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Link Budget Analysis for Underwater Communication System

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Abstract: **Link-budget analysis is the method to get the link margin of the underwater acoustic communication and it considering the transmitter signal power, transmitter antenna characterizes, propagation losses, channel ambient noise, and receiver antenna characterizes. Link-budget analysis is commonly applied to satellite and wireless communications for estimating signal-to-noise ratio (SNR) at the receiver. Underwater signal and the terms of the sonar equation translate easily to the formulation of the link budget. However, the high frequency dependence of the diffusion of underwater acoustics requires special attention, and is the result of an argument called signal to noise ratio channel. And compared too many of the problems of communication and voice navigation through link analysis of the large-scale budget. Link budget is applied to voice communications system using the same principles sea radio link budget. Three case studies have shown audio link budget of the utility systems in the design of broadband communications. Link budget is a useful tool in the perceived impact of the channel on the transmitted signal and evaluate the consequences of the strategic wireless transmission. Aim of this case of the research is design wideband frequency underwater acoustic communication system and comparative study of link budget analysis for underwater communication with the attenuation of the underwater channel by means of the modeling in the MATLAB software. Find out the channel conditions of the underwater acoustic communication in the wideband frequency are strongly range dependent due to underwater attenuation and interference noise.**

Keywords: **Link Budget, underwater communication system.**

I. INTRODUCTION

The availability of affordable and sophisticated digital signal processing has enabled modern undersea acoustic communications systems. Advances in this field have opened the door to autonomous sensors and untethered vehicles capable of networked operations in the undersea environment. For radio frequency (RF) communications, link budgeting is commonly used to predict system performance in a representative environment. The link budget estimates the signal level at the receiver for a given transmit power and antenna configuration and accounts for environmental factors such as transmission loss and interference. This project shows that the link budget can be readily applied to an undersea acoustic communication system using the same principles as the RF link budget. The acoustic link budget combines all terms of the active sonar equation to provide a first order approximation of signal available at the receiver. Link budget is a method for studying the effect of ambient noise such as wind speed, shipping density and thermal noise on the underwater acoustic signal. It analyses the link margin at the receiver. The link margin is the difference between the required power to noise ratio and the receive power to noise ratio at the receiver. The link budget for underwater acoustic signal estimates the signal level at the receiver for a given transmit power and antenna configuration and accounts for environmental factors such as transmission loss and interference. Link budget analysis for underwater acoustic channels is considered as one of the means of communication more difficult today. Attenuation coefficient of the underwater acoustic supports deployment to the best acoustic low frequencies and bandwidth available to communicate is very limited. Underwater communications that used wireless acoustic communication have several of applications in underwater war. So, Implementation of security wireless underwater communications is of great important to extend the network war under the water. However, underwater acoustic communication is the effect of ambient noise on the signal so the ambient noise is reduces the signal to noise ratio limited by the result is reduce the link margin. So in this project we will use the link budget analysis for underwater acoustic communication to improve the signal to noise ratio so the result is increase the link margin. The link margin is the difference between the received signal to noise ratio and the required signal to noise ratio.

