DEVELOPMENT OF AN INTUITIVE LINK BUDGET TOOL FOR MILITARY SATELLITE COMMUNICATIONS

BY

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ABSTRACT

Nowadays, the military needs to send and receive high quality videos, audios and pictures despite the all-year-around rain occurrences experienced by tropical countries including Malaysia. When it rains, military troops are then expected to adjust accordingly different parameters of their satellite communication (satcom) equipment. Military forces are expected to be highly mobile in all conditions regardless of time, location and weather. In a tropical environment such as Malaysia, where rain occurs almost all year around and in most instances, the rainfall rate is much higher when compared to temperate regions, it is therefore critical to calculate correlation of several factors, such as receiver sensitivity, bandwidth, transmit power, antenna gain and all losses. Military forces are not fixed in only one location. Today a troop might be settled in Taman Negara, Pahang; tomorrow in the jungles of Terengganu and within the next weeks perhaps the platoon could be sent to East Malaysia. Satellite communication equipment are strategic asset and very likely not fixed at only specific locations. They might have been hauled by the military forces from places to places from time to time. Satcom equipment might be carried by one soldier, as well as installed on the rooftop of a military truck depending on the size and measure. Taking into account all facts above, it is therefore essential to develop an Intuitive Link Budget Tool or Tool that incorporates elements of climate conditions, displacement to at specific region at a specified time of soldiers, as well as military trucks. Considering every previously mentioned certainty, it is without a doubt, critical to develop an intelligent real-time link budget tool. An Intuitive Link Budget Tool (ILB-T) that assimilates components namely atmosphere conditions and the troop's locality had been proposed and developed during the study. The proposed ILB-T for military satellite communication was developed using HTML, PHP, Javascript, and MySQL. The performance of the proposed ILB-T was also evaluated for the desired carrier over noise (C/N) ratio using rainfall rate, predicted attenuation over rainfall rate, and specific attenuation based on the rainfall rate. The acquired results suggest that the proposed ILB-T is more efficient in terms of real-time link budgeting compared to that of previously proposed methods.

خلاصة البحث

على الفيديو وأشرطة الجودة عالية الصور واستقبال لإرسال الحاضر الوقت في الجيش يحتاج .ماليزيا مثل الاستوائية البلدان في العام مدار على يحدث هي التي الغزيرة الامطار من الرغم عبر الاتصالات معدات في مختلفة معايير ضبط على العسكرية القوات حاجة تمطر عندما في الاستوائية وموقف الطقس حالة أي في الجيش التنقل لضرورة ونظرا .ل الصناعية الأقمار هو الأمطار هطول معدل فإن ،الحالات معظم وفي حول تقريبا سنة المطر يحدث حيث ،ماليزيا مثل ،العوامل عدة ارتباط لحساب بمكان الأهمية فمن ،المعتدلة المناطق مع بالمقارنة بكثير أعلى ليست .الخسائر من وغيرها الهوائي كسب ،والطاقة ،الترددي النطاق عرض ،المتلقي حساسية أدغال في وغدا ،وطنية حديقة في استقر قد أنه اليوم .فقط واحد مكان في العسكرية القوات ثابتة إجراء يمكن .ماليزيا شرق إلى إرسالها يتم أن يمكن المقبل الاسبوع خلال وربما تيرينجانو كوالا تتم قد .فقط واحد مكان في العسكرية القوات ثابتة ليست معدات (ساتكوم) الفضائية اتصالات عن فضلا ،واحد جندي قبل من المعدات (الصناعية الأقمار عبر الاتصالات) الساتلية الاتصالات تطوير الضروري فمن ،وبالتالي ،أعلاه الحقائق جميع الاعتبار بعين الأخذ مع .عسكرية شاحنة في صارمة منطقة إلى والنزوح ،المناخية الظروف من عناصر مع حاسبة الوصلة ميزانية بديهية ،اليقين كل المذكورة سابقا تدرس .عسكرية شاحنة عن فضلا ،واحد جندي قبل من المحدد الوقت تقترح ،لذلك .الوصلة ميزانية أداة الحقيقي الوقت في وضع خلق أن بمكان الأهمية فمن لذلك وفقا الغلاف الظروف من عناصر مع (ILB-T) بديهية الميزانية ربط أداة ويطور الأطروحة هذه HTML، باستخدام ILB-T المقترح تطوير تم .المحدد الوقت في صارمة لغة إلى نقل ،الجوي C لنسبة أيضا ILB-T المقترحة أداء تقييم يتم ،ذلك على وعلاوة .والخلية ،سكريبت جافا ،PHP على معين وتوهين ،معدل على الأمطار سقوط توهين وتوقع ،الأمطار هطول معدل على N / من كفاءة أكثر هو ILB-T المقترح أن إلى النتيجة وتشير .الأمطار هطول معدل الحقيقي الوقت في الارتباط. الميزانية حيث.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Computer and Information Engineering).

