بسم الله الرحمن الرحيم

Sudan University of Science and Technology

Faculty of Engineering

Aeronautical Engineering Department

LINK PERFORMANCE MODELING AND SIMULATIONS FOR AERONUTICAL MOBILE AIRPORT COMMUNICATION SYSTEM(AEROMACS)

Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Bachelor of Engineering. (BEng Honor)

By:

1. **Alaa Tajelsir Ali Mohammed**
2. **Doaa Magdi Ali Mohammed**
3. **Manahil Abubakr Osman Nuri**
4. **Nihal Altayeb Mohammed Ali**

Supervised By:

Dr. Elessaid Sulaiman Saad

October, 2017

الآية

بسم الله الرحمن الرحيم

{لاَ يُكَلِّفُ اللّهُ نَفْساً إِلاَّ وُسْعَهَا لَهَا مَا كَسَبَتْ وَعَلَيْهَا مَا اكْتَسَبَتْ رَبَّنَا لاَ تُؤَاخِذْنَا إِن نَّسِينَا أَوْ أَخْطَأْنَا رَبَّنَا وَلاَ تَحْمِلْ عَلَيْنَا إِصْراً كَمَا حَمَلْتَهُ عَلَى الَّذِينَ مِن قَبْلِنَا رَبَّنَا وَلاَ تُحَمِّلْنَا مَا لاَ طَاقَةَ لَنَا بِهِ وَاعْفُ عَنَّا وَاغْفِرْ لَنَا وَارْحَمْنَا أَنتَ مَوْلاَنَا فَانصُرْنَا عَلَى الْقَوْمِ الْكَافِرِينَ}

البقرة(286)

Abstract

It is nice to know about aviation world, especially the communications. The project estimates the simulation of AeroMACS which based on IEEE 802.16-2009 (mobile WiMAX) standard .

The aim of this project is to develop the existing communication system in aircrafts and to substitute it with the AeroMACS which is operating at C-Band. To Implement the AeroMACS it is crucial to examine its performance.

In order to examine the performance of any communication system we have to derive a relation between Signal to Noise Ratio (SNR) and Bit Error Rate (BER).

According firstly to the communication system model which consists of (source and encoder) in the transmitter, transmission medium, and (decoder and destination) in the receiver, and secondly to the standard of the International Civil Aviation Organization (ICAO), modeling and simulation examine the performance of the AeroMACS, the model consists of (source, convolutional Encoder, Inter-leaver, Modulator, And OSTBC Encoder) in transmitter, and a channel that varies according to the path of signals and (OSTBC combiner, Demodulator, Deinter-leaver, and Viterbi Decoder) in the receiver. The results were shown in Bit Error Rate destination and then the drawing of the required graphs to derive the relation.

التجريد

من الجميل أن تعرف عن عالم الطيران وخاصة الاتصالات ,يعرض المشروع محاكاة ايروماكس الذي يقوم على المعيار IEEE 802.16-2009 (mobile WiMAX) .

الهدف من هذا المشروع هو تطوير نظام الاتصال الحالي في الطائرات وذلك باستبداله بنظام الايروماكس الذي يعمل في النطاق (C).ولتطبيق نظام الايروماكس لابد من معرفة ادائه,ولمعرفة اداء أي نظام في الاتصالات لابد من ايجاد علاقة بين نسبة الاشارة الى الضوضاء ومعدل الخطأ في البيانات.

تبعاً اولاً لنموذج نظام الاتصال الذي يتكون من (مصدر ومشفر)في الارسال ,وسط لنقل البيانات و(فك التشفير والعارض) في الاستقبال,وثانياً للمقياس التابع لمنظمة الطيران المدني العالمية (ICAO) ,قمنا بعمل نموذج لمعرفة اداء النظام ايروماكس وكان النموذج يتكون من (مصدر ,مشفر,مدخل,مغير,ومشفر OSTBC) في الارسال ,قناة تتغير تبعاً لمسار الاشارات و (مجمع OSTBC ,مستخلص,مخرج ,وفك التشفير)في الاستقبال .وتم عرض النتائج في عارض معدل الخطأ في البيانات ,ومن ثم رسم المخططات اللازمة لايجاد العلاقة.

Acknowledgement

In performing our project, we had to take the help and guideline of some respected person, who deserve our greatest gratitude. The completion of this project gives us much Pleasure. We would like to show our gratitude Dr. Elessaid Suleiman for giving us a good guideline for project throughout numerous consultations. We would also like to expand our deepest gratitude to Dr.Omer Abd-Elrazig and Mrs.Salma Abd-Elgader and to all those who have directly and indirectly guided us in writing this project.

Dedication

To our Angels, Guardian, our Mothers

To the heroes of our childhood, our Fathers

To our Brothers and Sisters

To everyone who Taught us an alphabet throughout our way

To our Friends who never hesitated to share guidance and advice

To everyone who stood beside of us until we reached what we are in now

To the one that supported us the most in every step of the way and leaded us to the pathway of success, The Indescribable Human…. Mohammed Abd-Elazim.

Table of Contents

List of Figures

List of abbreviations

AeroMACS	Aeronautical Mobile Airport Communication System
ANSPs	Air Navigation Service Providers ,
AOC	Aeronautical Operational Control
ASK	Amplitude Shift Keying
ATM	Air Traffic Management
ATandT	American Telephone and Telegraph
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FCI	Future Aviation Communication Infrastructure
FEC	Forward Error Correction
FEC	Fast Fourier Transform
GPS	Global Positioning System
HF	High Frequency
ICAO	International Civil Aviation Organization
IEEE	institute of electrical and electronics engineers

IFFT	Inverse Fast Fourier Transform
ITU	International Telecommunication Union
LOS	line of site
LTE	long term evolution
MAC	Media Access Control
MSs	Mobile Stations
OFDMA	Orthogonal Frequency Division Multiple Access
OSI	Open Systems Interconnections
PSK	Phase Shift Keying
PHY	physical layer
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RTCA	Radio Technical Commission for Aeronatics
SNR	Signal to Noise Ratio
VHF	Very High Frequency
WiMAX	Worldwide Interoperability for Microwave Access

Chapter one: Introduction

1.1 Overview

AeroMACS (Aeronautical Mobile Airport Communication System) is the new aviation-dedicated transmission technology based on the WiMAX (Worldwide Interoperability for Microwave Access) IEEE 802.16e standard (institute of electrical and electronics engineers). The Aero MACS technology allows Mobile Stations (MSs) such as aircraft or surface vehicles, to communicate with airline operators and airport staff at three different surface zones: RAMP (where the aircraft is at the gate before departure), GROUND (the aircraft is taxing to the runway) and TOWER (until the aircraft takes-off).

1.2 Aim and Objectives

- **Aim**

Support safety and regularity of flight communications at the airport surface.

- **Objective**

Model AeroMACS Transceiver and Substantiate that AeroMACS performance is better. than traditional communication System performance.

1.3 Problem Statement

The current traditional communication system doesn't support high mobility, with less than optimum performance and not secure enough.

1.4 Proposed Solution

Change the aviation communication system in airports from traditional system to Aeronautical Mobile Airport Communication System (AeroMACS) gradually.

1.5 Motivation

To gain information and knowledge and to simplify connection between aircrafts and towers by using WiMAX network.

1.6 Contribution

We acquired a great deal of experience and a lot of information in communications.

1.7 Methodology

We chose the idea of the project at first. Secondly started searching, collected all information that we needed and then studied block diagram of AeroMACs, knew the function of each one and defined the results of AeroMACs performance (SNR and BER) from simulation of AeroMACs block using MATLAB.

Finally, evaluated the AeroMACs system by comparing the output results of AeroMACs performance (SNR and BER) with VHF performance (power received and BER).

1.8 Outlines

This thesis (report) consists of chapters and sections. The first one is an introductory chapter that elucidates the general idea of the project, purpose and methodology. The next chapter covers the basic history, background, and the critical literature review. Chapter three consists of the modeling and simulation. Chapter four is about the result and discussion and the final chapter includes the conclusion and recommendations.

Chapter two: Literature Review

2.1 Communication

Communication has long been suggested as a critical issue in all aspects of human interaction, which is reported to be the major contributing factor into aviation accidents. Communication is essential for organizational and managerial performance and success in any endeavor, including aviation environment Communication is a process by which and information is sent by a transmitter, it goes through a channel of propagation of information and is received by the receiver at the other end. An input transducer is applied before the transmission of data over the medium (also known as channel) to convert the signal into the required form and output transducer is applied to convert the signal to its original form.[2]

Figure 1: Aeronautical communication

Aviation communication refers to the conversing of two or more aircraft. Aircraft are constructed in such a way that make it very difficult to see beyond what is directly in front of them. As safety is a primary focus in aviation, communication methods such as wireless radio is an effective way for aircraft to communicate with the necessary personnel. Aviation is an international industry and as a result involves multiple languages. However, as deemed by the International Civil Aviation Organization (ICAO), English is the official language of aviation. The industry considers that some pilots may not be fluent English speakers and as a result pilots are obligated to participate in an English proficiency test.[3]

Aviation communication is the means by which aircraft crews connect with other aircraft and people on the ground to relay information. Aviation communication is a crucial component pertaining to the successful functionality of aircraft movement both on the ground and in the air. Increased communication reduces the risk of an accident.[4]

During the early stages of aviation, it was assumed that skies were too big and empty that it was impossible that two planes would collide. However, in 1956 two planes famously crashed over the Grand Canyon, which sparked the creation of the Federal Aviation Administration (FAA). Aviation was roaring during the Jet Age and as a result, communication technologies needed to be developed. This was initially seen as a very difficult task: ground controls used visual aids to provide signals to pilots in the air. With the advent of portable radios small enough to be placed in planes, pilots were able to communicate with people on the ground. With later developments, pilots were then able to converse air- to- ground and air- to- air. Today, aviation communication relies heavily on the use of many systems. Planes are outfitted with the newest radio and GPS (Global Positioning System) systems, as well as Internet and video capabilities.
English is the main language used by the aviation industry; the use of aviation English is regulated by the International Civil Aviation Organization (ICAO).[3]

Flight was considered a foreign concept until the Wright Brothers successfully completed the world's first human flight in 1903. The industry grew rapidly and ground crews initially relied on coloured paddles, signal flares, hand signs, and other visual aids to communicate with incoming and outgoing aircraft. Although these methods were effective for ground crews, they offered no way for pilots to communicate back. As wireless telegraphy technologies developed alongside the growth of aviation during the first decade of the twentieth century, wireless telegraph systems were used to send messages in Morse code, first from ground- to- air and later air- to- ground. With this technology, planes were able to call in accurate artillery fire and act as forward observers in warfare.