II. LITERATURE REVIEW

The scope of the current chapter was to provide a general insight into the underwater acoustic environment for system design purposes. "During the analysis, we observed that despite the similarities to the wireless networks, underwater communications are different from RF communications for several reasons [1]." Firstly, underwater communications use acoustic pressure waves to propagate through the medium instead of electromagnetic waves. Secondly, the underwater medium strongly attenuates frequencies and therefore the bandwidth available for communications is very small compared to that of RF channels. Link budget for underwater noise can be attributed to different categories of sources: Natural physical processes, biological sources, and anthropogenic sources. Common contributors to the ambient noise budget at frequencies included in this study include wind speed, thermal noise, ship traffic, and biological sources. A more accurate link budget analysis would not ignore the effects of scattering at the surface and bottom of the communications channel. One possible solution would be an additional term in the attenuation factor based on the mean bottom roughness and sea-state. This term would introduce additional losses due to the scattering effects of boundary interactions. Such a term would also be dependent on the sound speed profile to account for the increase in boundary interactions caused by gradient induced sound refraction. All developments of underwater acoustic communication systems depend on the development of the electronic devices and communication technology. So, to review study of underwater acoustic communication, three theses for three authors were chosen because of their close to the subject of my research. In [1]Houdeshell, is design underwater acoustic communication system operates in frequency band 1-10 kHz and utilizes various form of signal processing to improve data rate. In [5] Hansen, J. T. have shown system to communicate with telesonar link distances up to 5 Km. the system operates at 9-14 kHz using Omni-directional transducers.in [4] Dessalermos, S. Is developing of an adaptive receiver for underwater communication. In this type of wireless link, the radio channel is replaced by an underwater acoustic channel, which is strongly dependent on the physical properties of the ocean medium and its boundaries, the link geometry and the ambient noise. In other words, the channel of the link budget analysis for underwater acoustic communication is affected by the high frequency. So the systems which operate at high frequency have high attenuation. However the link budget of the underwater acoustic communication also affected by ambient noise. While, ambient noise depends on the wind speed noise, shipping density traffic, thermal noise and the animal sound.

A. Link Budget

Link budgeting is an established method of analyzing performance in wireless and satellite communications. Link budgets are a design tool to predict signal-to-noise ratio (SNR) at a receiver given system parameters such as transmit power and antenna gain, and channel parameters such as propagation loss and interference. This predicted SNR is compared to a minimum required SNR to obtain a link margin. Equation 1 and Figure 1 represent a simplified link budget for wireless communications [13] Pelekanos,

$$Pr = Pt + Gt + Gr + Ls + Ln \qquad (1)$$

Where, Pr = Received Power, equivalent to SNR (all quantities in dB), Pt = Transmitted Power, Gt = Transmitting Antenna Gain, Gr = Receiving Antenna Gain, Ls = Free Space Path Loss, spreading and atmospheric attenuation, Ln = Noise Factor,

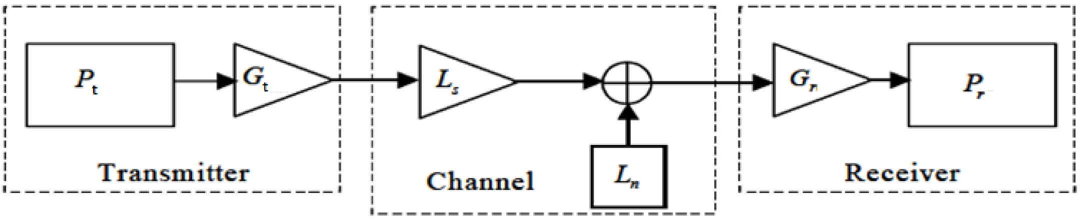

Fig.1 Block diagram representation of the link budget expressed in Equation 1

B. Required Signal Level (E_b/N_o)

In digital communications, required signal level is defined as a ratio of energy per bit to receiver noise level, ($\boldsymbol{E_b/N_o}$). This required signal level is a function of the bit error rate (BER) for the signaling scheme employed. BER represents the probability of a bit error at the output of the receiver. Figure 2 shows BER as a function of $\boldsymbol{(E_b/N_o)}$ for a M-QAM modulation.