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Erry Yulian Triblas Adesta
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except0 where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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Firstly, it is my utmost pleasure to dedicate this work to my dear parents and my family, who granted me the gift of their unwavering belief in my ability to accomplish this goal: thank you for your support and patience.

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LIST OF SYMBOLS

Notations	Explanation
Lat_E	Latitude of earth station
Lon_E	Longitude of earth station
Lat_S	Satellite latitude
Lon_S	Satellite longitude
H	Earth station altitude above sea level
r_e	Mean equatorial radius
r_s	Geostationary radius
e_e	Eccentricity of the earth
G	Antenna gain
λ	Wavelength
η	Antenna efficiency
d	Distance between satellite & ground station
Pt	Transmit Power
ψz	Azimuth angle

LIST OF ABBREVIATIONS

AJAX	Asynchronous JavaScript and XML
BER	Bit Error Rate
DTH	Direct to home
GPS	Global Positioning System
COOP	Congruity of Operations
C/N	Carrier to Noise Ratio
DoD	Department of Defense
DISA	Defense Information Systems Agency
DITCO	Defense Information
ITU	International Communication Union
ITU-R	International Telecommunication Union-Radio Communication
MEASAT	Malaysia East Asia Satellite
MMD	Malaysian Meteorological Department
HTML	Hyper Text Mark-up Language
RHI	Range Height Indicator
SHF	Super High Frequency
RF	Radio Frequency
SATCOM	Satellite Communication
PHP	Personal Home Page
VSAT	Very Small Aperture Terminal
XML	Extensible Markup Language
GHZ	Gigahertz
EHF	Extra High Frequency
HQ	Head Quarter
PC	Personal Computer
IIUM	International Islamic University Malaysia
MHZ	Megahertz
GEO	Geostationary Orbit

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

It is necessary for soldiers to have access to communication channels. Satellite communication can offer easy access means of communication at tactical level. Reliable transmissions of video, voice and data are critical parts of a successful communication sphere. Figure 1.1 presents a sketch of a satellite communication system used by military applications.

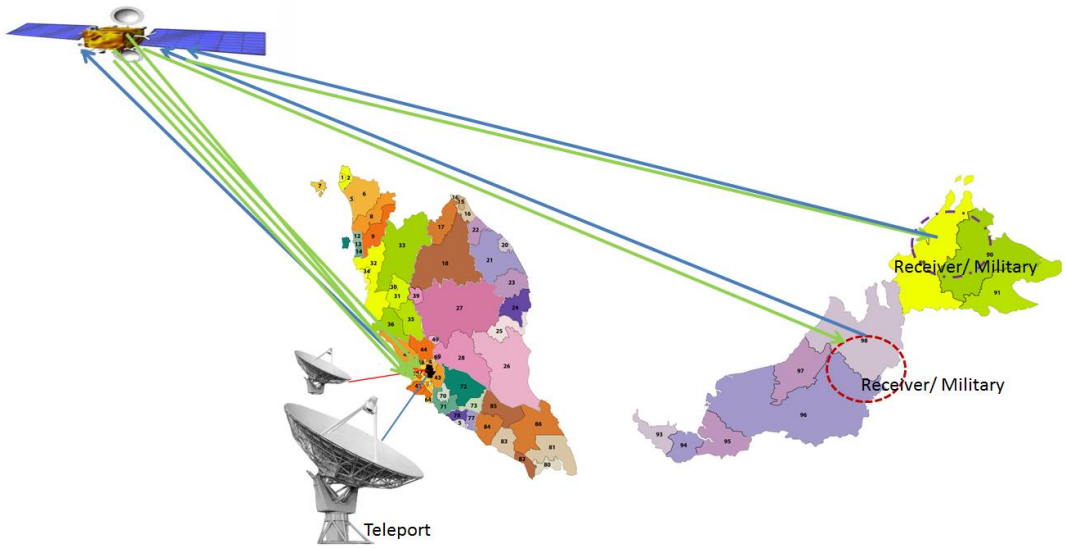

Figure 1.1: A potential Military Satellite Communication Set up

During fights, it is necessary to connect all soldiers, regardless wherever they are. Commanders do not have to concentrate their choices to demonstration of impressive power, while more and more chosen option of dominance in the ISR (Information Systems Research) area in order to unwrap high-precision arming or to provide most