In 1911, wireless telegraphy was put into operational use in the Italo- Turkish War. In 1912, the Royal Flying Corps had begun experimenting with "wireless telegraphy" in aircraft. Lieutenant B.T James was a leading pioneer of wireless radio in aircraft. In the spring of 1913, James had begun to experiment with radios in a B.E.2A. James managed to successfully increase the efficiency of wireless radio before he was shot down and killed by anti- aircraft fire on July 13, 1915.[5]

Nonetheless, wireless communication systems in aircraft remained experimental and would take years to successfully develop a practical prototype. The early radios were heavy in weight and were considered an unreliable piece of equipment; additionally, there were still major issues with ground forces using radio because signals were easily intercepted and targeted by opposing forces. At the beginning of World War 1, aircraft were not typically equipped with wireless equipment. Instead, soldiers used large panel cut outs to distinguish friendly forces. These cut outs could also be used as a directional device to help pilots navigate back to friendly and familiar airfields.[6]

In April 1915, Captain J.M. Furnival was the first person to hear a voice from the ground from Major Prince who said, "If you can hear me now, it will be the first time speech has ever been communicated to an airplane in flight." In June 1915, the world's first air- to ground voice transmission took place at Brook lands, England over about 20 miles. Ground- to- air was initially by Morse code, but it is believed 2- way voice communications were available and installed by July 1915. By early 1916, the Marconi Company (England) started production of air- to- ground radio transmitters/receivers which were used in the war over France.

In 1917, ATandT invented the first American air- to- ground radio transmitter. They tested this device at Langley Field in Virginia and found it was a viable technology. In May 1917, General George Squire of the U.S. Army Signal Corps contacted ATandT to develop an air- to- ground radio with a range of 2,000 yards. By July 4 of that same year, ATandT technicians achieved two- way communication between pilots and ground personnel. This allowed ground personnel to communicate directly with pilots using their voices instead of Morse code. Though few of these devices saw service in the war, they proved this was a viable and valuable technology worthy of refinement and advancement.[7]

Design of the future aeronautical communications based on diﬀ erent heterogeneous links. The global system is composed by air-ground, air-to-air, satellite and airport communications. each links is based on a diﬀ erent technology, in order to provide a solution to the requirement of the specific link.

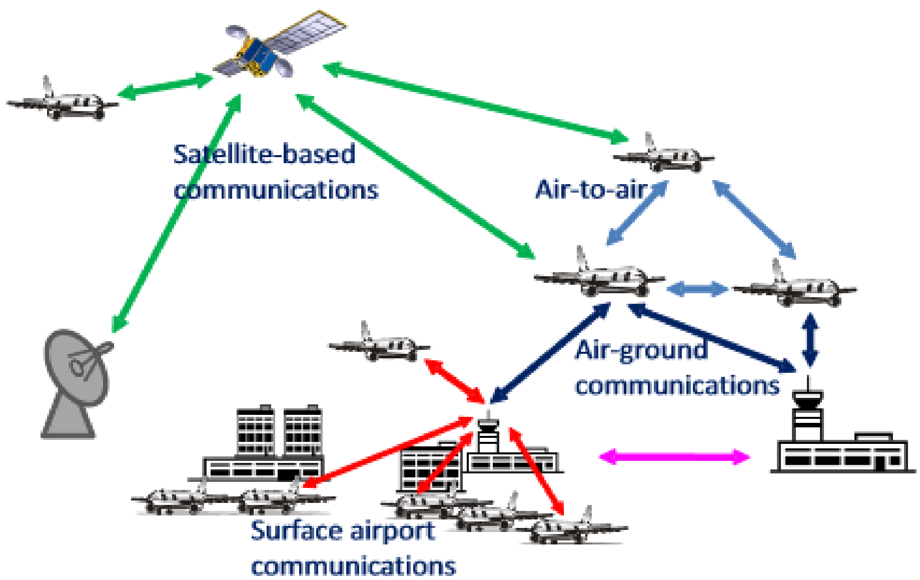


Figure 2: Future Aeronautical communication

2.2 VHF System

An aircraft uses a range of radio frequencies to navigate to its destination and communicate with air traffic control. To do this successfully, the onboard radio equipment uses different types and sizes of antenna's, each designed for their own frequency band.[8]

Each of these antennas have their own characteristics regarding frequency and application and thus location on the aircraft. Even the connection between the antenna and avionics has its own set of specifications.[8]

VHF (Very High Frequency) is a term use to describe the 30MHz to 300MHz portion of the radio spectrum. This range of frequencies will provide short range LOS (line of site) communications, the range of VHF communications depends on equipment used antenna height and terrain (typically 2 to 20 miles. Aircraft short range communication uses the VHF band between 118 MHz and 136 MHz to talk with air traffic control. And as the location of the receiving station is not always the same or known, the signal must be send in all directions (Omni) with a vertical polarization (upright, vertical antenna).[9]

Figure 3 show VHF block diagram:

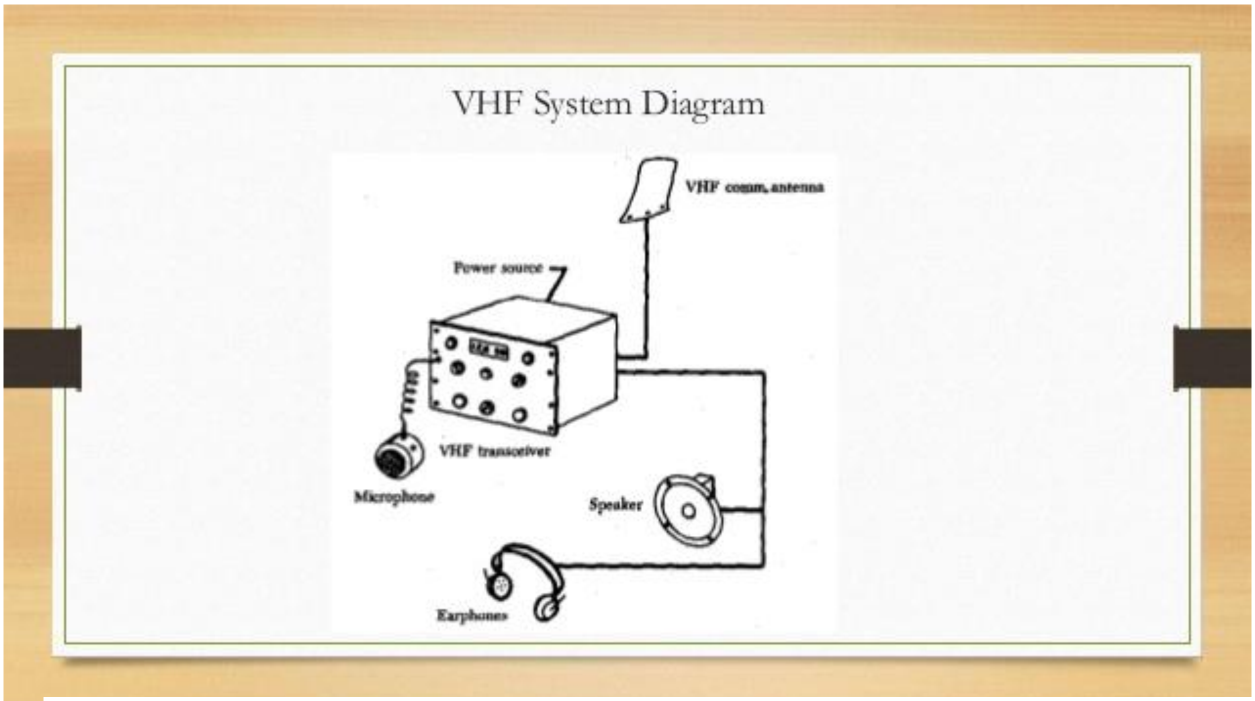


Figure 3: VHF block diagram

These VHF frequencies have a line of sight capability. This means VHF range is from where you stand or fly to the visible horizon. These signals normally do not follow the curvature of the earth.

The actual range depends also on the height of your antenna. Thus, an aircraft at FL 400 ft. has more VHF range than one flying at 1500 ft. It also depends on how much power your transmitter has (most have 7, some 10 or even 16 watts). Atmospheric conditions can either help increase range or make some frequencies unusable, this effect is sometimes noticeable on VHF but even more so on HF (3 MHz - 30 MHz) and LF (300 kHz - 3 MHz).[7]

2.2.1 VHF Radio Range

To calculate VHF range, you may want to use this formula:

$$\mathbf{VHF_{Range} = 1.33(\sqrt{H_{aircraft}} + \sqrt{H_{gs}})}$$

Where:

VHF_{Range} In nautical miles.

$H_{aircraft}$ Is the altitude of the aircraft in feet.

H_{gs} Is the height of the ground station antenna in feet.[10]

The range is a theoretical optimum but actual range is less due to:

1. Ttransmitter power
2. Receiver sensitivity
3. Antenna cable losses
4. Efficiency of the antenna

VHF problems caused by a number of items including:

1. Radio has been configured to "LOW Power" transmission mode
2. low battery level
3. Poor/corroded radio power leads
4. Insufficient power wire gauge
5. A failure of the VHF antenna
6. A failure of VHF antenna cable
7. Corrosion and/or failure of the antenna's PL-259 connector
8. A failure of an antenna splitter (if installed)
9. A failure within the VHF radio's transmitter circuitry [11]

As mentioned previously, VHF is limited to line of sight range and is not really suitable for direct communications over very long distances (although sometimes ionospheric conditions can open up the band and reflect even VHF beyond the curvature of the earth). For reasonable predictable long range communications, the HF (High Frequency) band (3 - 30 MHz) is usually used.

HF (High Frequency) is a term use to describe the 3MHz to 30MHz portion of the radio spectrum. This is used for long range communications because of the its longer transmission range, this is the basic band of long range communications, mainly because its transmission are reflected from the ionosphere. [12]

2.3WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) is a family of wireless communication standards based on the IEEE 802.16 set of standards, which provide multiple physical layer (PHY) and Media Access Control (MAC) options. The name "WiMAX" was created by the WiMAX Forum, which was formed in June 2001 to promote conformity and interoperability of the standard, including the definition of predefined system profiles for commercial vendors. The forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL". IEEE 802.16m or Wireless MAN-Advanced was a candidate for the 4G, in competition with the LTE Advanced standard. WiMAX was initially designed to provide 30 to 40 megabit-per-second data rates, with the 2011 update providing up to 1 G bit/s for fixed stations.

