration for 802.16-based frameworks have been completed in (Joseph et al. 2007). In (Rial et al. 2007), estimations of the transmitter to obstruction losses proportion appeared, and the actual estimated execution of an 802.16-based framework is inspected and acted in (De Bruyne et al. 2009).

In (Zhao et al. 2011) research an optimization of the link budget analysis of a free space optical framework comparable to varying edge of the optical pillar is given. In contrast with the other studies (Farid & Hranilovic 2007), where just the impact of the veering or varying edge over free space optical framework investigated, here is indicated the issue for finding the ideal side of uniqueness in general. Besides, in this work, only the scenario with atmospheric attenuation (extinction) is used. The primary explanation behind the deviations of the optical shaft from its main course is the climatic disturbance (for example, beam wandering) (Larry & Ronald 2005), causing mistakes. Also, the mechanical developments of the bases on which the sender/recipient hardware set separately on the structure influence (Arnon 2003) investigated in detail.

When evaluating a satellite communications link, there are at least three most important questions to be answered. These are: how much radio frequency (RF) power is accessible, how much transmission capacity is possible, and what is the necessary unwavering quality, which is determined or evaluated by the bit error rate (BER) and link margin level. So far, no such a tool developed even though there are some attempts. Therefore, we need a tool that come-up with a solution conveniently.

These days, a few investigations developed on interface link budget analysis exists. A fundamental link budget computation dependent on two reenactment strategies, GPS directions, and SRTM cartography, are acted in radio simulation programming. But the significant disadvantage of this examination is the considerable expense acquired. In (Berrezzoug et al. 2015), the level of intensity conveyed to the receiver is resolved, close by the fade margin, considering the output power limit of transmitter and summation of framework gains and misfortunes (losses). Despite that, the estimations in this paper give a hypothetical guess and do not represent all the feasible factors that can and may influence system performance losses.

For BILSAT-1, the link budget analysis small-computer program created is considering all the losses related to instruments, negative impacts, the general satellite framework criteria, time plan, and the task budget plan. In the link budget program, the losses, for example, free space, rain losses, vaporous absorption, and receiving wire feeder/pointing/polarization are determined by utilizing the equations given in (Maral et al. 1998).

Link budget analysis is finding the signal level collected from the signal level transmitted. The expertise to precisely figure a link budget is necessary for a communication framework configuration designer as it is the essentials of receiving antennas and information wave propagation. It is generous to make and ascertain the interface link budget in the most straightforward manner conceivable without causing costs. It is likewise noteworthy to figure out which recipe is generally reasonable to utilize in the link budget investigation.

In satellite communications, the carrier to noise proportion, regularly composed as a carrier to noise ratio (CNR), is a ratio of the received carrier quality comparative with the quality of the received noise. High CNR proportion gives better nature of reception, and higher communications precision and dependability. Designers determine the CNR proportion in decibels (dB) between the power in the carrier of the ideal signal, and the all-out received noise power (Nauman & Maqsood 2017). CNR proportion estimation is in a way like the path signal-to-noise proportion (SNR) is calculated, and both ratios reflect the nature of a correspondence channel. CNR proportion is generally utilized in satellite communication frameworks to point or adjust the receiving antenna. The best antenna alignment demonstration is by the maximum CNR proportion (De Bruyne et al. 2009; Cagliero et al. 2016), SNR ratio specification is progressively valuable in reasonable condition.

The extent of the proposed framework is to make a practical and most straightforward approach to calculate link budget related to satellite media transmission framework by building up a graphical user interface (GUI) utilizing STK® software. It provides better kinds of graphical display techniques, exporting & importing data files, printing link information, access data, and simulation are possible with the given inputs. It is mentioned as efficient because the time of analysis for the whole satellite communications parameter is fast. It is also stated as easiest because the developed tool can be useful for amateur users like nano-satellite developers in the universities. They may not know about the overall RF platform of the satellite communication system. Clients or users are required to enter some data preceding the explicit computing parameter, and the link budget analysis displaying windows provides the result. With the given data, different settings can be determined by (Shkelzen 2012). A few parameters are specified in dB, while some parameters use Watt and other standard units related to satellite and ground station parameters. There will be an error for the analysis whenever required data (inputs) are not full or complete. Finally, it can also provide better graphical display options with various reporting techniques, which makes it user friendly.

The STK Programming Interface provides a wide variety of means to automate and customize STK and to integrate its technology into other applications. Additional ways to let the user extend STK using plugins, interface to STK externally through scripting interfaces, and develop custom applications using the C# interface in this paper. From the top level of the STK object model, which is 'AgStkObjectRoot,' all the other object interfaces can be accessed. It can also provide methods and properties to load scenarios, create new ones, and obtain the object model unit preference. Next, the 'IAgStkObject' exposes methods and features common to all STK objects such as name, type, parent, children, path, data providers, access, etc. All parent or child objects inherit from the 'IAgStkObject' (satellite, facility, coverage definition, chain, sensor, transmitter, etc.). Besides, Objects expose an interface that contains properties and methods that are specific to the object type (IAgSatellite, IAgTarget, IAgTransmitter, etc.). Lastly, 'IAgStkObjectCollection' holds children objects of an object & the collection of object exposes and methods to iterate or enumerate children, create new objects, or unload the existing ones. The data providers allow the users to access data associated with an object, including every object that inherits from 'IAgStkObject' exposes the data provider properties. There are three types of data providers: fixed, time-varying, and interval. The fixed data provider does not change over time, like the position of a facility, the central body of an object, etc. But the time-varying data provider changes over time and therefore must be executed over a user-supplied time range and step size (such as satellite position, sun angle, sensor pointing, etc.). The interval data provider only exists over an interval of time, for example, access, link information, sunlight/umbra etc. In general, data providers are easy to view in the STK report and graph, which is the best way to determine data provider name, group name, element names, etc.

The objective of this research is to develop a link budget analysis tool for the satellite communications using the STK® software interfaced with the C# Visual Studio platform. In this paper, the STK® programming interfaced with the C# Visual Studio designed in such a way that it is easy and convenient for the users. As such, all the users must do is providing the inputs related to the satellite communication link, without even knowing the overall set up of the RF satellite communication platforms. Also, the users who are not familiar with the orbital mechanics, where all the working principle of orbit propagators and related orbital parameters, can be easily provided by this tool. The orbital components are the parameters required to distinguish a specific orbit exceptionally. In orbital mechanics, these components considered in two-body frameworks utilizing a Kepler orbit. There is a wide range of approaches to portray a similar orbit scientifically, yet specific plans, each comprising of a component of six parameters, are generally utilized in orbital mechanics. A precise orbit and its components change after some time because of gravitational irritations by different items and the impacts of general relativity. A Kepler orbit is a glorified, numerical estimate of the orbit at a specific time. All such kinds of mechanics and working principles handled by the developed tool itself. All the user must do is providing the orbital mechanics input parameters related to the six orbital elements. These elements are semi-major axis, eccentricity, inclination, argument of perigee, right ascension ascending node (RAAN), and true anomaly. And the type of propagators to be used is also necessary. A propagator is a model whose objective is to determine the position of the satellite at any instance of time, with a given acceleration and initial velocity. If the assumption of the earth is spherical and only the earth's gravitational field is affecting satellite motion, then the problem would be easy to solve. But the issue arises when other factors like earth oblateness, gravitational force from moon and sun, atmospheric drag and solar pressure come into play. All these kinds of complex orbital mechanics calculations are taking care of by the link analysis tool. Afterward, the results, including both the numerical and graphical effects, will be displayed on appropriate displaying windows.

