

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
CAIRO - A. R. E.

FREQUENCY HOPPING FOR SECURE COMMUNICATION

A Thesis Submitted in Partial Fulfillments of

The M. Sc. Degree

33644

IN

ELECTRICAL ENGINEERING

BY

ENG. EMAD MAHMOUD AZIZ AMIN

621.380.432
E. M



Scientific Supervisors :

Prof. Dr. SAFWAT MAHROUS

Prof. Dr. IBRAHIM SALEM

Col. Dr. MOSTAFA ABD EL KADER



1990

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

وَقُلْ أَعْمَلُوا فَسَيَرَى اللَّهُ
عَمَلَكُمْ وَرَسُولَهُ وَالْمُؤْمِنُونَ

- سورة التوبة ، ١٠٥ -



Examiners Committee

Name, Title & Affiliation

Signature

1-Prof. Dr. El-said Abdel-Hady Talkhan

E. A. Talkhan

2-Prof. Dr. Magdy Fikry Mohamed Ragae

M. Fikry

3-Prof. Dr. Ibrahim Ahmed Salem

I. Salem

4-Prof. Dr. Safwat Mahrous Mahmoud

Date : 26/9/1990

صفحة تعريف بمقدم الرسالة

=====

الاسم : عماد محمود عزيز أمين

تاريخ الميلاد : ١٩٥٠ / ١ / ٣١

محل الميلاد : القاهرة

الدرجة الجامعية الاولى : بكالوريوس الهندسة

التخصص : اتصالات

الجهة المانحة للدرجة الجامعية الاولى : الكلية الفنية العسكرية

تاريخ النسخ : ١٩٧٣/٤/١٦

الشهادات الاخرى الحاصل عليها وتواريخ الحصول عليها وجهات منحها :

١ - دبلوم الدراسات العليا فى الاتصالات بتاريخ ١٩٨٦ من كلية الهندسة - جامعة عين شمس

ملخص سابق الخبرة :

صيانة الاجهزة والاتصالات والحاسبات الالية بالقوات المسلحة

الوظيفة الحالية :

ضابط مهندس بالقوات المسلحة

التوقيع :

التاريخ : ١٩٨٠ / ٩ / ٢٦

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

استخدام القفز الترددي في
تأمين الاتصالات

عنوان الرسالة

by

عماد محمود عزيز أمين

أسم مقدم الرسالة

A Thesis
Submitted in partial fulfillment of
the requirements of the degree of
M.Sc. in COMMUNICATION ENGINEERING

Supervised by

أ.د. صفوت محروس أ.د. إبراهيم سالم
عقيد د. مصطفى عبد القادر

هيئة الاشراف

Cairo - 1990

STATEMENT

This dissertaion is submitted to AIN SHAMS UNIVERSITY for the degree of M. SC. in Electrical and Computer Engineering.

The work included in this thesis was carried out by the author in the Department of FACULTY OF ENGINEER, AIN SHAMS UNIVERSITY , from 10/11/1986 to 26/09/1990.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

Date : 26/09/1990

Signature : *Emad Aziz*

Name : Emad Mahmoud Aziz Amin

SUMMARY

Communication links intended for use in hostile environments must incorporate design features that reduce the vulnerability to jamming. To operate in the presence of jamming, communication systems must employ one or more of the primary electronic-counter countermeasure (ECCM) techniques in their designs such as error control coding, adaptive steerable null antennas, and spread spectrum SS techniques. A spread spectrum system is a system in which the transmitted signal is spread over a wide frequency band, much wider than the minimum bandwidth required to transmit the information being sent.

Spread spectrum modulation techniques are widely used in military and civilian applications for combatting intentional jamming as well as benign interference (e.g. multipath or multiple access crosstalk). Frequency hopping system is one type of SS systems. It offers some advantages over the other types : it can typically achieve much wider SS bandwidth resulting in higher processing gains and it generally use lower pseudonoise spreading code rates, and noncoherent demodulation permitting faster link acquisition.

In addition to the inherent processing gain of the SS systems, the performance can be further improved by adding external circuitry and using different interference suppression techniques which are designed to suppress interference.