Using a WiMAX-based technology standard is profitable for the aviation industry for many reasons. First, the current standardization and deployment processes are fast and cost-effective as opposed to a newly developed standard simply for the sake of airport communications. Moreover, the scientific community has been working on IEEE 802.16 standards for many years. Highly qualified certification agencies, such as the WiMAX Forum, are continuously looking out for interoperability and technical issues related to the standard.[13]

The AeroMACS standard is currently a hot topic in data link communications, and many tests are already running for a future deployment. Recently, the RTCA SC-223 and EUROCAE WG-82 have jointly defined an AeroMACS profile that is intended to fulfil performance requirements for the system implementation.

The IEEE 802.16 standard belongs to the IEEE 802 family, which applies to Ethernet. WiMAX is a form of wireless Ethernet and therefore the whole standard is based on the Open Systems Interconnections (OSI) reference model.

The WiMAX physical layer is based on OFDM. OFDM is the transmission scheme of choice to enable high speed data, video, and multimedia communications and presently, besides WiMAX, it is used by a variety of commercial broadband systems.

In the context of the OSI model, the lowest layer is the physical layer. It specifies the frequency band, the modulation scheme, error-correction techniques, synchronization between transmitter and receiver, data rate and the multiplexing techniques.

The OFDM system is also simpler to design based on FFT/IFFT method. These advantages are further extended for multiple access schemes by assigning a subset of subcarriers or tones of OFDM to individual users. This multiple access technique is termed as OFDMA. The allocation of subsets of tones to various users allows for simultaneous transmission of data from multiple users, allowing for sharing the physical medium.[14]

In OFDMA, sub channelization defines sub channels that can be allocated to subcarrier stations depending on their channel conditions and data requirements. Several SS can transmit in the same time slot over several sub channels. Depending on the channel conditions and data requirements modulation and coding is set individually for each subscriber. The transmitter power can be adapted separately as well, which optimizes the use of network resources. Because of sub channelization OFDMA signals are more complex than OFDM ones but offer better performance and scalability. This feature is very useful for WiMAX.

IEEE 802.16 physical (PHY) layer is characterized by Orthogonal Frequency Division Multiplexing (OFDM), Time Division Duplexing, Frequency division Duplexing, Quadrature Amplitude Modulation and Adaptive Antenna Systems. After discussing the basics of OFDM and Orthogonal Frequency division Multiple Access (OFDMA), scalable OFDMA is presented and supported frequency bands, channel bandwidth and the different IEEE 802.16 PHY are discussed.[15]

2.4 AeroMACS

AeroMACS (Aeronautical Mobile Airport Communications System) is a broadband wireless communications system that can support the transmission of safety and regularity of flight data for both fixed and mobile applications on the airport surface. It is based on the mature WiMAX standard (IEEE 802.16e) and operates in the protected aviation spectrum band from 5091 MHz to 5150 MHz.

Interference from AeroMACS systems to IEEE802.11a systems was obtained by relation between power received and distance.[16]

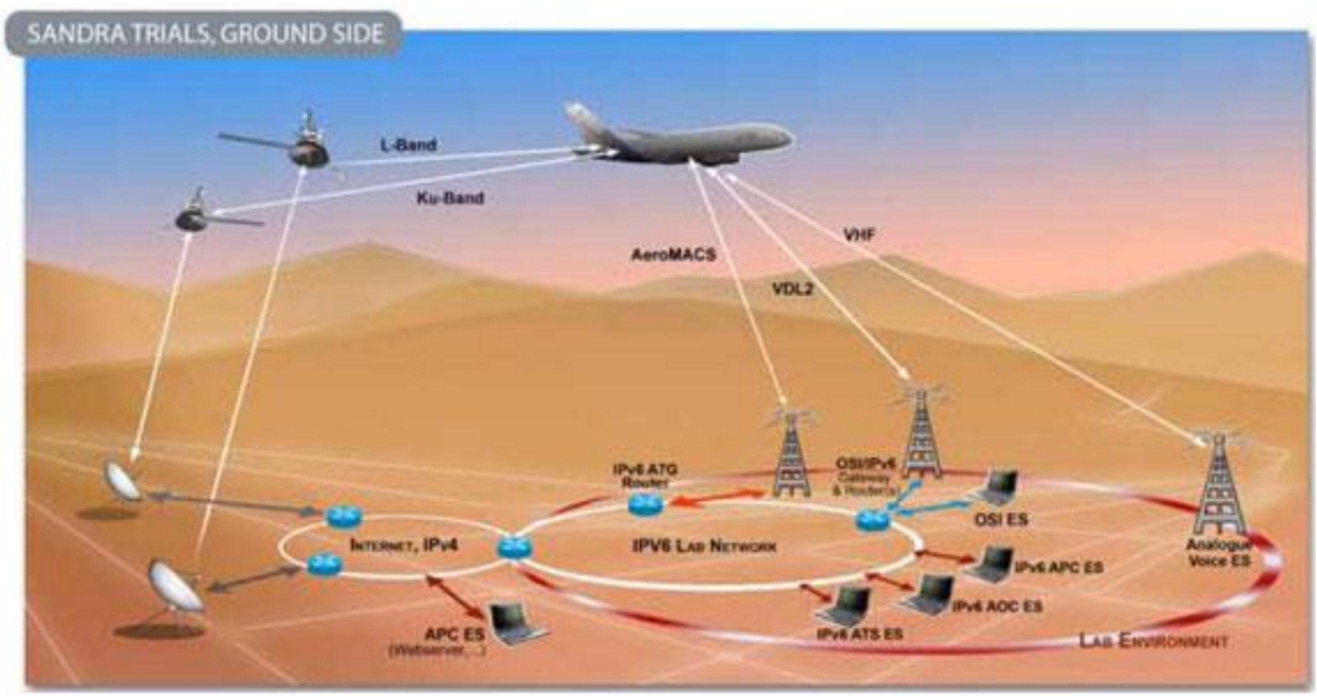


Figure 4: AeroMACS Illustration

2.5 C-Band

Frequency bands for aeronautics as any wireless communication network, ATN is subjected to the International Telecommunications Union (ITU, a specialized agency of the UNs) regulations for frequency allocation. In the following sections, the useful bands for aeronautics will be named according to the IEEE classification.

Frequency band	Frequency range	Wavelength
HF (high frequency)	3–30 MHz	100–10 m
VHF (very high frequency)	30–300 MHz	10–1 m
UHF (ultra high frequency)	300 MHz to 3 GHz	10 cm to 1m
L (long wave)	1–2 GHz	
Ku (Kurz-under)	12–18 GHz	
K (Kurz)	18 to 27 GHz	
Ka (Kurz-above)	27 to 40 GHz	

Figure 5: Frequency Bands

The C-band is a designation by the Institute of Electrical and Electronics Engineers (IEEE) for a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 4.0 to 8.0 gigahertz (GHz);[1] however, this definition is the one followed by radar manufacturers and users, not necessarily by microwave radio telecommunications users. The C-band (4 to 8 GHz) is used for many satellite communications transmissions, some Wi-Fi devices, some cordless telephones, and some weather radar systems.

The communications C-band was the first frequency band that was allocated for commercial telecommunications via satellites. The same frequencies were already in use for terrestrial microwave radio relay chains. Nearly all C-band communication satellites use the band of frequencies from 3.7 to 4.2 GHz for their downlinks, and the band of frequencies from 5.925 to 6.425 GHz for their uplinks.

The C-band is primarily used for open satellite communications, whether for full-time satellite television networks or raw satellite feeds, although subscription programming also exists. This use contrasts with direct-broadcast satellite, which is a completely closed system.

used to deliver subscription programming to small satellite dishes that are connected with proprietary receiving equipment.

The satellite communications portion of the C-band is highly associated with television receive-only satellite reception systems, commonly called "big dish" systems, since small receiving antennas are not optimal for C-band systems. Typical antenna sizes on C-band capable systems ranges from 7.5 to 12 feet (2.5 to 3.5 meters) on consumer satellite dishes, although larger ones also can be used. For satellite communications, the microwave frequencies of the C-band perform better under adverse weather conditions in comparison with the Ku band (11.2 GHz to 14.5 GHz), microwave frequencies used by other communication satellites.[3] Rain fade – the collective name for the negative effects of adverse weather conditions on transmission – is mostly a consequence of precipitation and moisture in the air.[17]

The C-band frequencies of 5.4 GHz band [5.15 to 5.35 GHz, 5.47 to 5.725 GHz, or 5.725 to 5.875 GHz, depending on the region of the world] are used for IEEE 802.11a Wi-Fi and cordless telephone applications, leading to occasional interference with some weather radars that are also allocated to the C-band.

2.6 AeroMACS and aviation

It is for:

1. High capacity, modern data link (4G) for communications in the airport surface (vehicles and aircraft on ground, as well as fixed coms)
2. Part of the wider future aviation communication infrastructure (FCI)
3. Operation in regulated spectrum (5GHz) offering protection from interference (for safety and regularity of flight communications)
4. ITU allocation maintains aeronautical usage for 5 GHz band
5. Supports ATM, AOC and Airport communications using single technology.