2. METHODOLOGY

Fig. 1 shows the way toward creating and confirming link budget analysis programming in STK® program. When recipe and parameter is distinguished, the link budget framework can be customized, and its link budget analysis tool can be structured utilizing STK® software interfaced with the C# visual studio platform. Link budget computation comprises of numerous recipes, a few equations and parameters used by importing predefined packages from the STK® with the help of the C# interface.

The developed link analysis tool has necessary components (Figs. 2 and 3) such as, menu, used to create input parameters. This input system includes (1) Scenario: - which provides time, link types, and propagator selection. (2) Facility: - which defines the ground station parameters, including the minimum elevation definition part. (3) Satellite: - which provides the orbital parameters of the spacecraft, such as semi-major axis, eccentricity, inclination, argument of perigee, RAAN, and true anomaly. (4) Ground station and satellite transmitter & receiver parameters: - which defines transmitters and receivers' parameters, including the antennas and sensors specifications used within the respective parameters. The ground station transmitter parameter consists of frequency, power, data rate, transmitter model including simple and complex model, and the type of modulator (i.e., BPSK, QPSK, etc.) are defined. The ground station receiver parameter provides a receiver model including simple and complex receiver, losses related between LNA and receiver, LNA gain, and link margin (i.e., the minimum strength of signal required (in dB) for meaningful satellite communication). The spacecraft or satellite transmitter and receiver parameters are designed in the same way as the ground station transmitter and receiver as it's explained above. The antenna parameters specification both for the spacecraft and the ground station are available in the spacecraft and ground station transmitter and receiver parameters. The only difference in the antenna parameter specifications for the satellite and ground station is that at the ground station, all the transmitter and receiver antennas have a connection to some sensors which act as the antenna rotor to track the satellite as it goes by the ground station. This antenna rotor is defined as a sensor with some cone angle in the developed link analysis tool. Also, the users can select the type of antennas they want or import an external antenna pattern if it is needed. Besides, the user does not worry about the attitude and sun pointing of the satellite or communication to the ground station, which is handled by the link analysis tool itself. The other components of the link analysis tool are simulation, file, export, graphical report, and help parts. The simulation components can provide the 'compile' and 'run' function once the user provides all the inputs. Before 'run,' the user can compile for some errors so that it can be corrected. The file component gives a filing function such as saving as a scenario for more professional analysis once created by the link analysis tool, opening, and copying. In the export component of the tool, it is possible to export the data generated as an excel file, and the generated graphical data as an image file. The graphical display component provides the visual display means for the link analysis tool result. Also, if the user requests some help on the link budget analysis, it can be provided by the 'help' and 'search' component of the link analysis tool.

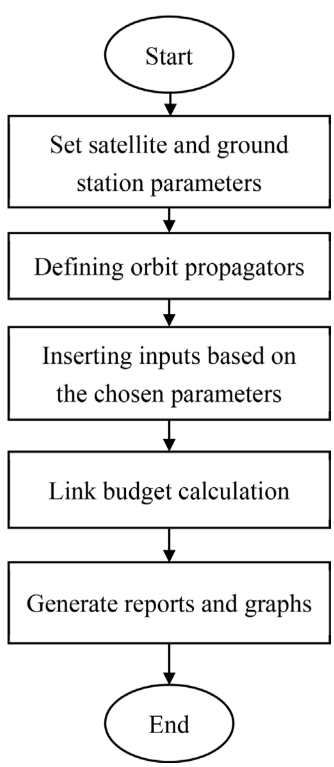


Fig. 1. Flowchart for link analysis using the developed tool.

In general, the design of the link analysis tool consists of five main parts. The first part of the interface is to set the satellite and ground station parameters of each link type.

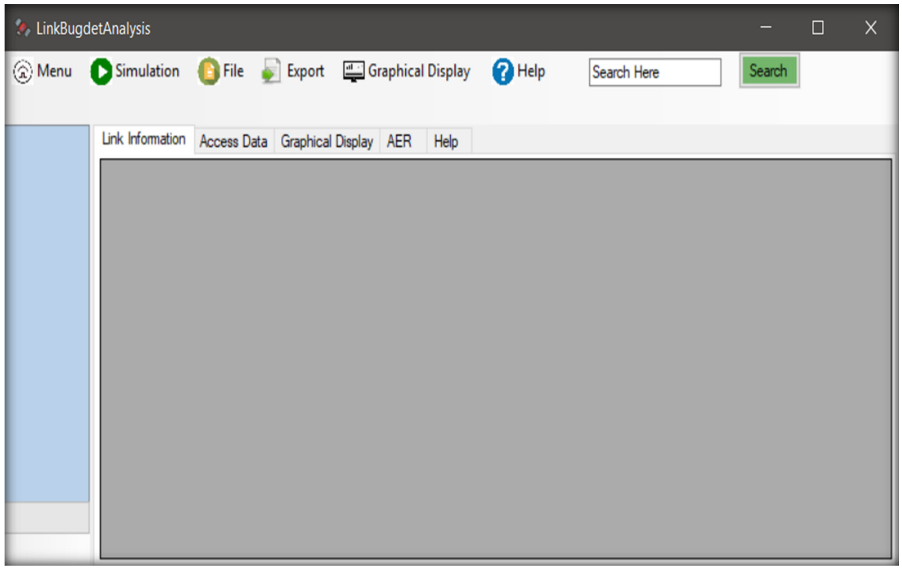


Fig. 2. The overall overview of the link budget link analysis tool.