suitable circumstances for their subdivision. It is required to expanse the baseband, however it can be improved only at the expansion of tactical satcom. Most of the systems of military satcom work in Super High Frequency (SHF) X-band (8.0-12.0 GHz) frequency, which have high bandwidth. It is also commonly known as the military band. The properties of X-band satcom equipment are relied upon to be composed particularly for military operations and they are anticipated that would contrast especially to those of commercial frequencies. The satcom will be probably going to be solely intended to low controlled, strategic terminals conveyed over different operations. What's more, X-band connection is moreover expected to offer a more considerable expanded of framework limit because of its higher frequencies contrasted with the herald S-band and C-band. The X-band satcom technology is drawing growing interest from military users including of the Malaysian authorities. Be that as it may, there are numerous parts of X-band that are harder to acknowledge than of those of at lower frequencies. X-band frequencies certainly have higher atmospheric propagation losses, higher RF losses, and certainly much severe signal degradation due to rain.

Considering all aforementioned facts, therefore it is necessary to develop “intuitive” link budget tool for those high frequencies mainly for X and Ka Bands. The word “intuitive” means, that Link budget tool would consider real time atmospheric attenuations, namely rain and location of military troops.

The next section and subsections are discussing the open issues, problem statement and its significance, research scope, research objectives and research methodology. Finally the chapter finishes with the dissertation organization.

1.2 PROBLEM STATEMENT AND ITS SIGNIFICANCE

In view of necessity for army mobility in any condition of weather and the Tropical position of Malaysia, where rain occurs almost year around and in most instances, the rainfall rate is much higher when compared to temperate regions, it is critical to calculate correlation of several factors, such as receiver sensitivity, bandwidth, power, antenna gain and other losses.

Military forces are not fixed in only one location. Today it might be settled in Taman Negara, tomorrow in the Jungles of Kuala Terengganu and within the next week perhaps it could be sent to East Malaysia. Satellite Communication (Satcom) equipment might be carried Military forces may not fixed in only one location. Satcom equipment carrying by one soldier, as well as the military truck. Taking into account all aforesaid facts, therefore it is extremely important to develop an intuitive Link Budget Tool with an element of climate conditions, displacement to strict region in specified time. Another important issue is, if military troop know how much power needs satcom equipment, they would be safe its normal work condition consecutively. For instance, when the military soldier has just arrived at the state Melaka was the sunny day, however on the half of a day has started rain. An operator who is trying to connect this troop with their commander must know which characteristics need to report for adjustment of transmitters from both sides respectively. For this instances, an ideal link budget tool is necessary in order to adjust the configuration of transmitter and receivers. The existing tools that had been proposing with the predictive parameters such as rain attenuation, and rain fall rate. However, due to this predictive parameters the existing tools are not enough precise.

Therefore, considering real-time parameters an intuitive link budget tool design is necessary for the military communications.

1.3 RESEARCH QUESTION

The key question in which research tries to answer is how to develop an intuitive Link budget tool for military satcom, namely for high frequencies (X or Ka – bands). The target band X and KA are suffers by the rain attenuation. The existing link budget tools are not precise for the military communications since, all of the tools are considered offline (predictive) parameters. Therefore, design and development of the link budget tool by integrating the real-time metrological data is challenging.

1.4 RESEARCH OBJECTIVES

The study aimed to achieve the following objectives:

1- To study the link budget parameters for both uplink and downlink communications. One of the key parameter is rain attenuation, due to this rain attenuation X-band military communication systems suffers mostly.

2- To design and develop of an Intuitive Link Budget Tool (ILB-T) for both of the uplink and downlink communications with the integration of real-time rainfall rate data reading from Malaysian Department of Irrigation and Drainage at specific location (namely military troop location). The designed ILB-T is able to differentiate the carrier to noise ratio threshold level at the receiver terminal in accordance with the rain attenuation level.

1.5 RESEARCH SCOPE

Nowadays Military needs to transmit and receive high quality pictures and videos despite on rains which occurs all year around in tropical countries like Malaysia. When it rains military troop needs to adjust different parameters in satcom

equipment's, due to the heavy rain attenuation. From all open issues, this research is concentrating on designing an ILB-T which can calculate characteristics of high frequency bands with the integration of real-time rainfall rate.

