HF MESSAGING SYSTEM WITH AUTOMATIC LINK ESTABLISHMENT (ALE) CAPABILITY

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Dedicated to my beloved husband and parents

Thank you for the inspirations

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ABSTRACT

HF radio spectrum, ranging from 3 to 30 MHz can be utilized for voice and data communication. One of the benefit of using HF for communicating is that HF system is low-cost, requires minimum equipments and easy to set up. But due to the unpredictability and propagation problems such as multipath fading, interference and attenuation, communication using HF becomes very challenging. Besides, the availability of the channels varies depending on the time of day, seasons and the condition of the ionosphere. The purpose of this research is to design a HF messaging system equipped with Automatic Link Establishment (ALE) capability. ALE is an adaptive radio technology for automatically establishing communications over HF single sideband (SSB) links using the best frequency possible. The objective of the research is to design a messaging system that permits reliable data transmission over the HF radio with minimum cost and equipments. This research also looked at the feasibility of implementing ALE as software, designed using Visual C++ programming language. Equipments used in this research are commercial HF radio and modem, which are both controlled by the software. Field testing is conducted between UTM Skudai and several places in Malaysia to verify the performance of the system. From the results, it is proven that by applying adaptive radio technology, propagation problems can be overcome and reliability of data transmission can be improved. Moreover, amateur radio users can use the system, as it requires minimum equipment.

ABSTRAK

Spektrum radio berfrekuensi tinggi atau HF iaitu dari 3 hingga 30 MHz boleh digunakan untuk komunikasi suara dan juga data. Salah satu kebaikan menggunakan HF ialah ia memerlukan kos yang rendah, memerlukan peralatan yang minimum dan mudah untuk dibangunkan. Tetapi disebabkan keadaan HF yang sukar dijangka dan masalah perambatan seperti *multipath fading*, gangguan dan pelemahan isyarat menjadikan komunikasi menggunakan HF mencabar. Selain itu, kebolehan sesuatu frekuensi bergantung kepada faktor masa, musim dan keadaan lapisan ionosfera. Tujuan kajian ini adalah untuk membina sebuah sistem pesanan HF yang dilengkapi dengan kebolehan capaian pautan secara automatik (ALE). ALE merupakan teknologi radio ubah suai yang digunakan untuk menghasilkan jaringan komunikasi dalam jalur tunggal (SSB) HF menggunakan frekuensi yang terbaik. Objektif kajian ini adalah untuk menghasilkan sistem pesanan HF yang membolehkan penghantaran data melalui HF dilakukan dengan baik menggunakan kos serta peralatan yang minimum. Kajian ini juga bertujuan mengkaji kesesuaian menghasilkan ALE dalam bentuk perisian, yang dibangunkan menggunakan bahasa pengaturcaraan Visual C++. Peralatan yang digunakan dalam kajian ini adalah radio HF dan modem HF komersil yang mana keduanya akan dikawal oleh perisian yang dinyatakan tadi. Kajian lapangan diadakan antara UTM Skudai dan beberapa tempat di Malaysia untuk menguji prestasi sistem tersebut. Keputusan yang diperolehi dapat membuktikan bahawa dengan menggunakan teknologi radio mudah ubah suai, masalah perambatan dapat diatasi dan kebolehpercayaan penghantaran data ditingkatkan. Malah, sistem tersebut dapat digunakan oleh pengguna radio amatur kerana ia memerlukan peralatan yang minimum.

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LIST OF SYMBOLS

φ_I	-	Angle of incidence
f_c	-	Critical frequency
k	-	Correction factor
f_N	-	Plasma frequency
h	-	Height
h_m	-	Height of a layer's peak
R	-	Levels of solar activity
Ap	-	Geomagnetic effects
Kp	-	Geomagnetic effects
T_{CC}	-	Calling cycle
T_{SC}	-	Scanning call cycle
T_{LC}	-	Leading call section
T_s	-	Total scan period
T_d	-	Dwell time
T_{rw}	-	Redundant word time
T_s	-	Total scan period
T_{wr}	-	Wait-for-response time
L	-	Length of the antenna
F	-	Desired dipole antenna frequency