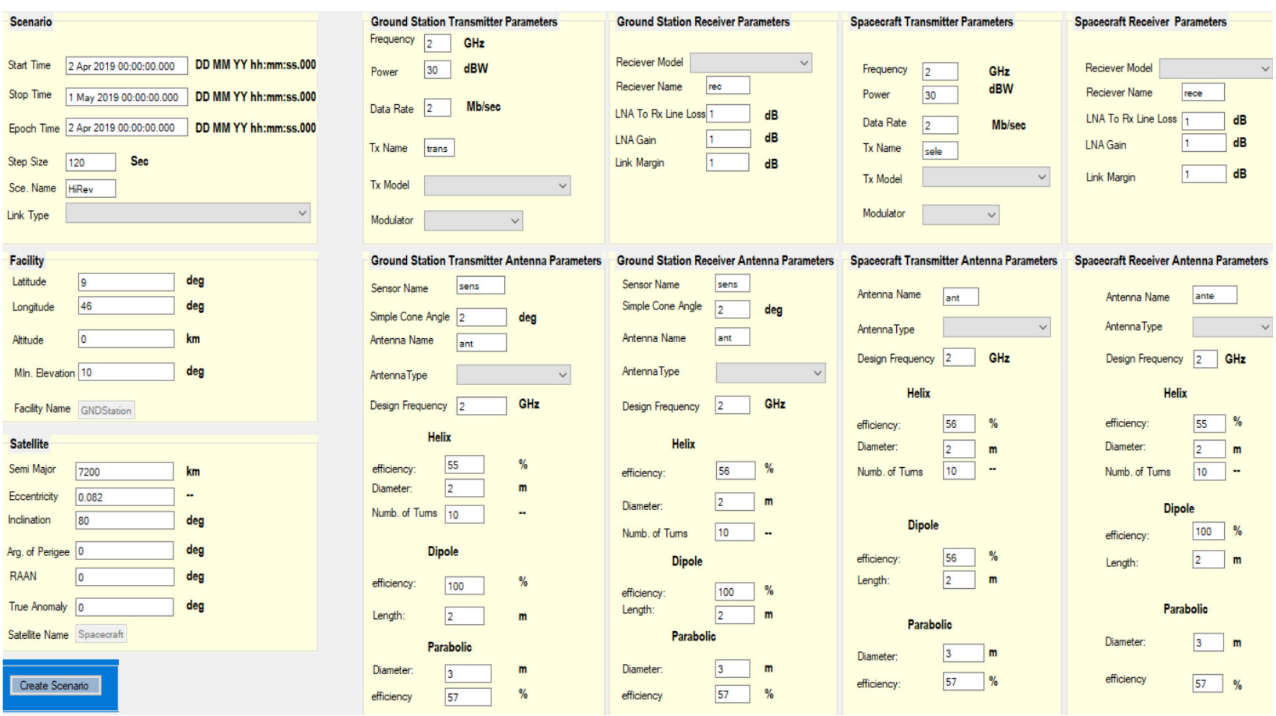


Fig. 3. Input parameters needed for the link budget analysis.

There are two sorts of connections: the first is a link type in which the satellite is a transmitter, and the ground station is a receiver. And the second type of the link is the satellite acting as a receiver and ground station as a transmitter. Once we set the parameters related to the satellite and ground station, the second part of the interface is applied, which is to define the orbit propagator. The orbital dynamics for this propagator are taking care of by the link analysis tool, in which the user does not has to worry about it. The user selects the propagators (e.g., two body, J2, etc.) needed for the mission using the link analysis tool. The third part of the interface is useful to insert the input based on the chosen types of links using the designed link analysis tool. The data related to those parameters are provided by the menu (Fig. 1) component of the link analysis tool, as explained above. The fourth part of the interface is to calculate and process the overall link analysis depending on the given input parameters. Finally, the fifth part of the interface is necessary to display the generated numerical or reports and graphical data on the appropriate displaying windows. The statistical data generated will show on the link information, access data, and azimuth-elevation-range (AER) displaying windows. And the visual results for the link analysis are displayed on the graphical display windows.

3. RESULTS AND DISCUSSIONS

The link budget investigation or analysis tool developed is to assess signal misfortune (losses) factors during spreading (propagation) as the transmitted information signal from the sender travels through a channel (free space path) to the receiver in a satellite communication system. In the satellite communication link analysis, it needs to determine whether the strength of the established link is good enough to form a meaningful communication or not. Finding the reliability of satellite communication is possible by designing a proper link analysis tool that provides needed link information, including the link margin for the satellite communication. The link margin is one of the most critical link information which provides the minimum signal strength (i.e., ~3 dB for satellite communication) required to establish closed link analysis. Unless supplied with such kind of information, there is no way to confirm whether a closed link will exist between the satellite and the ground station. The developed tool provides such type of information related to the satellite communication link efficiently and easily for the users.

In Table 2, mission input parameters are given for the demonstration of the results using the developed tool. The objective of the mission is earth observation, which takes images over the Ethiopian region (Adama City), which defined in the mission definition part of the table. All the orbital parameters for the mission are available in the mission orbit specification (i.e., semi-major axis, eccentricity, inclination, etc.). The ground station parameter, including the facility location and the minimum elevation required for the line of sight communication, is also provided. Once the parameters related to satellite or spacecraft and ground station are defined, the specification of the payload and antennas parameters to be used is in the payload types and ground station antennas specification. The design frequency of 2 GHz and a data rate of 2 Mbps with a scenario times of 1 Apr 2019 00:00:00.000 UTCG to 7 Apr 2019 00:00:00.000 UTCG. With the given input parameters of the corresponding spacecraft and ground station, it is necessary to determine the reliability of the established link through the analysis of the link information both from the numerical and graphical data.

Before the demonstration, a discussion of the essential components of the link budget analysis (Fig. 4) is useful. For the satellite communication link, there are two sorts of connections to be analyzed. The first type is a link in which the satellite is a transmitter, and the ground station is a receiver. In the second type of the link, the spacecraft is a receiver, and the ground station is a transmitter. Whether the first or the second link is selected, they both have a transmitting and a receiving party. All the components related to those link types need to be known. Then it is given as an input to get a reliable solution of the link budget analysis. For both the transmitting and receiving parts, there is a respective antenna connected to each component. Also, cable or feeder line specifications between the transmitter and receiver with their corresponding antenna must be specified. In satellite communication systems to strengthen the transmitted signal, an amplifier is necessary, and to change the low power received signal wave due to propagation effects LNA

Table 2. Mission example (demonstration samples) for the satellite communication link budget analysis

Parameters		Values
Mission	Earth observation	Taking images over the ethiopian region
Mission orbit	Semi-major axis	7,278.14 km
	Eccentricity	0.082
	Inclination	80°
Ground stations	Adama GS latitude	8.5263°
	Adama GS longitude	39.2583°
	Minimum elevation angle	12°
Payload (2)	S-band transceiver & gain	8 dB
	Data rate	2 Mbps
Ground station antennas	Type	Parabolic
	Diameter	3 m
Design frequency	Tx & Rx model, modulator	BPSK
	Model	Complex
	Scenario times	1 Apr 2019 00:00:00.000 UTCG to 7 Apr 2019 00:00:00.000 UTCG