These techniques are : autocorrelation-domain (ACD) techniques [14,18,19], diversity combining techniques [11,12,21,24,25,43,46], adaptive filter techniques [17,20], coding techniques [7,15,29,32,37,45,47], least-square estimation techniques [14,26], and digital whitening techniques [22,23].

The purpose of this thesis is to study different techniques for improving spread spectrum performance under the presence of narrow band interference and additive white Gaussian noise (AWGN). This work justifies by means of the digital computer simulation the improvement in anti-jam (AJ) capability of FH system by employing digital whitening techniques prior to frequency dehoppping . So an improvement in performance results by filtering the total received signal. Digital computer simulation for FSK/FH has been carried out in the presence of the desired signal, Gaussian noise, and partial-band jamming. The results are illustrated for two different case : with and without filtering. The main results of the simulation tests show that the proposed connection posses superior performance for different values of SJR. It is also shown that there is an optimum value for the bandwidth of the filter (\mathcal{B}) used prior to frequency dehoppping.

TABLE OF CONTENTS

SUMMARY.....	I
TABLE OF CONTENTS.....	III
LIST OF FIGURES.....	VIII
LIST OF TABLES.....	XII
TABLE OF SYMBOLS AND ABBREVIATIONS.....	XIII
1. INTRODUCTION.....	1
1.1 GENERAL.....	1
1.2 MOTIVATION OF THE WORK.....	3
1.3 SCOPE OF THE WORK.....	5
2. SURVEY OF COMMUNICATION SYSTEMS.....	6
2.1 INTRODUCTION.....	6
2.2 OVERVIEW OF COMMUNICATION SYSTEMS.....	6
2.2.1 High Frequency Radio.....	8
2.2.2 Radiolink Systems [Line of Sight Microwave(LOS).....	9
2.2.3 Tropospheric Scatter.....	9
2.2.4 Earth Station Technology (Satellite Communication).....	10
2.2.5 Millimeter Wave Transmission.....	10
2.2.6 Coaxial Cable Systems.....	12
2.2.7 Fiber Optic Communication Links.....	12
2.2.8 Video Transmission.....	13
2.2.9 Facsimile Communications.....	14

2.2.10 Digital Radio.....	15
2.3 THE APPLICATION OF ELECTRONIC WARFARE (EW) TECHNIQUES.....	16
2.3.1 Electronic countermeasures - ECM.....	17

PART 1 : PREVIOUS WORK

3. SPREAD SPECTRUM TECHNIQUES.....	19
3.1 INTRODUCTION.....	19
3.2 FUNDAMENTAL CONCEPT OF SPREAD SPECTRUM SYSTEMS.....	19
3.3 TYPES OF SPREAD SPECTRUM SYSTEMS.....	22
3.3.1 Direct Sequence Spread Spectrum (DS/SS) Systems.....	23
3.3.2 Frequency Hopping Spread Spectrum (FH/SS) System.....	25
3.3.3 Time Hopping (TH) Systems.....	35
3.3.4 Pulsed FM (chirp) Systems.....	35
3.3.5 Hybrid Systems.....	37
3.4 PROCESSING GAIN AND JAMMING MARGIN.....	39
3.5 ADVANTAGES AND DISADVANTAGES OF SS SYSTEMS.....	40
3.6 APPLICATIONS OF SPREAD SPECTRUM METHODS.....	45
3.6.1 Space Systems.....	45
3.6.2 Avionics Systems.....	46
3.6.3 Test Systems And Equipment.....	46
3.6.4 Message Protection.....	46
3.6.5 Position Location.....	47

4. JAMMING TECHNIQUES.....	48
4.1 INTRODUCTION.....	48
4.2 FUNDAMENTAL CONCEPT OF JAMMING TECHNIQUES.....	49
4.3 JAMMING WAVEFORMS.....	51
4.3.1 Noise Jamming.....	53
4.3.1.1 Broadband (Barrage) Noise Jamming.....	53
4.3.1.2 Partial-band Noise Jamming.....	54
4.3.2 Tone Jamming.....	56
4.3.3 Pulsed Noise Jamming.....	59
4.3.4 Repeat Back Jamming.....	60
4.4 PERFORMANCE OF FH SYSTEMS IN DIFFERENT JAMMING ENVIRONMENT.....	62
4.4.1 Performance in AWGN or Broadband Noise Jamming.....	62
4.4.1.1 MFSK/FH System.....	62
4.4.1.2 DPSK/FH System.....	65
4.4.2 Performance in Partial-band Confined to Single Band..	66
4.4.2.1 Conventional MFSK/FH System.....	66
4.4.2.2 Random 2-ary FSK/FH System.....	71
4.4.2.3 DPSK/FH System.....	72
4.4.3 Performance in Pulsed-Noise Jamming.....	74
4.4.3.1 MFSK/FH System.....	75
4.4.3.2 DPSK/FH System.....	76
4.4.4 Performance in Multitone Jamming.....	76