LIST OF ABBREVIATIONS

AFSK	-	Audio FSK
ALE	-	Automatic Link Establishment
ALF	-	Absorption limiting Frequency
AMD	-	Automatic Message Display
AMTOR	-	AMateur Teleprinting Over Radio
ASAPS	-	Advanced Stand-Alone Prediction System
ASCII	-	American Standard Code for Information Interchange
BER	-	Bit-Error Rate
BUF	-	Best Usable Frequency
CDMA	-	Code Division Multiple Access
CME's	-	Coronal Mass Ejection
CRC	-	Cyclic Redundancy Check
CS	-	Control Signals
CSMA	-	Carrier Sense Multiple Access
CW	-	Morse Code
DBM	-	Data Block Mode
DCE	-	DataCircuit-terminating Equipment
DTE	-	Data Terminal Equipment
DTM	-	Data Text Message
EIRP	-	Effective Isotropic Radiated Power
EMUF	-	E-layer Maximum Usable Frequency
EPR	-	Estimated Power Required
EUV	-	Extreme Ultraviolet
FEC	-	Forward Error Correction

FSK	-	Frequency Shift Keying
GTOR	-	Golay Teleprinting Over Radio
HF	-	High Frequency
ISI	-	Inter Symbol Interference
LAN	-	Local Area Network
LQA	-	Link Quality Analysis
LSB	-	Least Significant Bit
LSB	-	Lower Side Band
LUF	-	Lowest Usable Frequency
MCMC	-	Malaysian Communications and Multimedia Commission
MSB	-	Most Significant Bits
MUF	-	Maximum Usable Frequency
OWF	-	Optimum working Frequency
PACTOR	-	Packet Teleprinting Over Radio
RTCE	-	Real-Time Channel-Evaluation
RTTY	-	Radio Teletypewriter
SINAD	-	Signal–plus-noise-plus-distortion to noise-plus-distortion ratio
SMARTNET	-	Skywave Management for Automatic Robust Transmission Network
SNR	-	Signal-to-Noise Ratio
SSB	-	Single Sideband
TDMA	-	Time Division Multiple Access
TNC	-	Digital Terminal Node Controller
UD MUF	-	Upper Deciles Maximum Usable Frequency
UT	-	Universal Time

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CHAPTER I

INTRODUCTION

1.1 Background

For decades, HF radio frequencies spectrum from 3 to 30 MHz has been used as a medium for long distance communication. This is possible because these bands of frequencies are reflected back to earth by free electrons in the ionosphere layer. By using the proper frequency and set of equipments, a person can communicate with another person as far away as on the other end of the earth via the HF layer. Moreover, transmissions of digital data such as text, fax and images is also possible by using HF modem, which converts digital data into analog form when transmitting, and converts analog data to digital form when receiving.

Compared to satellite communication, the cost to set up and maintain a HF communication system is much lower [Abdullah et. all, 2003]. Also, unlike the high payment needed to use satellite communication services, the usage of HF does not require payment to any service provider. HF communication however, suffers from several propagation problems and effects from the variation of the ionosphere layer. But today, with new technologies and many researches done, HF radio's usage has been expanded and propagation problems can be overcome. Adaptive and automatic

radio technology for example, permits modern radio systems to adjust automatically to changing propagation condition [Hess, 2000].

The purpose of this research is to design a HF messaging system that has automatic link establishment (ALE) capability. The messaging system allows digital data to be exchanged via HF medium. ALE is an adaptive radio technology, which make HF radio communication more reliable and less prone to propagation problems by automatically selecting the best channel to use at any given time and place.

1.2 Objective

The objective of this research is to allow effective and reliable data transmission over HF radio with ALE capability. The system is to be built with minimum cost and equipments so that it can be made available to amateur radio operator, telemetry and shipping. The main features of this research are as follows:

i) Design a HF messaging system
ii) Improve the reliability of data transmission of the messaging system by including ALE capability to the messaging system.
iii) ALE is implemented as software.
iv) Commercial modems and radios are used as the building block of the system.
v) Field testing is conducted to verify the system.

1.3 Problem Statement

Unlike telephone line and fiber optic, the HF environment is not noiseless as interference does exist; transmitted signal is distorted and with high noise levels [Goodman, 1992]. The effects of multipath fading and interference are significant in HF communication. Moreover, its propagation environment is also constantly changing due to the seasonal and diurnal variations in the ionosphere. Propagation conditions vary by location, frequency, season, time of day, and can be affected by unexpected ionospheric disturbance.