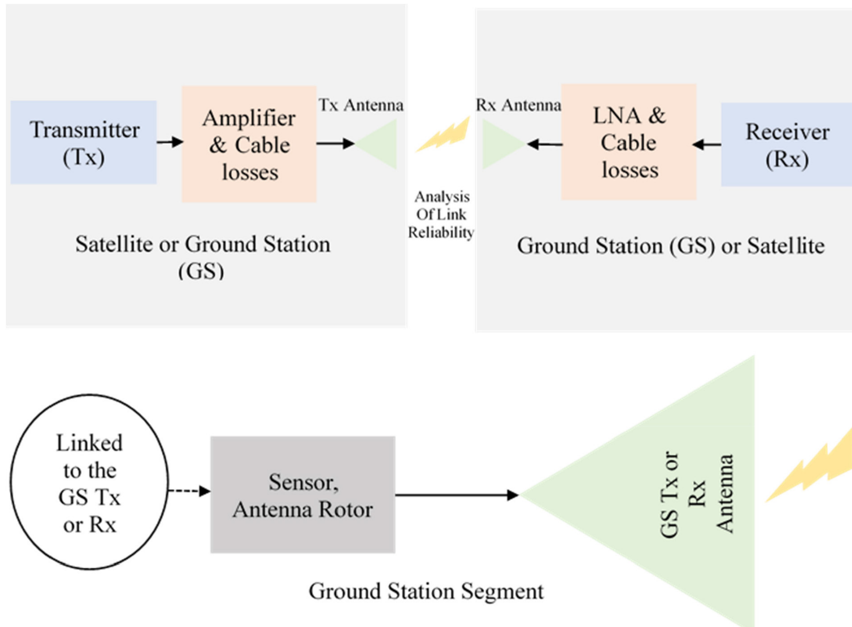


Fig. 4. RF Components of link budget analysis for satellite communication system.

is used. All the antennas have internal links to their respective transmitter and receiver. In the ground station segment, all the antenna is connected to a sensor (antenna rotor) to track the moving on-orbit satellite as it goes by the ground station. Also, the antennas at the ground station need to have a specified minimum elevation angle values to avoid the signal blockage due to the surrounding mountains, significant buildings, and other interfering things near the ground station.

Using the developed link budget analysis tool shown in Fig. 2 with the input parameter example provided for the mission shown in Table 2, the link budget calculation demonstration is provided. The first step in finding the link budget analysis is identifying the link types to be used (Fig. 3). For the mission example given, the payload attached to the satellite is a transmitter, and the ground station is acting as a receiver with the given corresponding antenna parameters. So, choosing the second type of link, which is link budget from ground station 'Rx' to spacecraft 'Tx,' only the parameters associated with the given mission example will be active (Fig. 5). Once the link type is selected, the user does not worry about the attitude determination, the sun pointing, satellite tracking, antennas links with their respective transmitter and receiver, and any communication chains in general. All the tasks mentioned above are to be handled by the tool inside by itself. The requirements of the user are providing all the information's related to the scenario, facility (ground station), satellite (spacecraft), ground station receiver parameters, GS receiver antenna parameters, spacecraft transmitter parameters, spacecraft transmitter antenna parameters depending on the mission example in Table 2. In the ground station segment, the sensor specification, which acts as an antenna rotor, also must be provided as an input from the user.

Once the appropriate input parameters for the mission example provided, the link budget analysis is possible to simulate over a scenario time given as from 1 Apr 2019 00:00:00.000 UTCG to 7 Apr 2019 00:00:00.000 UTCG which is one week. The analysis is to be handled by the simulation part of the interface, which has a 'compiler' and 'run' part. The compiler looks for any errors in the given input parameters or misused input parameters, so that it is possible to take some measures. After compiling, the interface can run the overall satellite communication link analysis. Once the link budget analysis simulation is over, the result display will show on the appropriate windows as numerical and graphical data. The numerical displays are through link information, access data, and AER windows (Figs. 6 and 7). The graphical data are displayed using the graphical display windows. Specific limitations or constraints, for example, small flux density at the receiver, limited electrical energy or power, and restricted dimensions, are relevant in designing a satellite communication system. For that reason, link budget analysis is regularly useful to investigate the ability of the link to overcome these kinds of constraints and meet the required minimum specification or link margin. An example of satellite transmitter gain (dB) variation (due to different losses) over one week is shown in Fig. 8, which

(A) (B)

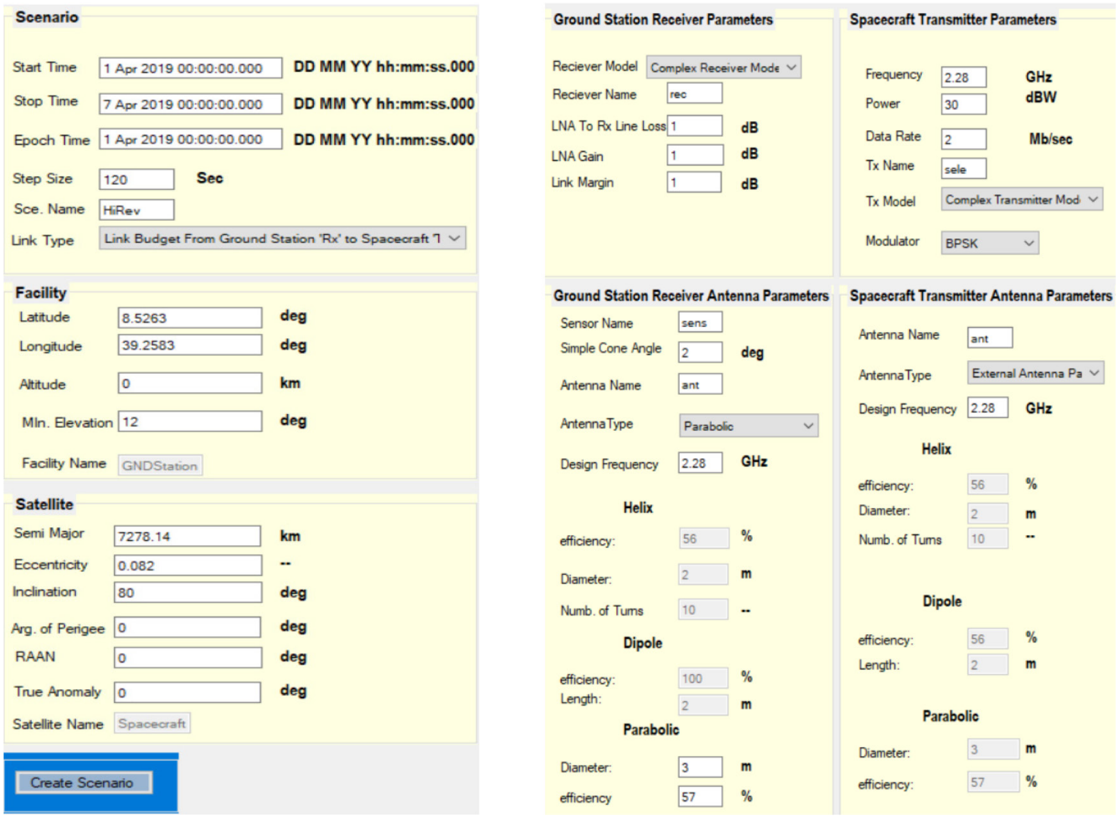


Fig. 5. Input parameters with second type of link types (Link Budget from Ground Station 'Rx' to Spacecraft 'Tx'). (A) Scenario, facility & satellite parameters, (B) GS receiver and spacecraft transmitter parameters.