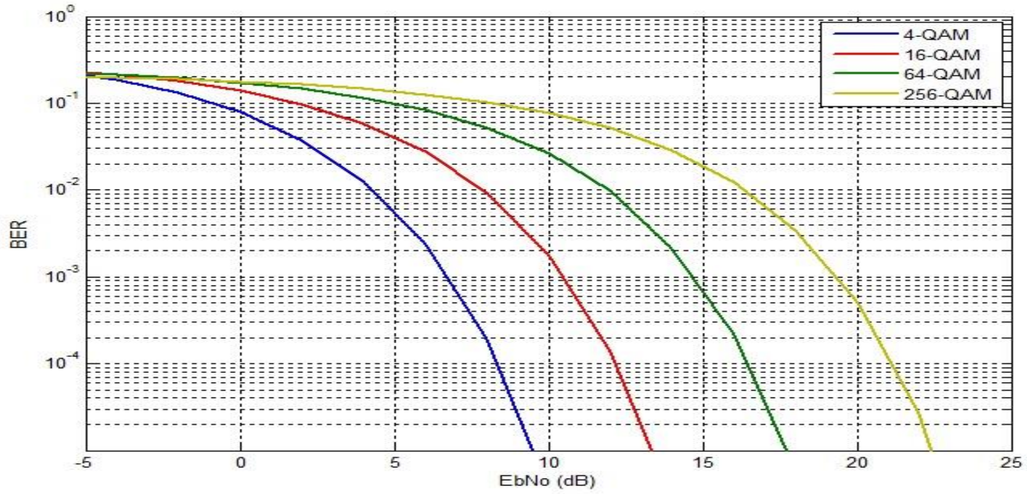

Fig. 2 Theoretical bit error rate vs. E_b/N_o for selected modulation schemes 4-QAM, 16-QAM, 64-QAM and 256-QAM

C. Available Signal Level

The product of the link budget analysis is available SNR at the receiver. To compare with required E_b/N_o, received power [16] is translated to an energy-per-bit

$$[E_b/N_o]_r = P_r * \left[\frac{W}{R}\right] \qquad (2)$$

D. Link Margin

The link margin (LM) compares received E_b/N_o with that required for the established BER,

$$LM = (\frac{E_b}{N_o})_{receive} - \left(\frac{E_b}{N_o}\right)_{required} \qquad (3)$$

Although this calculation of link margin has been used primarily in the fields of satellite and wireless communications, this metric is also relevant in predicting performance for an acoustic digital communications system .

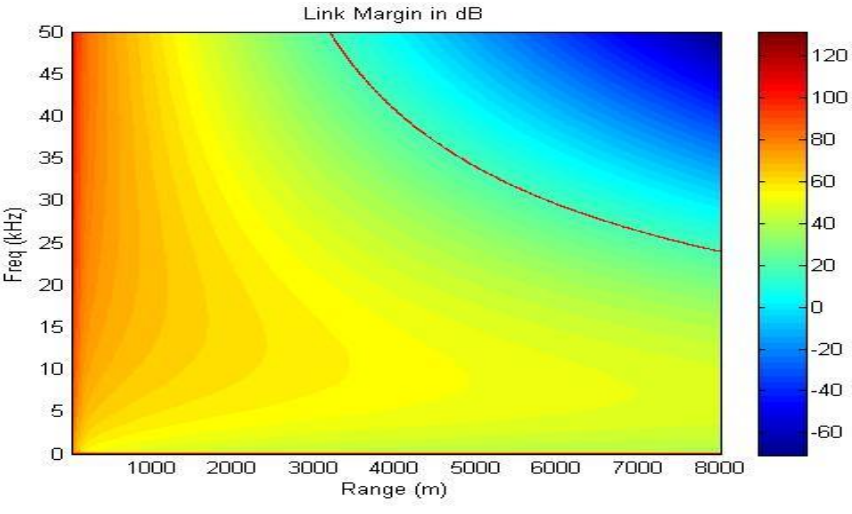

Fig. 3 Frequency dependent Link margin (ws=25 m/s & D=0.5)

E. SONAR EQUATION (Received SNR)

In a standard writing of the sonar equation the left hand side is SE, for signal excess. “Work by Wiley [9] developing the sonar equation as a link budget model (rather than detection model), we seek to represent the system’s ability to maintain a communications link in a given environment.” A complete link budget yields the link margin based on signal processing and other system considerations. In this thesis we limit our development to SNR, expressed as:

$$SNR = PSL - TL - AN + DIr + DIt \quad (4)$$

Where, SNR is Signal to Noise Ratio at the receiver, PSL is Pressure Spectrum Level of transmitting platform, TL is Transmission Loss of the medium, AN is Ambient Noise Spectrum Level of the environment, DI is Directivity Index of the receiver and transmitter.

III. RESEARCH METHODOLOGY

A. Method of Design Telesonar Transmitter

We consider a communications system designed to operate in the 15-20 kHz frequency band. A design specification of this system will be a bit error rate (BER) of 10^{-5} for noise environments corresponding to a wind speed of 15 m/s. Maximum communications range will be 8 km.