Synergies between Airports, Airlines and ANSPs business models an effective Total Airport Management System allows people to reach their own flight/destination without any troubles or delay and where the various Airport End Users, as Air Navigation Service Providers (ANSPs), Airliners, Airport Handlers, Air Manufacture Industries, Passengers, Cargo, Security and Government Agency, provide services efficiently at lower cost, respective of the environment. Performance requirements for

Airport domain are becoming increasingly complex and demanding and need to be considered as part of an integrated and holistic System of Systems, which includes mobile and fixed system and applications considering convergence towards a common infrastructure, and a unified concept of operations, where possible, across the different, ground- and air-based, domains. In parallel, Airport systems and Communication Infrastructure for both airborne and ground must take a more business-, dependable- and performance oriented approach with efficient use of resources delivering the required capability in a cost-effective and spectrum efficient manner.[18]

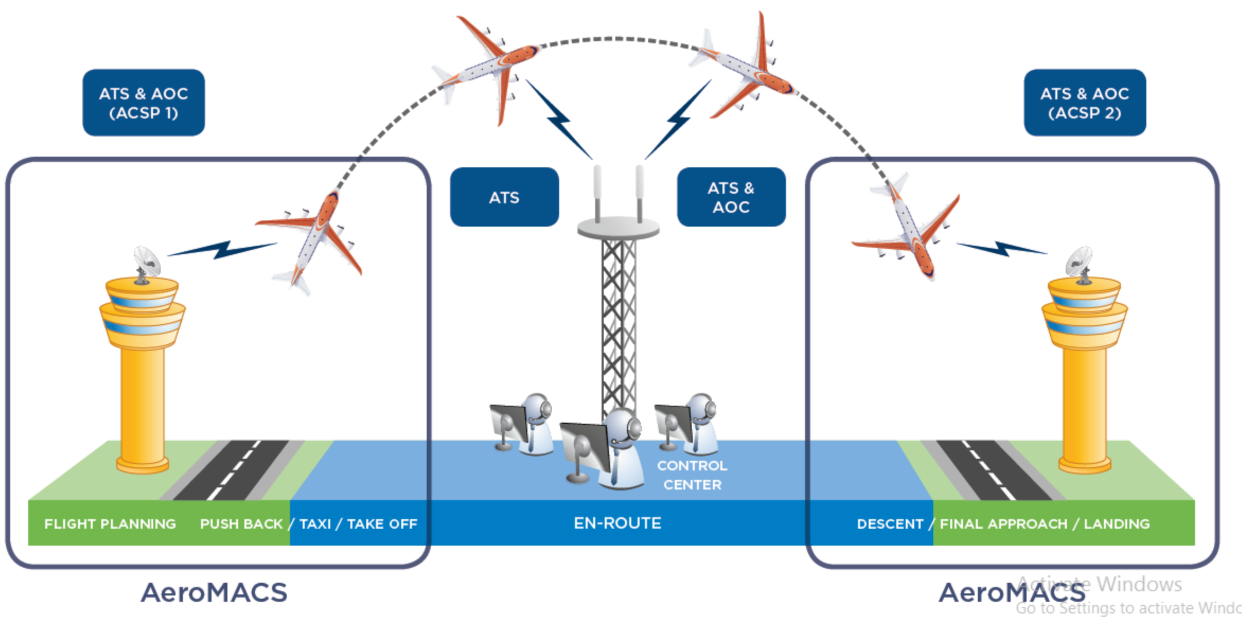


Figure 6 : AeroMACS Illustration 2

The Airport Surface Data Link Infrastructure solution is able to guarantee to the End Users the satisfaction of the following non-functional capabilities, which are some of the components of the Dependability Concept (Reliability, Availability, Maintainability and Safety and Security) as requested and recommended by international directives, regulations and guidelines, before to be put into operations.

1. Safety Resilience

In general, data link infrastructure is very complex in terms of functional and architectural aspects, including the huge and heterogeneous number of involved stakeholders. This implies that also if it is designed in order not to have a single point of failure, it can suffer of many domino effects.

2. **Security resilience**

The Airport Surface Data Link Infrastructure Solution includes the security and cyber-security countermeasures in order to protect the ground infrastructure perimeter, in terms of:

a. Confidentiality
b. Integrity
c. Denial of service
d. Trustworthiness.

3. **Reliability**

The ability of the system to deliver the operational services as specified.

4. **Availability**

The ability of the system to deliver the operational services when requested.

5. **Maintainability**

The likelihood of the system to provide the requested operational services when the proactive and corrective actions (procedure and means) are performed according to defined specifications.[18]

Chapter three: Methodology

3.1 AeroMACS Link Performance Modeling

The radio frequency link components that need to be modeled in order to simulate the end-to-end performance through the radio mobile channel for the AeroMACS system are the convolutional encoder, interleaver, Modulators, AWGNand fading Channels, Demodulators, deinterleaver, and Viterbi decoder.

The end-to-end performance simulation of the wireless transmission requires models for all these components, which are depicted in Figure7. These components represent the main blocks needed to mitigate the radio propagation impairments in order to receive correctly the transmitted information bits.

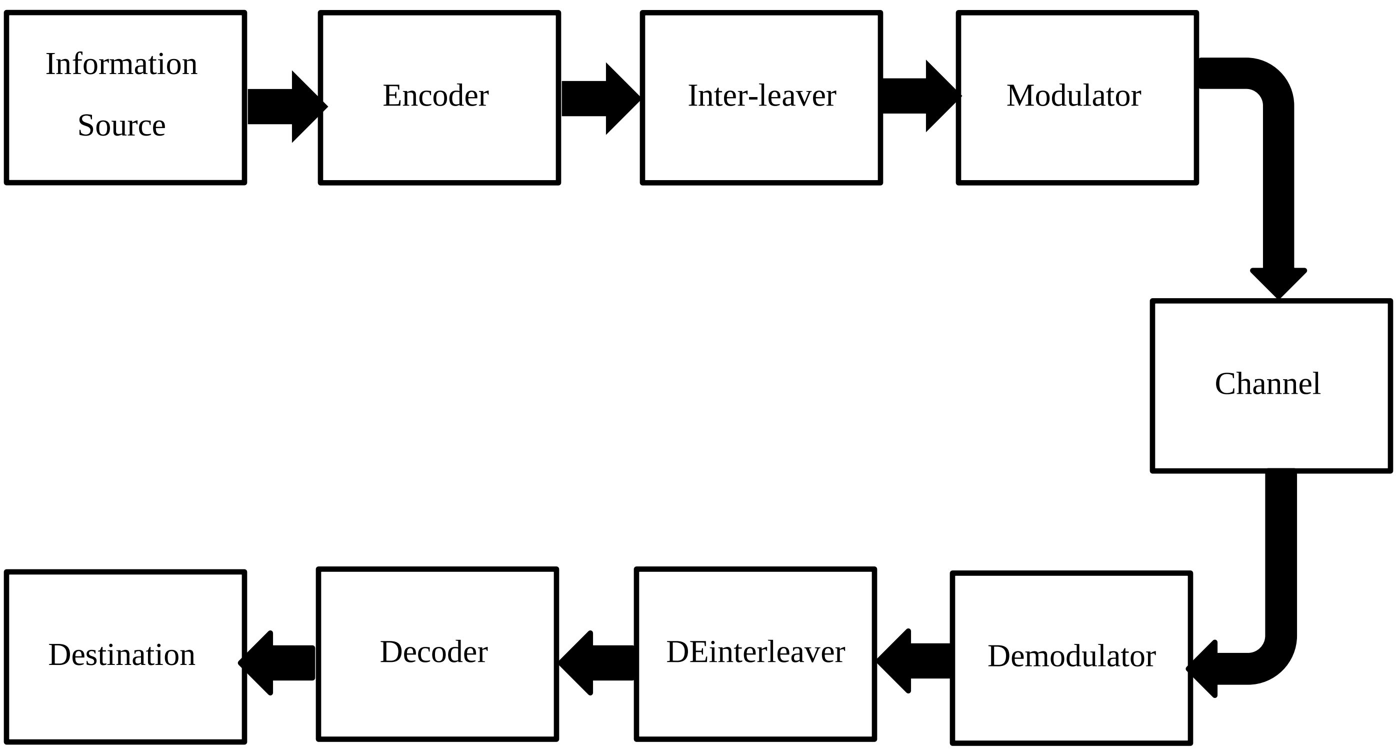


Figure 7: The General Performance Modeling of AeroMACS

The General Performance Modeling of AeroMACS in details:

3.1.1 Source and Destination

Source is one of the basic concepts of communication and information processing. Sources are objects which encode message data and transmit the information, via a channel, to one or more observers (or receivers).

In the strictest sense of the word, particularly in information theory, a *source* is a process that generates message data that one would like to communicate, or reproduce as exactly as possible somewhere else in space or time. A source may be modeled as memory less, ergodic, stationary, or stochastic, in order of increasing generality.shown in appendix A 1

The **destination** which used to display the calculation of bit error rate is the Error Rate display, the error rate display compares input data from a transmitter with input data from a receiver and calculates the error rate as a running statistic. To obtain the error rate, the object divides the total number of unequal pairs of data elements by the total number of input data elements from one source.

Figure 8 display the number of errors introduced by the channel noise. When you run the simulation, three small boxes appear in **Error Rate Display**.

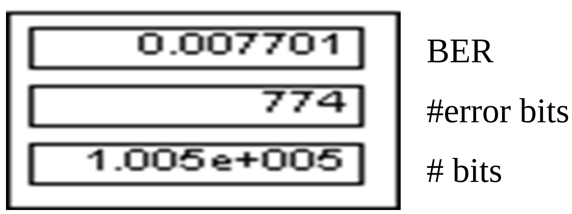


Figure8 :Error Rate Display

The block displays the output as follows:

1. **(BER)**The first entry is the symbol error.
2. **Total number of errors** is the second entry.
3. The third entry is the **total number of comparisons made.** The notation 1e+004 is shorthand for 104.

3.1.2 Convolution encoder and Viterbi decoder

1) Convolutional encoder

The mandatory channel coding schemes in AeroMACS are based on binary no recursive convolutional coding (CC).

The Convolutional Encoder block encodes a sequence of binary input vectors to produce a sequence of binary output vectors. This block can process multiple symbols at a time

This block can accept inputs that vary in length during simulation. shown in appendix A 2

Trellis structure is MATLAB structure that contains the trellis description of the convolutional encoder.

Operation mode In Continuous mode (default setting), the block retains the encoder states at the end of each frame, for use with the next frame.

2) Viterbi decoder

Hard and soft decisions using Viterbi algorithm can be used at the receiver to restore the transmitted bits using the convolutional encoder. shown in appendix A 3

3.1.3 Interleave and de Interleave

Inter-leavers and deinter-leavers are designed and used in the context of characteristics of the errors that might occur when the message bits are transmitted through a noisy channel.

1) Inter-leaver

After channel coding, the next step is interleaving. The interleaver is defined by a two-step permutation. The first ensures that coded bits are mapped onto nonadjacent subcarriers. The second permutation insures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, thus avoiding long runs of low-reliability bits.