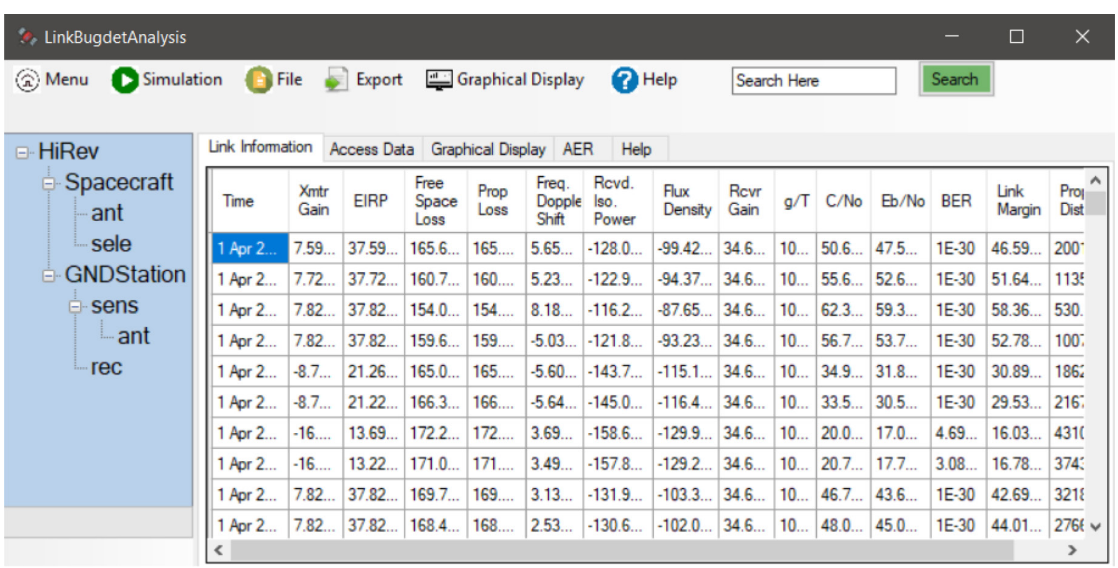
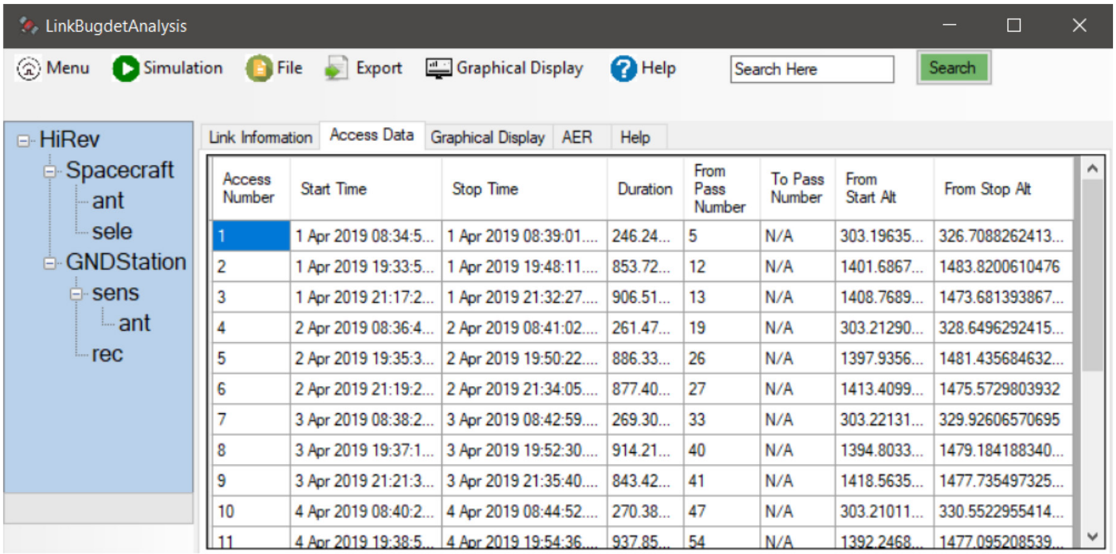


Fig. 6. Display: link information.

is displayed using the graphical display windows. The graphical display window provides a reliable and efficient feature for the users. Some of the features include different graphical plot type is possible (Figs. 9–11) and all the data related to the link information, access data, and AER can be plotted graphically (Fig. 12).



Access Number	Start Time	Stop Time	Duration	From Pass Number	To Pass Number	From Start Alt	From Stop Alt
1	1 Apr 2019 08:34:5...	1 Apr 2019 08:39:01....	246.24...	5	N/A	303.19635...	326.7088262413...
2	1 Apr 2019 19:33:5...	1 Apr 2019 19:48:11....	853.72...	12	N/A	1401.6867...	1483.8200610476
3	1 Apr 2019 21:17:2...	1 Apr 2019 21:32:27....	906.51...	13	N/A	1408.7689...	1473.681393867...
4	2 Apr 2019 08:36:4...	2 Apr 2019 08:41:02....	261.47...	19	N/A	303.21290...	328.6496292415...
5	2 Apr 2019 19:35:3...	2 Apr 2019 19:50:22....	886.33...	26	N/A	1397.9356...	1481.435684632...
6	2 Apr 2019 21:19:2...	2 Apr 2019 21:34:05....	877.40...	27	N/A	1413.4099...	1475.5729803932
7	3 Apr 2019 08:38:2...	3 Apr 2019 08:42:59....	269.30...	33	N/A	303.22131...	329.92606570695
8	3 Apr 2019 19:37:1...	3 Apr 2019 19:52:30....	914.21...	40	N/A	1394.8033...	1479.184188340...
9	3 Apr 2019 21:21:3...	3 Apr 2019 21:35:40....	843.42...	41	N/A	1418.5635...	1477.735497325...
10	4 Apr 2019 08:40:2...	4 Apr 2019 08:44:52....	270.38...	47	N/A	303.21011...	330.5522955414...
11	4 Apr 2019 19:38:5...	4 Apr 2019 19:54:36....	937.85...	54	N/A	1392.2468...	1477.095208539...

Fig. 7. Display: access data.