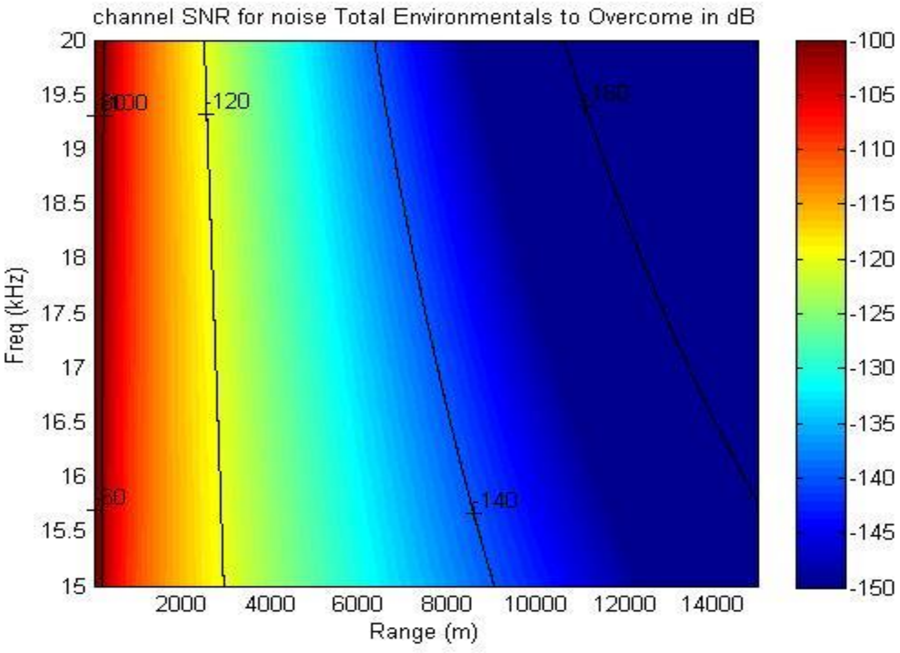

Fig. 4 Channel SNR for 15 m/s wind speed exhibiting strong frequency dependent

We begin by calculating the required receiver SNR for this system. Using a BER is 10^{-5}, we determine the required E_b/N_0 for 16-QAM modulation using Figure 2 E_b/N_0 In this case is 13.5 dB. A conservative design would call for a link margin of 10 dB, therefore the system should be designed so that received E_b/N_0 equals 23.5 dB. Employing Equation 2 for R=1.2 kpbs and W=5 kHz, we calculate a required power to noise ratio (P_r). Converting to a decibel equivalent yields=17.3 dB. No directivity is present in the receiver; therefore the required SNR will also be 17.3 dB. We now select a PSL that will achieve the required SNR at mid band.

B. Experiment and Practical measurement of underwater channel SNR

The experimental data for the underwater acoustic channel signal to noise ratio (channel SNR) test was collected in the UTM. The water depth was 2 meters. We are taking into consideration the same design in the simulation, 15-20 kHz frequency band. A design specification of this system will be a bit error rate (BER) of 10^{-5} for noise environments corresponding to a wind speed of 15 m/s. We now select a PSL that will achieve the required SNR at mid band.