The main challenge in HF communication is to choose the most suitable frequency to be used for communication. Conventionally, radio operators must always listen to HF channels, to find available channel for communication. However, in order to do this, the operators must be highly trained in operating a HF radio, besides knowledgeable in HF radio propagation and channel predictions. Another way is by using propagation prediction programs that predict the best channel based on empirical data. Unfortunately, this is not the best way to determine the best channel for communication. The frequency prediction method does not give real time channel evaluation because all the data are obtained from calculation and forecasting. Sometimes, the data acquired are not accurate. This is due to unpredictable propagation factors such as sporadic E-layer propagations, interference from other users on an otherwise usable channel [Johnson et al, 1997]. To solve this problem, ALE is used. ALE performs real time channel evaluation, and helps select the most suitable frequency to be used at different time of day.

Even though ALE can help improve the reliability of HF communication, available ALE systems today are in a form of optional equipment for HF system. The equipment is usually known as ALE controller and has its own modem for ALE purposes. Thus users who want to experience the benefits of using ALE, has to buy the expensive equipments and end up having two different modems, each for ALE and data transmission.

1.4 Scope of Study

Existing systems such as ALE controllers developed by Rockwell-Collins Company [Rockwell-Collins, 2004] and Rhode-Schwarz Company [Rohde-Schwarz, 2004], implement ALE as additional equipment, which controls an HF radio. However in this research, ALE is implemented as software and part of a messaging system. Thus in the system developed in this research, no additional equipment is needed for ALE. The scope of this research are as follows:

i) This research does not involve building a HF radio and HF modem. Existing radio and modem is used.

ii) The equipment compatible with the system are limited to KENWOOD TS-570D HF Transceiver and Kantronics Kam 98 HF modem. This is because other equipments require different controlling methods and may not be suitable for the system designed in this research.

iii) Unlike existing systems, this system will use the same modem for both data transmission and ALE purposes.

1.5 Research Methodology

The following steps are taken to achieve the research objective:

i) To understand the basic concept and problems, literature and technology review on HF communication was done. Review on ALE technology and available HF messaging systems is also required for comparison and reference.

ii) Attend DSP and digital communication courses to enhance basic knowledge on the area of the research.

iii) The system design begun with building a messaging system using Visual C++. This system connects two computers via HF radio as a medium. The program is capable to control basic functions of both transceiver and modem such as transmitting data and scanning through channels (for transceiver).

iv) The next step is to design the ALE system, first for single channel followed by multiple channels. Next sounding processes, together with link quality analysis (LQA) are included to the system.

v) Before testing the system, frequency prediction was done. The purpose of this is to choose the suitable channel to use for field-testing. Advanced Stand-Alone Prediction System (ASAPS) is the frequency prediction software chosen used for this purpose.

vi) The final step was field-testing that which was conducted at several sites in Malaysia.

1.6 Thesis Outline

This report is divided into seven chapters. Chapter 1 is the introduction; which includes objective, scope of study, and problem statement. Next, in chapter 2, the literature review on HF radio, including its propagation characteristic and problems. Other than that, recent developments in adaptive HF radio communication systems are also presented. Then chapter 3 describes on frequency management and prediction, an important tool in HF communication. Next, explanation on ALE is presented in chapter 4. In this chapter, the concept and theory of ALE is described

including the frame structures and protocols used. Following after that is Chapter 5, which concentrate in explaining system design and implementation. This chapter explains in detail how the system is built, including equipments used, system requirements and ALE protocols. Then the result of the system's field-testing is presented in chapter 6. Here, the LQA results are presented using graphs and then discussions are done based on the results. Finally the last chapter, which is chapter 7, is for conclusion and recommendations.

ii) Other ALE features such as orderwire message capability and multi stations application can also be added to the system.

iii) To upgrade the efficiency of this system, the predicted results from propagation prediction programs such as ASAPS should be uploaded automatically by the system. The system can also be made able to select which frequencies to be used automatically based on the results from propagation prediction software. Frequency selection should be based on predicted OWF, MUF, ALF and also the SNR of the possibly usable frequencies.

iv) The field-testing sites selected in this research are both located in peninsular Malaysia. For future work, the field-testing sites can be expanded to location outside peninsular Malaysia. Other than that, field-testing can also be done between land and sea (on ship).

v) Finally, this system can also be upgraded to make it available to use with other type of HF radio and modem.

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