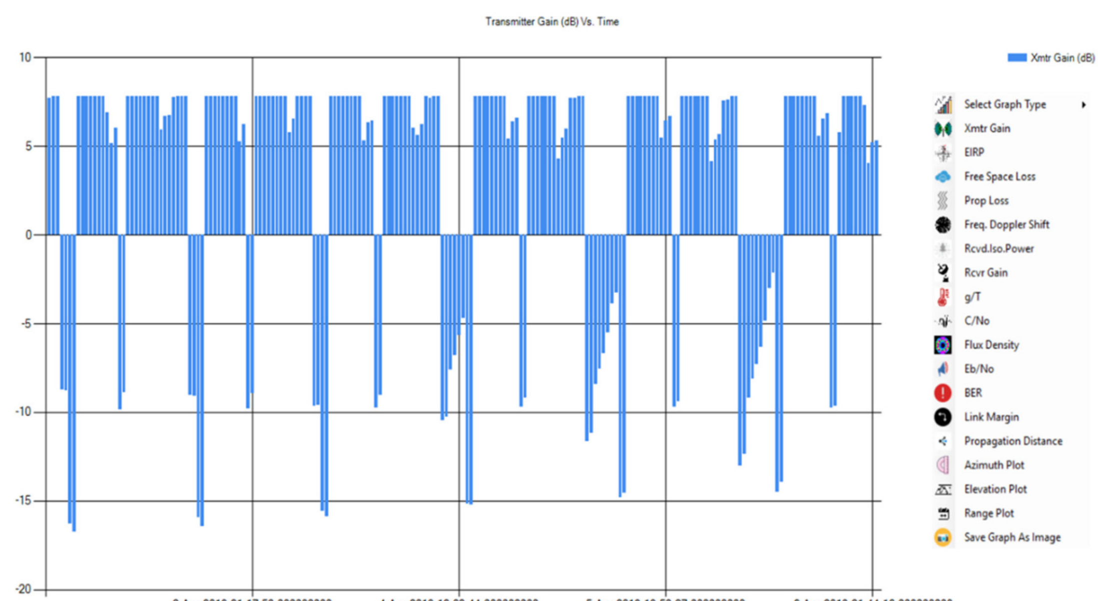


Fig. 8. Graphical displays: Transmitter gain variation over the given scenario times.

The reliability of the established link between the satellite and the ground station should be analyzed using the link information components (i.e., EIRP, BER, link margin, etc.). When evaluating a satellite communication link, at least it is needed to answer the following essential questions. How much RF power (i.e., EIRP) is available and what is the required reliability, which is determined by the BER and link margin evaluation. For reliable satellite communication to establish a minimum link margin of ~3 dB and BER of less than ~10^{-5} is required. For the given mission example (Fig. 11), the link margin almost lies between 20–60 dB, which is more than the minimum necessary link margin. Additionally, BER for the given mission from Fig. 6 is ~10^{-30}, which is almost negligible BER. Note that, those results of the BER and link margin of the given mission example considered for free space ideal conditions for the sake of simplicity and demonstration of the tool. Therefore, different kinds of losses like frequency Doppler shift, free space loss, etc. are minimal. Besides, the LNA also applied to the receiver side, which increases further the link margin and decreases the

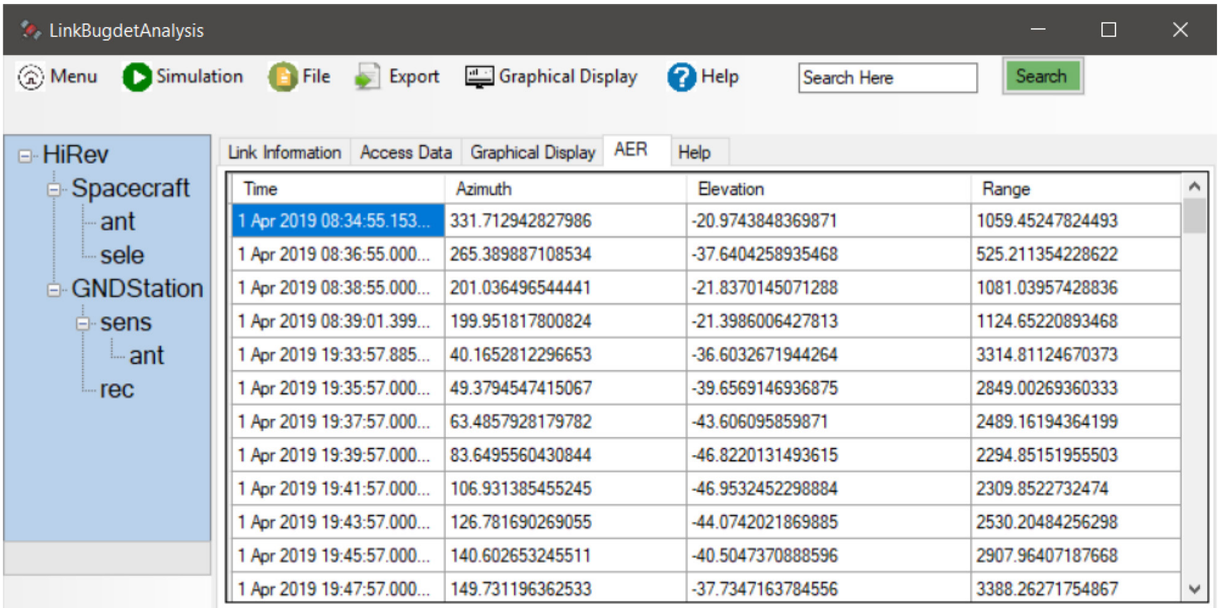


Fig. 9. Display: AER. AER, azimuth-elevation-range.