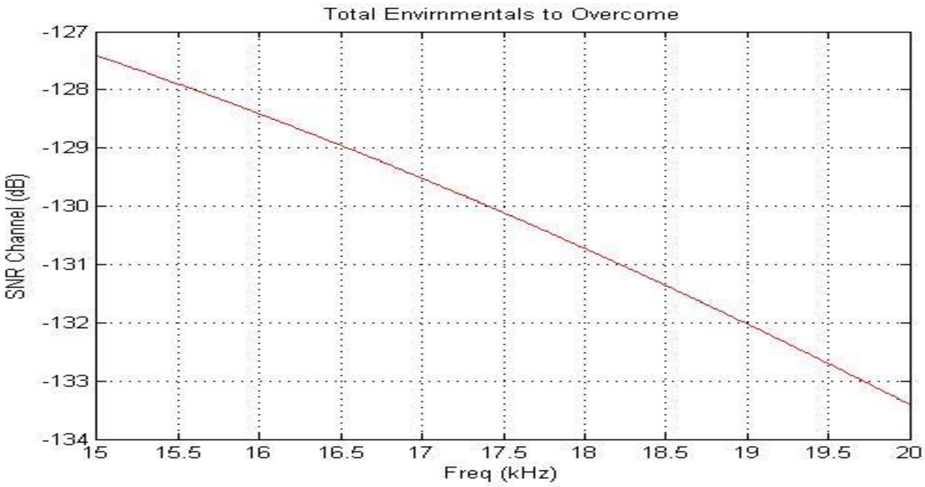

Fig. 5 Channel SNR (dB) as a function of frequency for r=15000 m and 15 m/s wind speed.

Channel SNR at mid-band is -130.7 dB. A PSL of 148 is required to obtain a received SNR of 17.3 dB .We apply a PSL of 148 dB uniformly across the spectrum and observe the results. Received SNR is plotted in Figure 6. The uniform PSL results in a region of unsatisfactory reception.

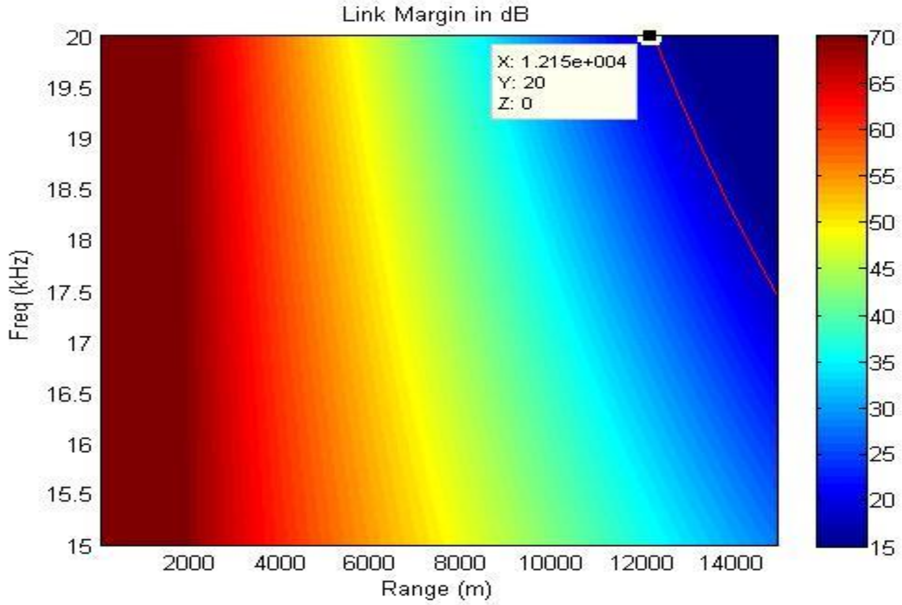

Fig. 6 link margin for uniform PLS=148 dB. Note that a region of unsatisfactory SNR exists at high frequencies for range greater than 12150 m

IV. CONCLUSION AND FUTURE WORKS

A. Conclusion of Result

The link budget is applied to an underwater acoustic communication system using the same principles as the RF link budget. The acoustic link budget incorporates terms of the active sonar equation to provide a first-order estimate of signal available at the receiver. Three case studies demonstrated the utility of an acoustic link budget in designing wideband communications systems. Link budgeting considers the range and frequency dependence of wideband signals in the acoustic medium. In particular, the channel SNR is strongly frequency dependent in the bands of interest. The link budget is a useful tool in visualizing the channel’s influence on the transmitted signal and in assessing the consequences of adapting the transmission strategy.

B. Future Work

A more accurate link budget analysis would not ignore the effects of scattering at the surface and bottom of the communications channel. One possible solution would be an additional term in the attenuation factor based on the mean bottom roughness and sea-state. This term would introduce additional losses due to the scattering effects of boundary interactions. Such a term would also be dependent on the sound speed profile to account for the increase in boundary interactions caused by gradient induced sound refraction.

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