1.6 RESEARCH METHODOLOGY

The research methodology in achieving the above stated objectives of this study is discussed below:

- A concrete literature review have done on existing link budget tools. The numerical analysis of link budget models with the loss influenced parameters have studied.
- The ILB-T is designed by using PHP (server side programming, database), HTML, Javascript (client side), Ajax (web applications with the help of XML), and MYSQL server. The real-time data will be measured from the experimental laboratory work (i.e. Malaysian Meteorological Department). Thereafter, a comprehensive assessment has done with the strictness of losses caused by rain to the military X Band. Finally, the designed an intuitive Link budget tool integrated the real-time rainfall rate data and position of military troop.
- The outcome of this study have published one conference proceeding paper and a Scopus indexed journal paper, and a dissertation is produced and submitted to the department of Electrical and Computer Engineering, International Islamic University Malaysia.

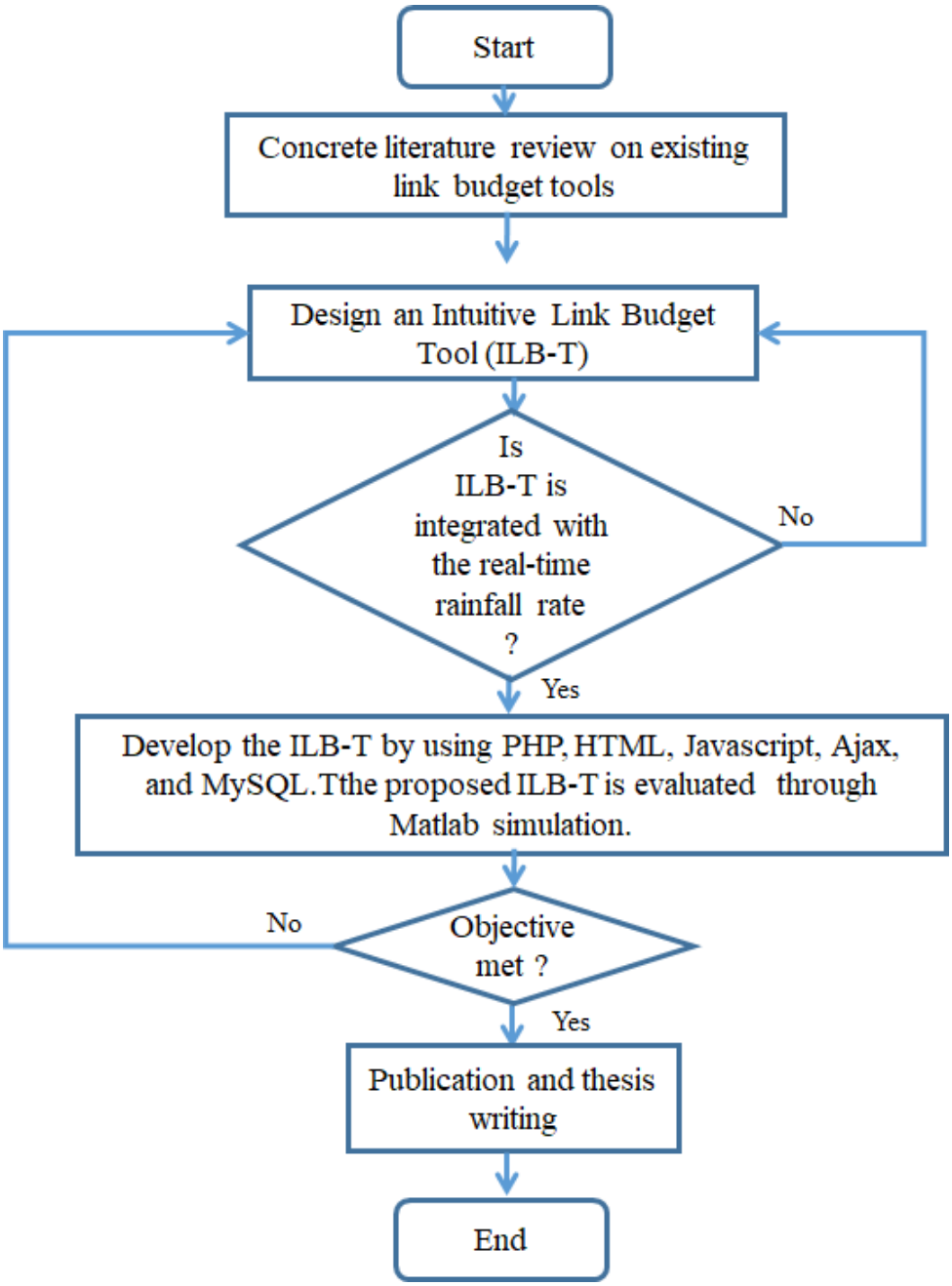

Figure 1.2: Research methodology flow chart

1.7 DISSERTATION ORGANIZATION

This dissertation is organized as follows:

Chapter one provides a overview of link budget for the Malaysian Satcom. Then, the problem statement, objectives, research approach and scopes are mentioned in depth.