Data interleaving is generally used to scatter error bursts and thus, reduce the error concentration to be corrected with the purpose of increasing the eﬃ ciency of FEC by spreading burst errors introduced by the transmission channel over a longer time. Interleaving is normally implemented by using a two-dimensional array buﬀ er, such that the data enters the buﬀ er in rows, which specify the number of interleaving levels, and then, it is read out in columns. The result is that a burst of errors in the channel after interleaving becomes in few scarcely spaced single symbol errors, which are more easily correctable.

The Number of rows and Number of columns parameters are the dimensions of the matrix that the block uses internally for its computations dependings on data input that coming from convolution encoder. This block accepts a column vector input signal. shown in appendix A 4

2) De Inter-leaver

The Matrix Deinterleaver block performs block deinterleaving by filling a matrix with the input symbols column by column and then sending the matrix contents to the output port row by row. The Number of rows and Number of columns parameters are the dimensions of the matrix that the block uses internally for its computations.

This block accepts a column vector input signal. double, and fixed-point. The output signal inherits its data type from the input signal. shown in appendix A 5

3.1.4 Modulator and Demodulator

1) Modulator

A modulator is a device that performs modulation. In electronics and telecommunications, modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal that typically contains information to be transmitted.

The modulators which used are:**QPSK Modulator and QAM Modulator.** The **QPSK Modulator** Baseband block modulates using the quaternary phase shift keying method. The output is a baseband representation of the modulated signal. shown in appendix A 6

The General **QAM Modulator** Baseband block modulates using quadrature amplitude modulation. The output is a baseband representation of the modulated signal.

The Signal constellation parameter defines the constellation by listing its points in a length-M vector of complex numbers. The input signal values must be integers between 0 and M-1. The block maps an input integer m to the (m+1)st value in the Signal constellation vector. This block accepts a scalar or column vector input signal. shown in appendix A 7

2) Demodulator

Demodulation is extracting the original information-bearing signal from a carrier wave. A demodulator is an electronic circuit (or computer program in a software-defined radio) that is used to recover the information content from the modulated carrier wave. The demodulators which used are: **QPSK demodulator and QAM demodulator. The QPSK Demodulator** Baseband block demodulates a signal that was modulated using the quaternary phase shift keying method. The input is a baseband representation of the modulated signal.The input must be a complex signal this block accepts a scalar or column vector input signal. shown in appendix A 8

The General **QAM Demodulator** Baseband block demodulates a signal that was modulated using quadrature amplitude modulation. The input is a baseband representation of the modulated signal.

The input must be a discrete-time complex signal. The Signal constellation parameter defines the constellation by listing its points in a length-M vector of complex numbers. The block maps the mth point in the Signal constellation vector to the integer m-1. shown in appendix A 9

3.1.5 Channel

The term channel refers to the medium between the transmitting antenna and the receiving antenna as shown in figure below:

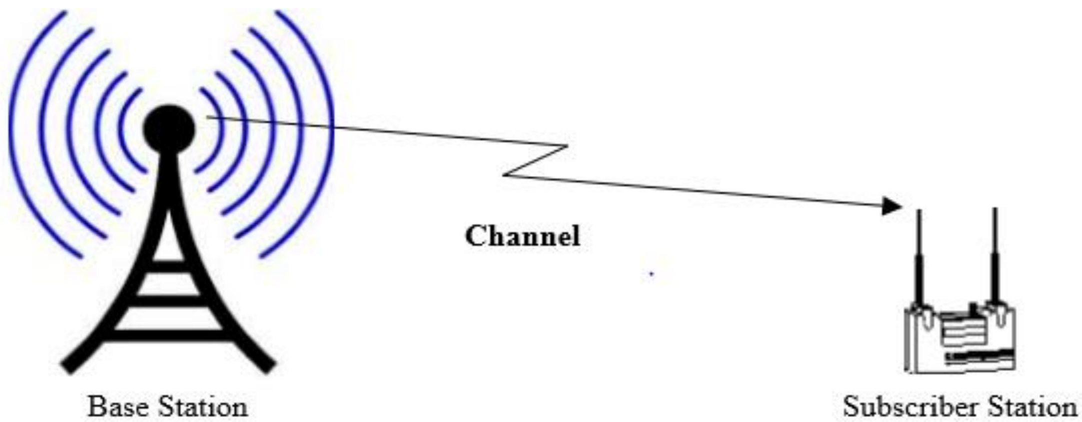


Figure 9:The Channel

We want to simulate the performance of AeroMACS due to number of input and output:

firstly ,single input single output by AWGN channel **.**The AWGN Channel block adds white Gaussian noise to a real or complex input signal. When the input signal is real, this block adds real Gaussian noise and produces a real output signal. When the input signal is complex, this block adds complex Gaussian noise and produce complex output signal. This block inherits its sample time from the input signal.

This block accepts a scalar-valued, vector, or matrix input signal with a data type of type single or double. The output signal inherits port data types from the signals that drive the block.

Secondly,multiple input multiple output by fading channel **.**The Multipath Rician Fading Channel block implements a baseband simulation of a multipath Rician fading propagation channel. You can use this block to model mobile wireless communication systems.

This block accepts a scalar value or column vector input signal. The block inherits sample time from the input signal. The input signal must have a discrete sample time greater than 0. shown in appendix A 10

3.1.6 OSTBC Encoder

Encode the input message using an Orthogonal Space Time Block Code. shown in appendix A 11

3.1.7 OSTBC Combiner

Combine the recived signal and channel estimate inputs in accordance with the structure of the Orthogonal Space Time Block Code shown in appendix A 12