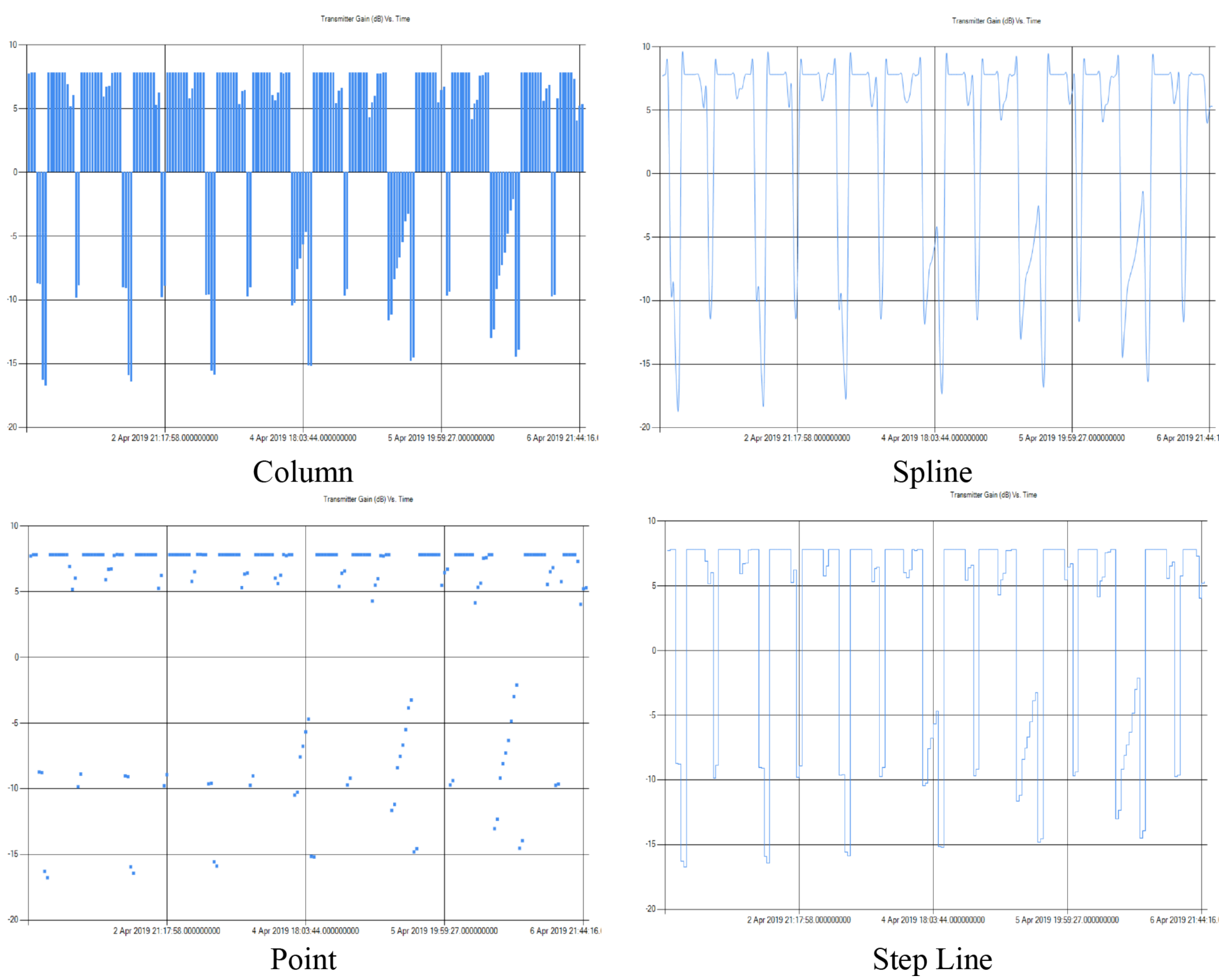


Fig. 10. Transmitter gain variation over the given scenario times using different graphical displaying options.

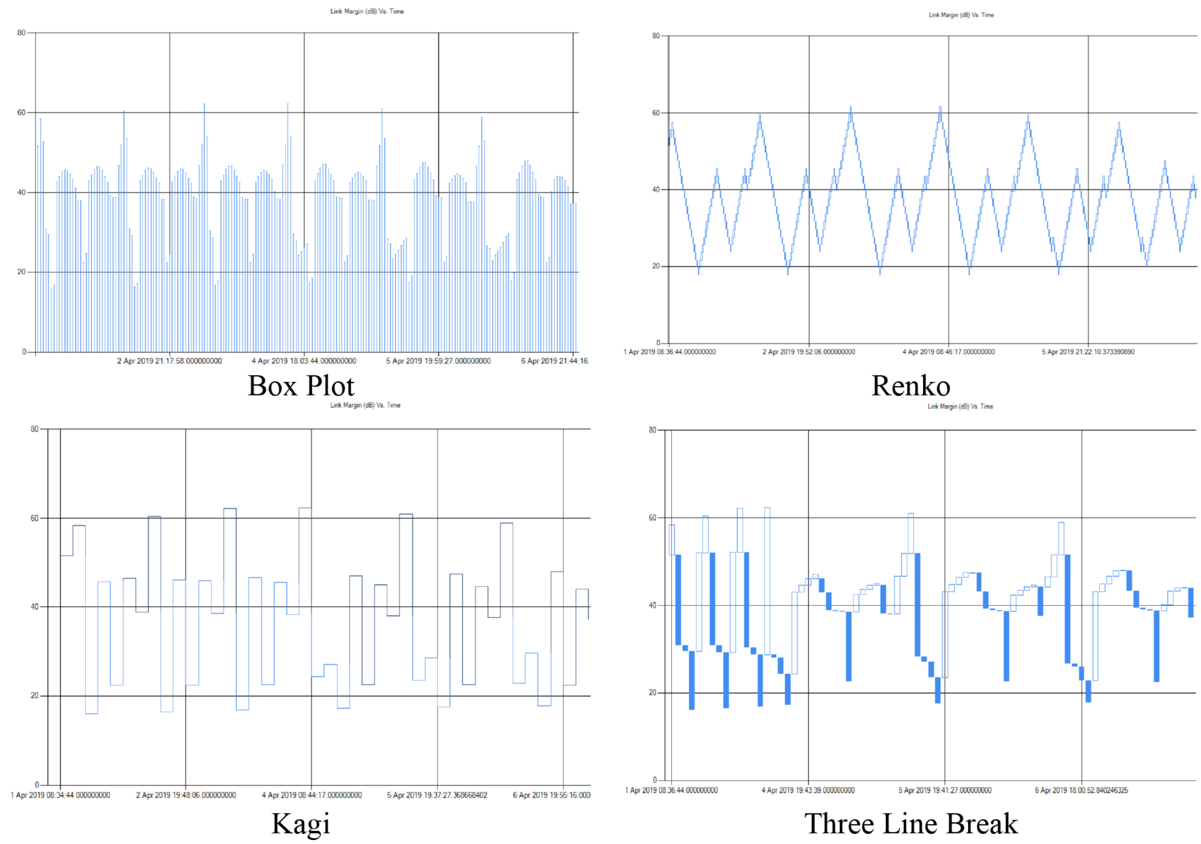


Fig. 11. Link margin variation over the given scenario times using different graphical displaying options.