Chapter two presents an overview of the existing link budget models with the advantages and shortcomings. It continues with the brief discussion and evaluation of the existing techniques and models for the Satcom.

Chapter three explains the methodology proposed in details to achieve an intuitive link budget tool model for the Royal Malaysian Army communication system. It is also calculate threshold level of carrier to noise ratio (C/N) through an intuitive link budget estimation. The model also calculate different path loss based on longitude and lattitude of the millitary troop location. This tool can also measure the rain attenuation at the area of the military terminal receiver. Besides calculating the threshold of C/N level, path loss and rain attenuation, this tool facilitates the changes of few critical parameters such as bandwidth of the receive antenna, rainfall rate, location (longitude, latitude) and transmitted power

Chapter four highlights the results and performance analysis for the proposed tool and chapter five concludes with an overall summary as well as a list of recommendation for future work.

CHAPTER TWO
LITERATURE REVIEW

2.1 INTRODUCTION

Nowadays the Malaysian Royal Army is using own transponder on X-band frequency. Satellite to earth communication system in tropical regions such as Malaysia is limited by attenuation due to rain. This study will propose an intuitive model to be use by the Royal Malaysian Army. This section will explain the relevant models and tools that are already existed and applied to be compared in this region.

The basis of my research is considering Malaysian Satellite MEASAT 3b, which was successfully launched at 12 September 2014. According to Nuroddin et.al (2013) the propagation impairment is explained and the consequence is indeed be quite severe for Malaysian tropical climate to consider X-band transmission for military Satcom. Therefore, it is essential to develop application which will consider close to real-time data. Consequently it will inform the parameters for satcom equipment for the military troop, as well as to know bandwidth, power, antenna gain, signal sensitivity (C/N) in rainy and clear sky condition respectively. The link budget tool is an application for computing signal strength through a frequency link using various components and determine, whether acceptable information signal can be received.

2.2 SATELLITE COMMUNICATION SYSTEMS

These days, satellite designs are more customized for a specific operation which is driven for the long run necessities. The subsystems are additionally designed with high reliability which required vital changes for one satellite to another. In spite of the

fact that it suggests spacecraft greatly skilled to satisfy its main goal, secluded, minimal effort and little outlines are the present pattern. It implies a prospect for scholastic foundations and little associations' access to space. Manufactured satellites have various approaches to be ordered, by capacity, kind of circle, cost, execution, size, and this last has a course in the cost, with the end goal that in scholarly ambit is the most significant element. Table 2.1 presented satellite classifications as per mass [1].

Table 2.1: Satellite classification

Satellites	**Mass**
Large Satellites	Less than 1000 kg
Mini Satellites	100 to 1000 kg
Micro Satellite	10 to 100 kg
Nano Satellite	1 to 10 kg
Pico Satellite	0.1 to 1 kg
Femto Satellites	1-100 kg

The Satcom which remains for "satellite Communication", is an artificial satellite. The employments of Satcom are given as below:

a) Interactive voice, video, or information systems for applications, for example, remove learning and telemedicine.
b) Communications progressing answers for Department of Defense (DoD) applications.
c) Broadcast satellite administrations with system operations and administration bolster.
d) Network differing qualities/congruity of operations (COOP) systems, for example, VSAT reinforcement systems.
e) Emergency reaction and calamity recuperation correspondences frameworks.

f) Long span, standard correspondences administrations and foundation to bolster persisting client necessities.
g) Short duration communications services to support temporary user requirements.
h) Satellite transport (bandwidth).
i) Fixed or mobile satellite service.
j) Service-enabling components such as terminals, handsets, and tail circuits with engineering services to integrate, operate, and maintain the solution.

The above operations need to be finished by transmitting signals from earth to the geo-stationary satellite that receives, processes gets, opens up and transfers the signals down to Earth. It is a capable type of radio and can cover significantly more separation and more extensive zones than most other radio innovations. It can transmit with words, pictures and different types of data. More often than not, DoD customers ought to experience Defense Information Systems Agency (DISA) and Defense Information Technology Contracting Organization (DITCO). The military interchanges are essentially utilized for the radio correspondences with the Head Quarter (HQ) which incorporates interface spending plan, climate estimating, and mapping. With the assortment of satellite recurrence groups that can be utilized, assignments have been created so they can be alluded to effectively. The higher recurrence groups ordinarily offer access to more extensive transmission capacities, but on the other hand are more helpless to flag corruption because of 'rain blur' (the ingestion of radio flags by air rain, snow or ice). In any case, military interchanges utilizes just saved X-groups, however the correspondence interface endures by the rain blur, and some different misfortunes.