3.2 AeroMACS Performance Simulation

3.2.1 By AWGN channel with QAM modulator and rate 1/2

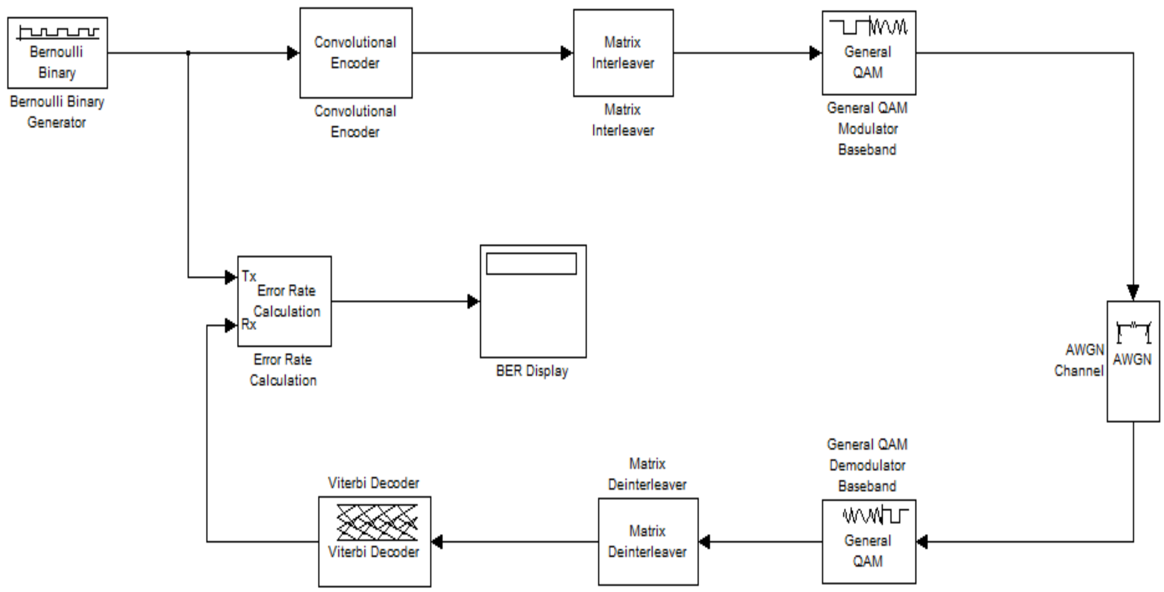


Figure10 : AWGN channel with QAM modulator and rate 1/2

3.2.2 By AWGN channel with QPSK modulator and rate 1/2

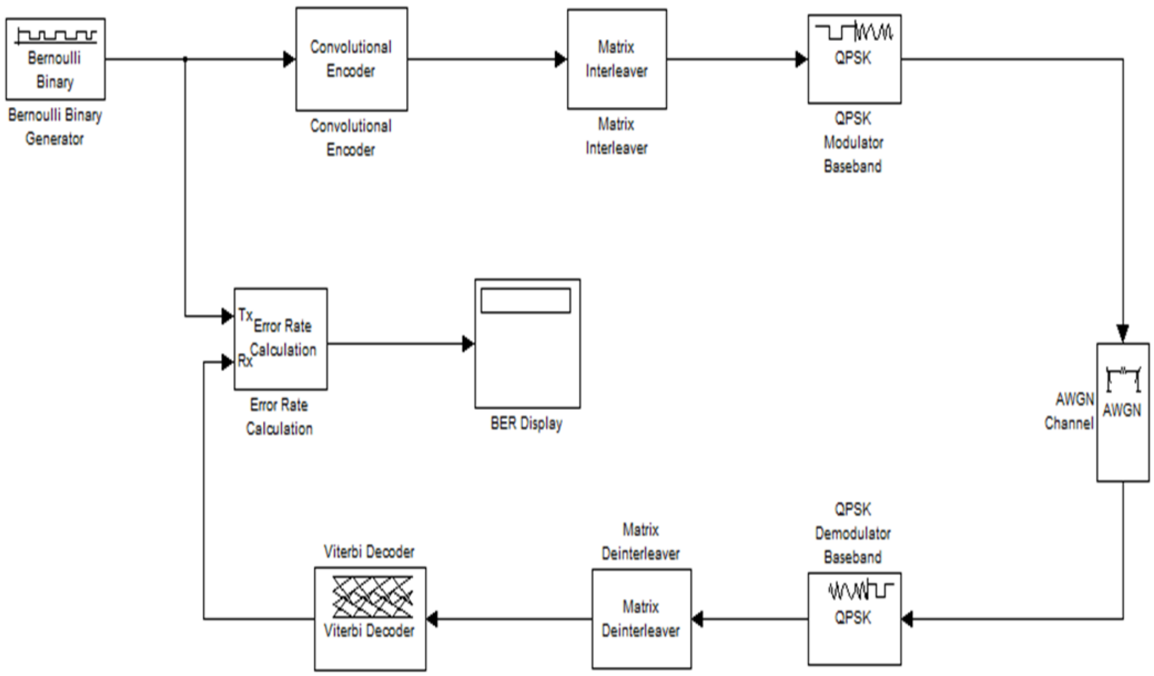


Figure11 : AWGN channel with QPSK modulator and rate 1/2

3.2.3 By fading channel with QPSK modulator and rate 3/4

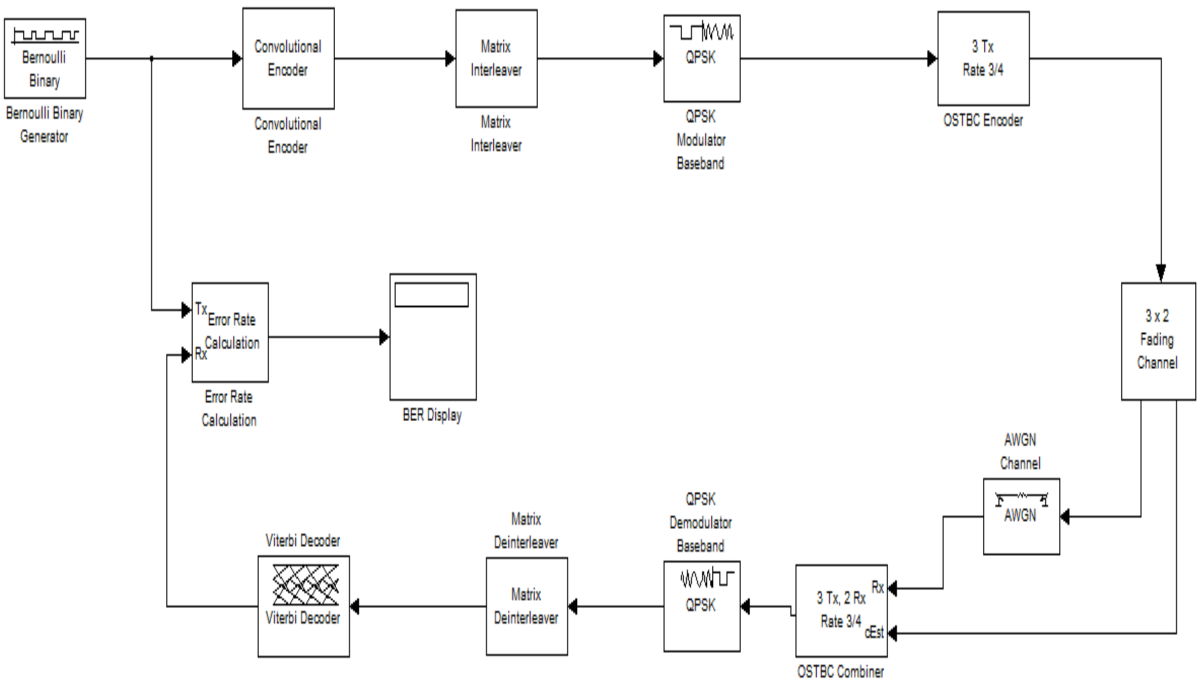


Figure12 : fading channel with QPSK modulator and rate 3/4

3.3 Comparing between AeroMACS performance and VHF performance

Based on the VHF system that cannot be operated in high order modulation that's why its performance has been found using BPSK modulator.in contrast of AeroMACS which uses high order modulation.

But to compare between two mentioned systems in performance, we must use the same type of modulation.as result to this we use the BPSK modulator to simulate the performance of AeroMACS*.*

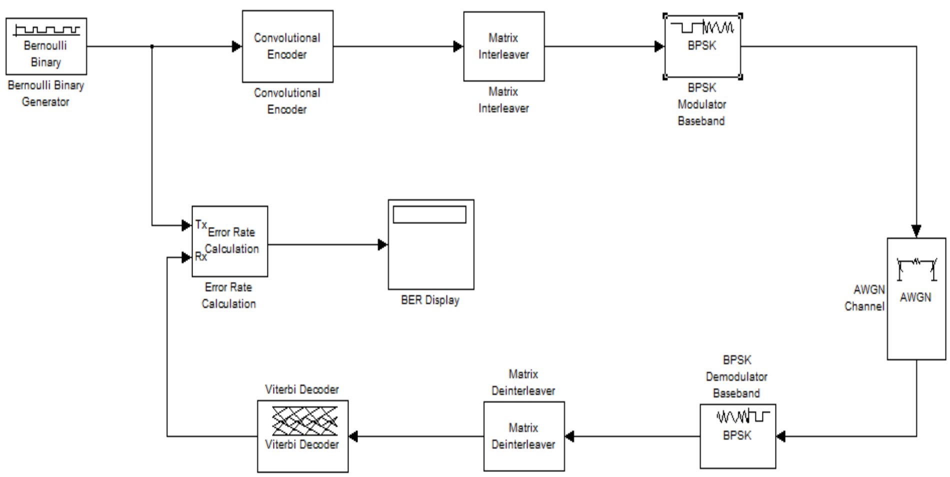


Figure 13:AeroMACS Performance with BPSK Modulator

Chapter four: Results and Discussion

We perform link level simulations for a variety of combinations of digital modulation schemes and convolutional coding techniques defined as mandatory in the AeroMACS standard, to determine the BER versus Signal-to-Noise Ratio (SNR) performance curves.

4.1 SISO Soft Decision in AWGN Channel

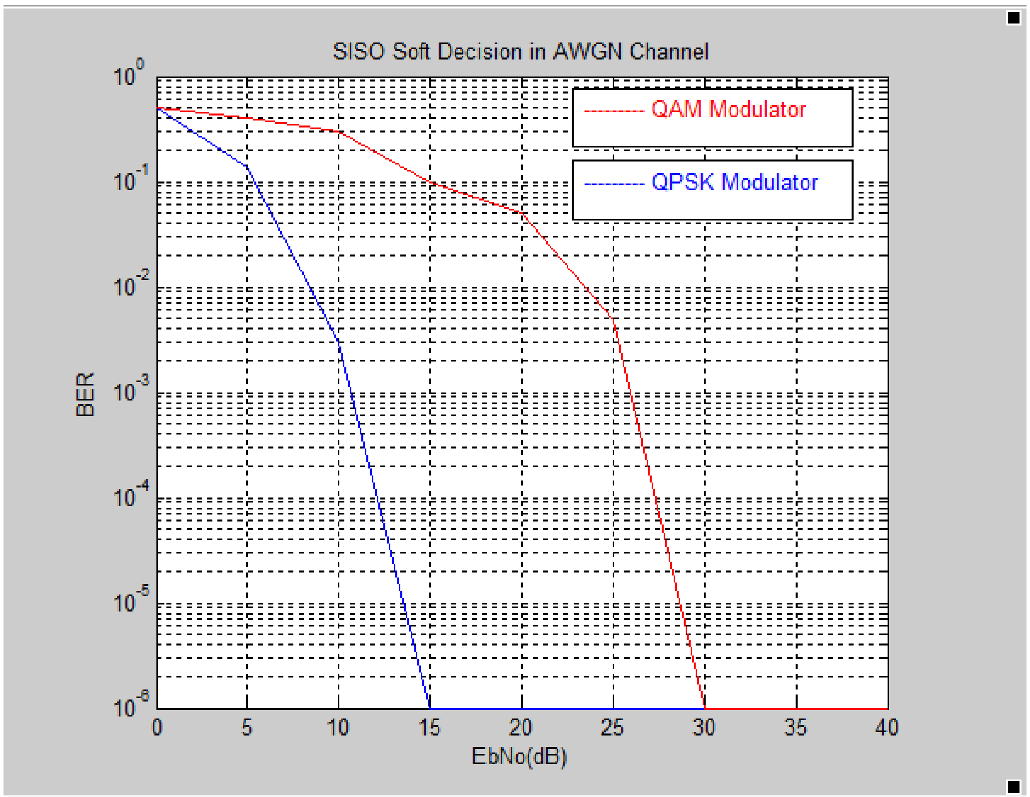


Figure14 : SISO Soft Decision in AWGN Channel

Figure 14 explains performance of AeroMACS when we use AWGN channel, QPSK and QAM modulators and Rate ½ . X-axes represents Sginal to Noise Ratio (EbNo)dB and Y-axes represents Bit Error Rate (BER), when Signal to Noise Ratio is equal to zero the BER is at maximun and it decreases according to the increase of signal to noise ratio. Untill it reaches ($0.1x10^{-5}$) when signal to noise ratio is (30dB) in QAM modulator, but in QPSK modulator it reaches to the same value when signal to noise ratio is (15dB), from this results the QPSK modulator soft decision is better than the QAM modulator soft decision.