BER furthermore. Due to these kinds of factors assumed, the BER achieved is minimal, and the link margin seems higher than the minimum link margin provided. From these two basic requirements, at least, it is known that a reliable link budget established. Moreover, from the other link information components, the established link budget can be analyzed in detail. For example, as given in Table 2, the transmitter gains from the satellite, which is an S-band is given as 8 dB. Now, considering some mismatch and cable losses (Table 1), the gain of the signal ready to be transmitted from the satellite is almost around ~7.7 dB (Fig. 6). Since there are different kinds of satellite communication losses as the signal propagates from the satellite to the ground station, a LNA is necessary at the receiver side, in these cases, the ground station. So, using a LNA of 1 dB for the given mission, the receiver gain is around ~34.6 dB (Fig. 6). Also, the quality of the transmitted signal from the transmitter considering isotropic radiation expressed in terms of flux density. The flux density is one of the link information for the link budget analysis, which analyzes the variation of how much radiated power (in dBW) from the transmitter is to radiate in an isotropic direction over a given spherical areas (in m^2) in the given time scenarios. For the given mission example, the power flux density (Fig. 12) varies between –80 to –135 dBW/m^2. Also, the propagation distance variation of the assigned mission scenarios (Fig. 12) as the times goes by, which is between ~400 km to 4,500 km over the given simulation period, is provided by the tool. Therefore, the reliability of the established satellite communication link analysis is possible with the given link information. Also, access data and AER reports provide more information about the status of the established link for satellite communication. For instance, in Fig. 7, the access reports for the link is generated. It includes the start and stop time of each access between the satellite and the ground station for the given mission scenario. Besides, it provides for how long, which is a duration; each access is lasting with a starting and stopping altitude is as well demonstrated in detail. For the given mission over the given scenario simulation, there are 18 access numbers (a total contact number between a satellite and ground station at a specific time windows) with a different time interval window at a different accessing point generated for the given mission scenario. In Fig. 9, the azimuth, elevation, and range variation of the established link between the satellite and ground station as the time goes by for the given scenario time interval of the mission

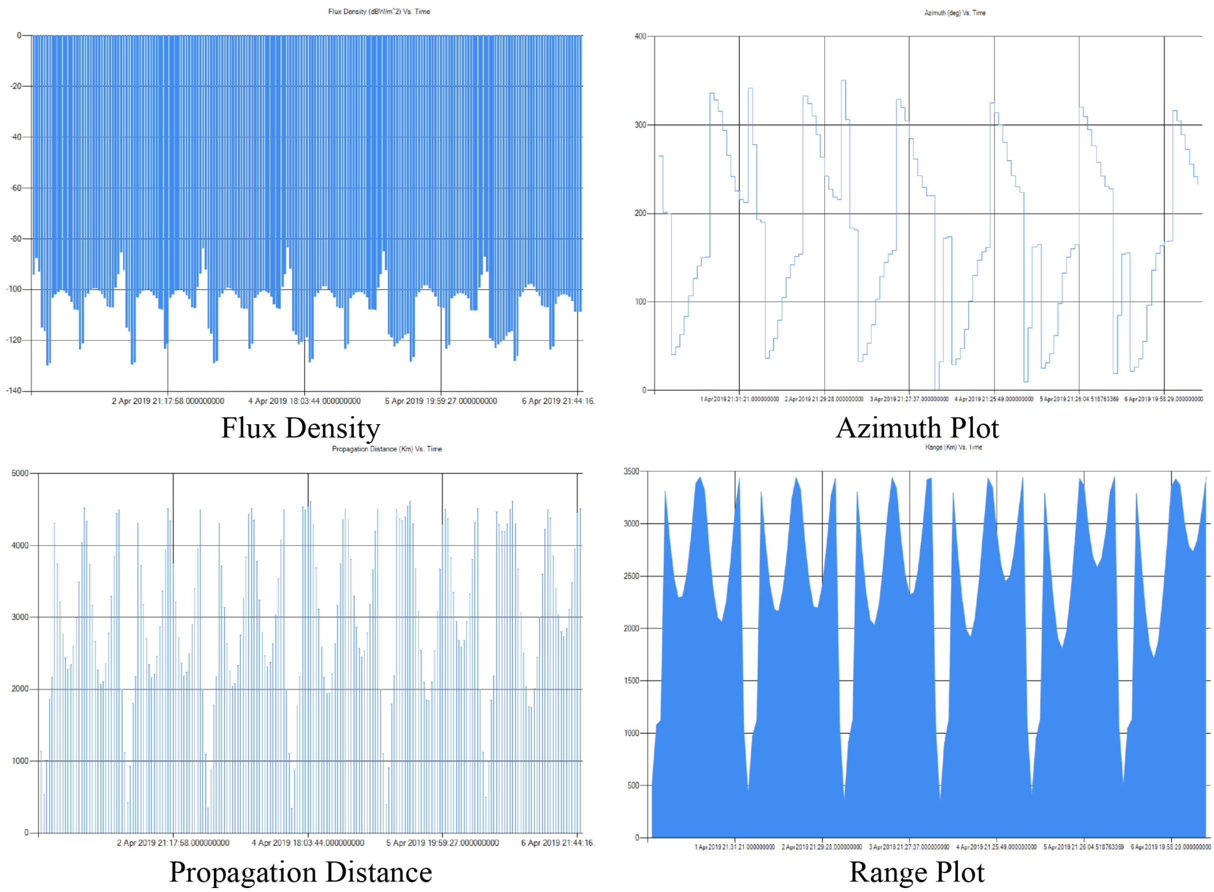


Fig. 12. Link information's graphical display samples.

successfully generated.

In addition to the numerical and graphical data generation related to the satellite communication link analysis, the interface provides some extra features. These features include (1) Exporting all statistical data as an excel file. (2) Saving the satellite communication system designed as a scenario which can open using the STK® software for further professional analysis. (3) Saving the graphical data as an image file (numerous kinds of an image file are possible i.e., JPEG, PNG, bitmap, etc.). (4) Importing an externally designed antenna pattern (which constructed from phi, theta, and pattern value of the antenna). (5) Help window, search tab, and the generation of the tree view of the overall RF platform for the satellite link analysis are some of the features to be mentioned.

4. CONCLUSIONS

A link budget analysis tool using STK® software successfully developed. The link budget investigation is an essential tool as it explores all the regions, gains, and misfortunes (losses) that may happen between the sender (transmitter) and receiver of a satellite communication framework. The developed tool provides an efficient and user-friendly way of analyzing the problems related to satellite and ground station link budgets. Also, the tool can be used by the users who are not familiar with the orbital mechanics of the spacecraft. Orbital mechanics is the application of celestial mechanics to the practical problems concerning the motion of the satellite in each orbit. For this purpose, a propagator is useful, which is a model whose objective is to determine the position of the satellite at any instance of time, with a given acceleration and initial velocity. If the earth is assumed to be spherical and only the earth's gravitational field is affecting satellite motion, then the problem would be straightforward to solve. But the issue arises when other factors like earth oblateness, gravitational force from moon and sun, atmospheric drag and solar pressure come into play. All these kinds of complex orbital mechanics calculations are taking care of by the link analysis tool itself. It is efficient in the sense of the low computational time needed for the link budget analysis. In addition to the fast analysis time, the interface provides the easiest link analysis for the satellite communication system. This tool can be useful for amateur users who may not know about the RF system of the satellite communication system, such as CubeSat developers in the universities. Besides, various reporting techniques, including the graphical display, is possible and helpful to understand the satellite communication link system.

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