4.4.4.1 MFSK/FH System.....	78
4.4.4.2 DPSK/FH System.....	80
4.4.5 Performance in Repeat-back Noise Jamming.....	82
4.4.5.1 Random FSK/FH System.....	82

PART II : CONTRIBUTION

5. TECHNIQUES FOR IMPROVING SS COMMUNICATIONS PERFORMANCE IN THE PRESENCE OF NARROWBAND JAMMING AND INTERFERENCE. ...	85
5.1 INTRODUCTION	85
5.2 AUTOCORRELATION TECHNIQUES	86
5.3 DIVERSITY COMBINING TECHNIQUES	90
5.3.1 Non-coherent reception of MFSK with Diversity	90
5.3.2 Non-linear combining techniques	91
5.3.3 FH/BFSK system with Diversity	95
5.3.3.1 Square-law linear combining receiver	96
5.3.3.2 Square-law nonlinear combining receiver ...	96
5.3.3.3 Diversity Ratio-Statistic Combining	107
5.4 ADAPTIVE NONLINEAR SUPPRESSION OF INTERFERENCE	109
5.4.1 A frequency domain time-dependent adaptive filter	109
5.4.2 Time Sequenced Adaptive Filter (TSAF)	111
5.5 CODING TECHNIQUES	112
5.5.1 Error Correcting Coding Techniques	114
5.5.2 Coding for Fast Frequency Hopped Noncoherent MFSK	122
5.5.2.1 Performance of Convolutional Codes	124

5.5.2.2 Performance of Block Codes	125
5.5.2.3 Performance of Concatenated Codes	125
5.6 LEAST-SQUARES ESTIMATION TECHNIQUES	127
5.7 DIGITAL WHITENING TECHNIQUES	130
6. COMPUTER SIMULATION OF THE PROPOSED CONNECTION WITH FH SYSTEM	142
6.1 INTRODUCTION	142
6.2 SIMULATION OF THE INPUT COMPOSITE SIGNAL	144
6.2.1 Simulation of BFSK signal	144
6.2.2 Simulation of the Gaussian noise	147
6.2.3 Simulation of the Bandlimited Gaussian noise	152
6.2.4 Simulation of the Partial-band jamming noise	153
6.3 SIMULATION OF THE BFSK DEMODULATOR	154
6.3.1 Simulation of the bandpass filter	155
6.3.2 Simulation of the multiplier	157
6.3.3 Simulation of the integrator	158
6.4 SAMPLING RATE CONSIDERATION	159
6.5 INFLUENCE OF THE FILTER BANDWIDTH	160
7. CONCLUSIONS	168
 BIBLIOGRAPHY	 170

LIST OF FIGURES

Figure	
3-1	Spectra of desired signal and interference24
3-2	Block diagram of a frequency hopping system26
3-3	Ideal operating frequencies of FH/SS system28
3-4	Frequency versus time sketch for FH/SS system28
3-5	Repeater-type interference diagram32
3-6	Simple time hopping system36
3-7	A scenario for SS link operation43
4-1	Communication system overview50
4-2	Different jamming waveforms52
4-3	Geometrical configuration of communicators and jammer ..61
4-4	Performance of a BFSK/FH spread spectrum system in broadband noise jamming64
4-5	Performance of convolutional BFSK/FH spread spectrum in partial-band jamming69
4-6	Performance of convolutional MFSK/FH system in worst case partial-band jamming70
4-7	Random M-ary FSK/FH performance against worst repeat noise jamming84
5-1	Suboptimal processing87
5-2	Mathematical model of a real-time autocorrelation detector87