4.2 SISO Hard Decision in AWGN Channel

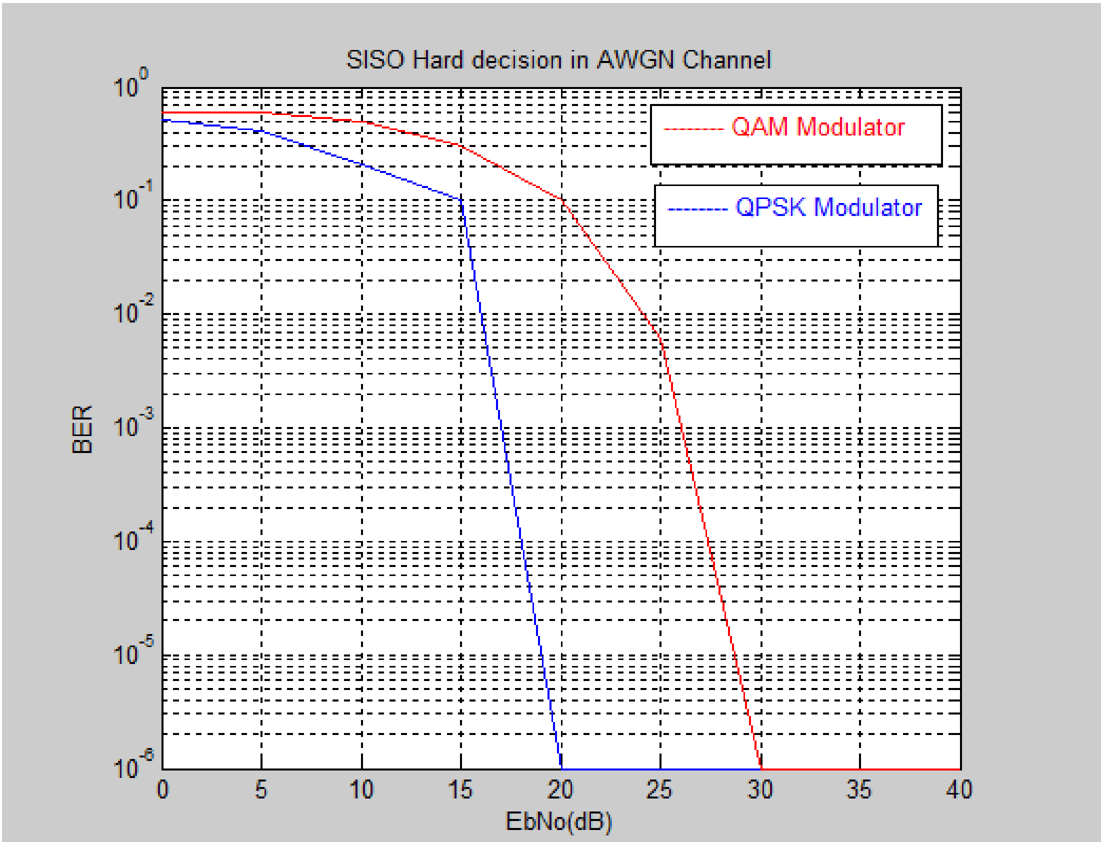


Figure15 : SISO Hard Decision in AWGN Channel

Figure 15 explains performance of AeroMACS when we use AWGN channel, QPSK and QAM modulators and Rate ½ . X-axes represents Sginal to Noise Ratio (EbNo)dB and Y-axes represents Bit Error Rate (BER), when Signal to Noise Ratio is equal to zero the BER is at maximun and it decreases according to the increase of signal to noise ratio. Untill it reaches ($0.1x10^{-5}$) when signal to noise ratio is (30dB) in QAM modulator, but in QPSK modulator it reaches to the same value when signal to noise ratio is (20dB), from this results the QPSK modulator hard decision is better than the QAM modulator hard decision.

From the above curves, we found that the QPSK modulator is better than the QAM modulator, and the soft decsion of the QPSK is better than the hard decision of the QPSK.

4.3 MIMO Hard andSoft Decision in Fading Channel with QPSK Modulator

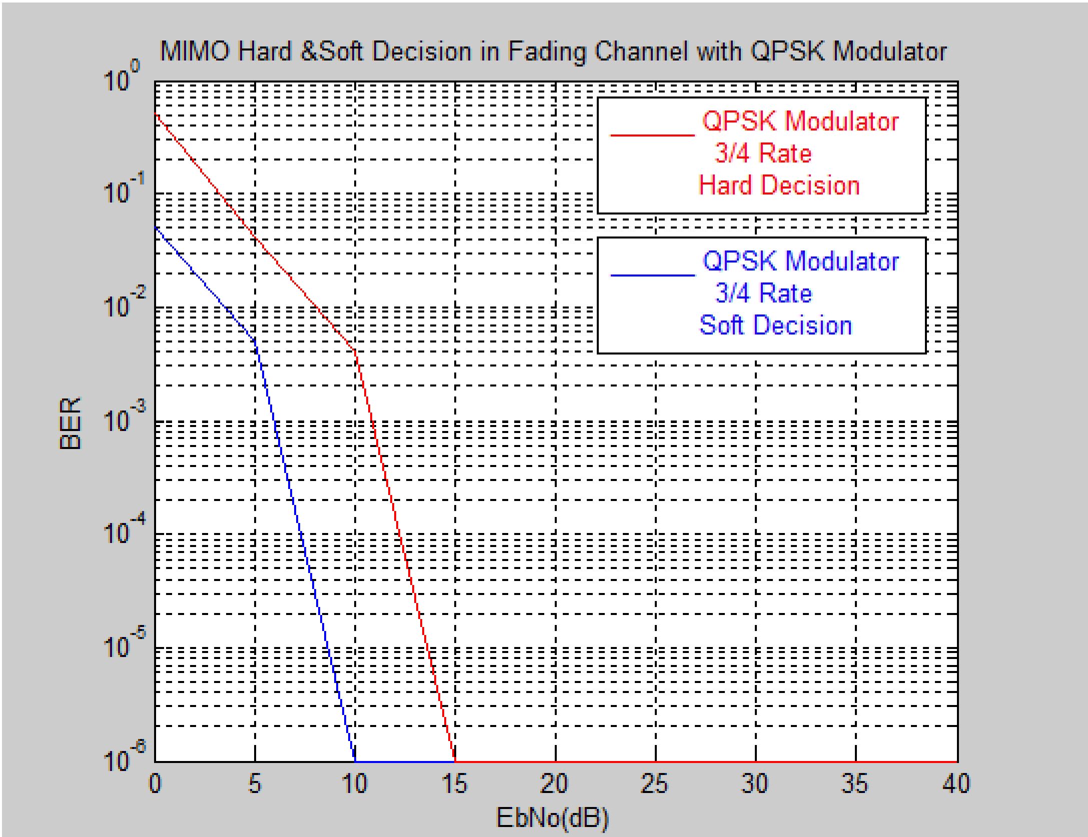


Figure16 : MIMO Hard andSoft Decision in Fading Channel with QPSK Modulator

Figure 16 explains the performance of the AeroMACS when we use multiple input multiple output channel (Fading Channel). The X-axes explains signal to noise ratio and the Y-axes explains the Bit Error Rate.

The relation between the Signal to Noise Ratio and the the Bit Error Rate is opposite relationship that means when Signal to Noise Ratio increases the Bit Error Rate decreases, until the Signal to Noise Ratio reaches (15dB) in hard decision and (10dB) in soft decision, the Bit Error Rate is ($0.1x10^{-5}$). the soft decsion of the QPSK is better than the hard decision of the QPSK.

4.4 Comparing Results

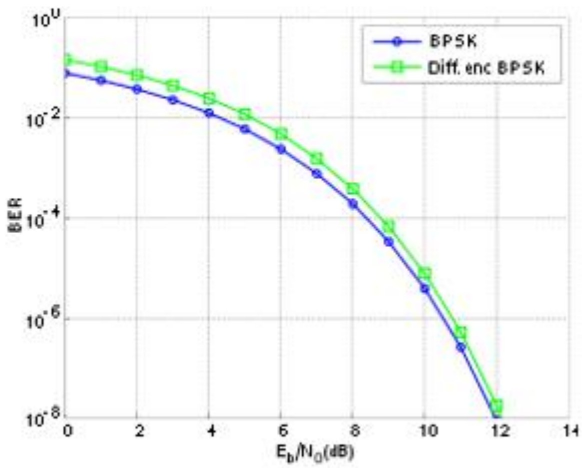


Figure 17: VHF Performance[1]

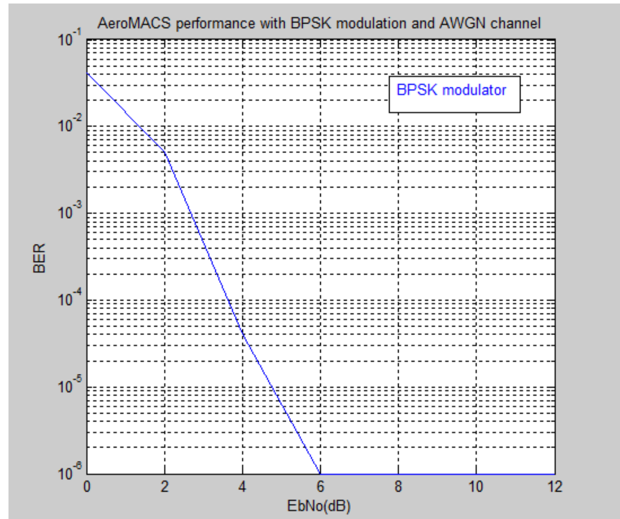


Figure 18:AeroMACS performance

Figure 17 and 18 explains the performance of VHF and AeroMACS systems respectively with BPSK modulator. The X-axes explains signal to noise ratio and the Y-axes explains the Bit Error Rate.

The relation between the Signal to Noise Ratio and the the Bit Error Rate is opposite relationship that means when Signal to Noise Ratio increases the Bit Error Rate decreases, until the Signal to Noise Ratio reaches (12dB) in VHF system and (6dB) in AeroMACS system, the Bit Error Rate is $(0.1x10^{-5})$.

From curves, we found that the AeroMACS system is better than the VHF system.

Chapter five: Conclusion and Recommendation

5.1 Conclusion

For the important of aviation communication , the communications have to be developed because the traditional system had some problem like a Radio has been configured to "LOW Power" transmission mode, low battery level, poor/corroded radio power leads, insufficient power wire gauge, a failure of the VHF antenna, a failure of VHF antenna cable, corrosion and/or failure of the antenna's PL-259 connector, a failure of an antenna splitter (if installed) and a failure within the VHF radio's transmitter circuitry . In our simulation of AeroMACS performance we obtain plots between the signal to noise ratio and the bit error rate according to the problem and the simulation we found that the AeroMACS has a better performance.

5.2 Recommendation and Future Work

After Months of dedication and hard working, we manage to find out a better performance for a new communication system at C-Band, we recommend anyone who will follow after to :

1. continue checking and examining other components of AeroMACS.
2. further to study other systems which operate at L-Band,this system is called (LDACS) to complete the new communication system from the takeoff to the landing.

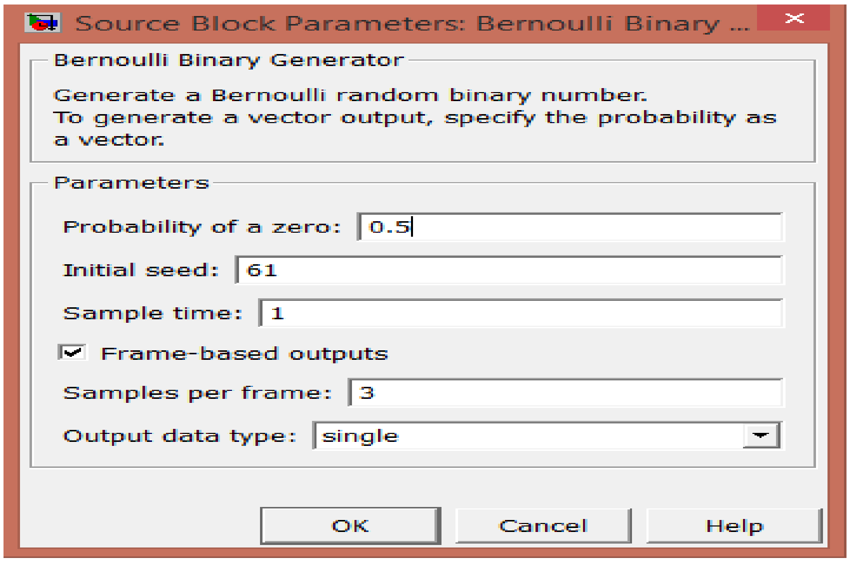
References

1. Wyatt, M.T.a.D., *Aircraft Communications and Navigation Systems.* 2007.
2. Guzzo, R.A. and M.W. Dickson, *Teams in organizations: Recent research on performance and effectiveness.* Annual review of psychology, 1996. **47**(1): p. 307-338.
3. Clark, H.H. and S.E. Brennan, *Grounding in communication.* Perspectives on socially shared cognition, 1991. **13**(1991): p. 127-149.
4. De Beaugrande, R. and W. Dressler, *Text linguistics.* 1994) Encyclopedia of Language and Linguistics, Oxford: Pergamon, 1994. **9**: p. 4573-8.
5. Boyne, W.J., *Air Warfare: An International Encyclopedia*. Vol. 1. 2002: Abc-clio.
6. Huurdeman, A.A., *The worldwide history of telecommunications*. 2003: John wiley and sons.
7. Levine, S., K. Baxter, and K. Fisher, *Low cost inertial navigator*. 2002, Google Patents.
8. Schiller, J.H., *Mobile communications*. 2003: Pearson Education.
9. Yick, J., B. Mukherjee, and D. Ghosal, *Wireless sensor network survey.* Computer networks, 2008. **52**(12): p. 2292-2330.
10. De Waal, P., J. Nooteboom, and J.P. Poley, *Use of VHF dielectric measurements for borehole formation analysis.* The Log Analyst, 1978. **19**(03).
11. Wang, K., A.-C. Wong, and C.-C. Nguyen, *VHF free-free beam high-Q micromechanical resonators.* Journal of microelectromechanical systems, 2000. **9**(3): p. 347-360.
12. Kenward, R.E., *A manual for wildlife radio tagging*. 2000: Academic Press.
13. Nair, G., et al., *IEEE 802.16 Medium Access Control and Service Provisioning.* Intel Technology Journal, 2004. **8**(3).
14. Andrews, J.G., A. Ghosh, and R. Muhamed, *Fundamentals of WiMAX: understanding broadband wireless networking*. 2007: Pearson Education.
15. Velez, R.P.a.F.J., *OFDMA WiMAX Physical Layer.*
16. Williams, M.D., et al. *RF-DNA fingerprinting for airport WiMax communications security*. in *Network and System Security (NSS), 2010 4th International Conference on*. 2010. IEEE.
17. Maral, G. and M. Bousquet, *Satellite communications systems: systems, techniques and technology*. 2011: John Wiley and Sons.
18. S.p.a, L., *AwreMACS.* 2017.

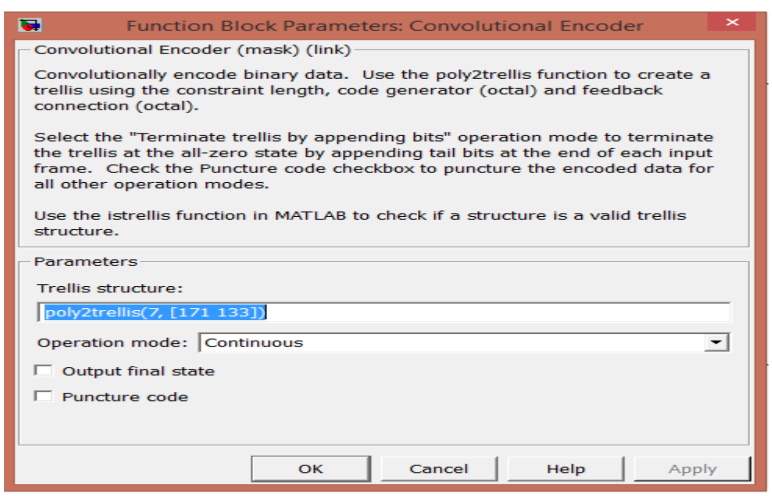
Appendices

Appendix (A)

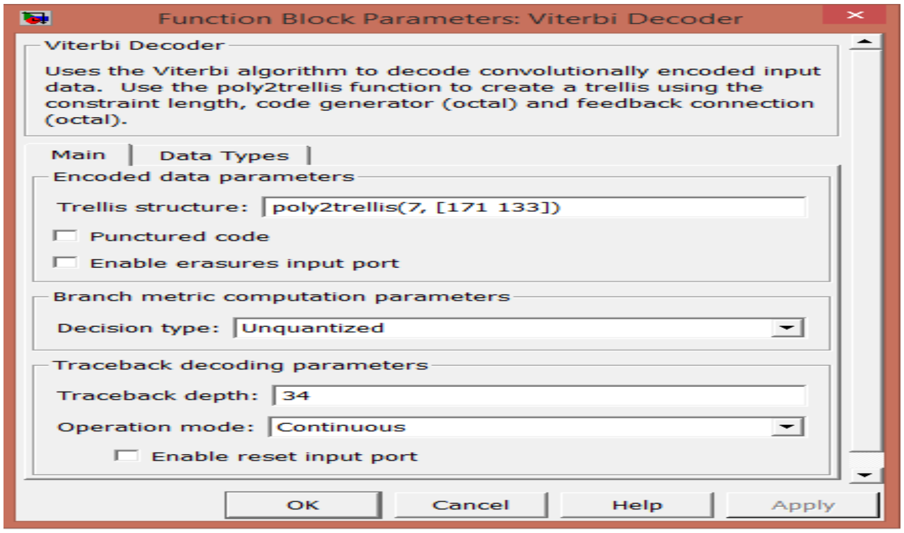
1. source



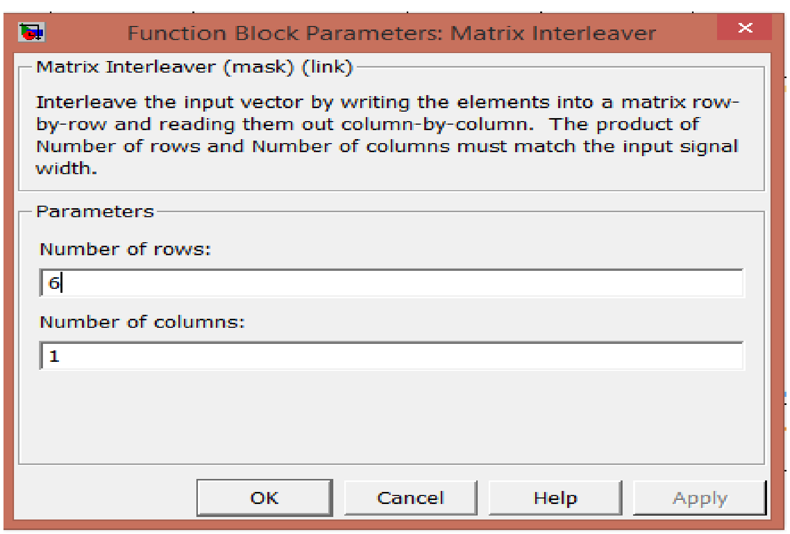
2. Convolutional Encoder



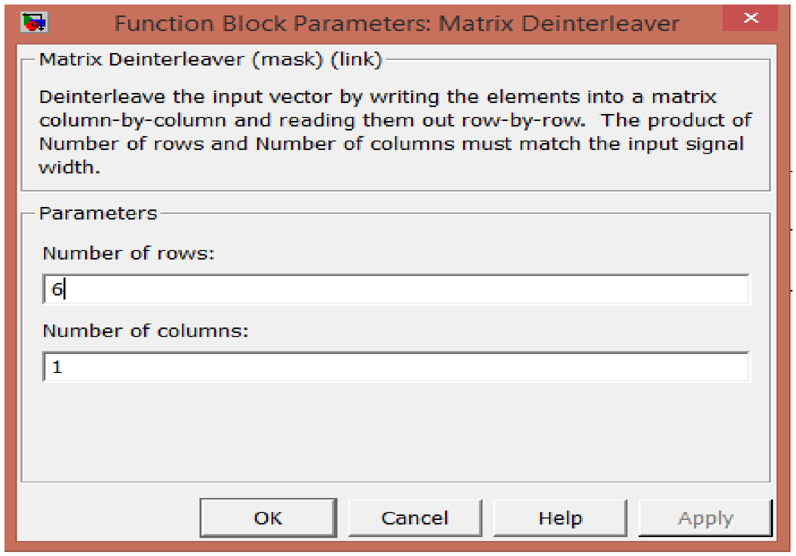
3. Viterbi Decoder



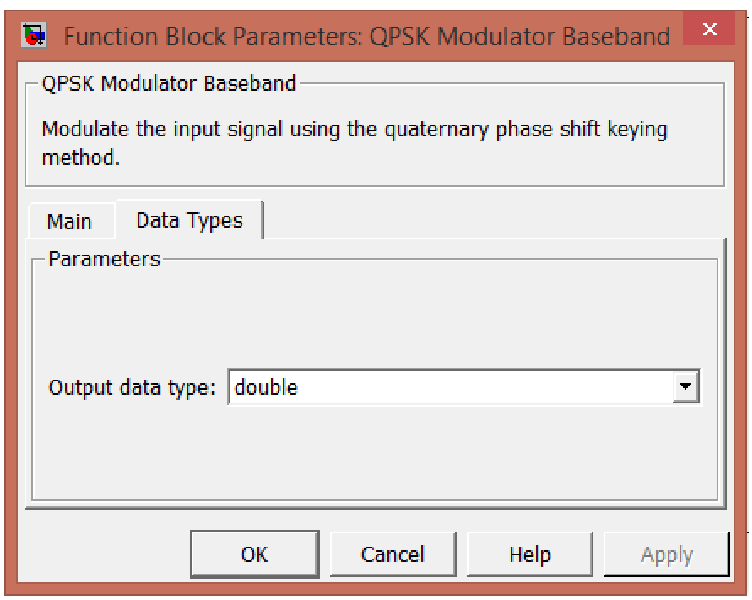
4. Inter_leaver



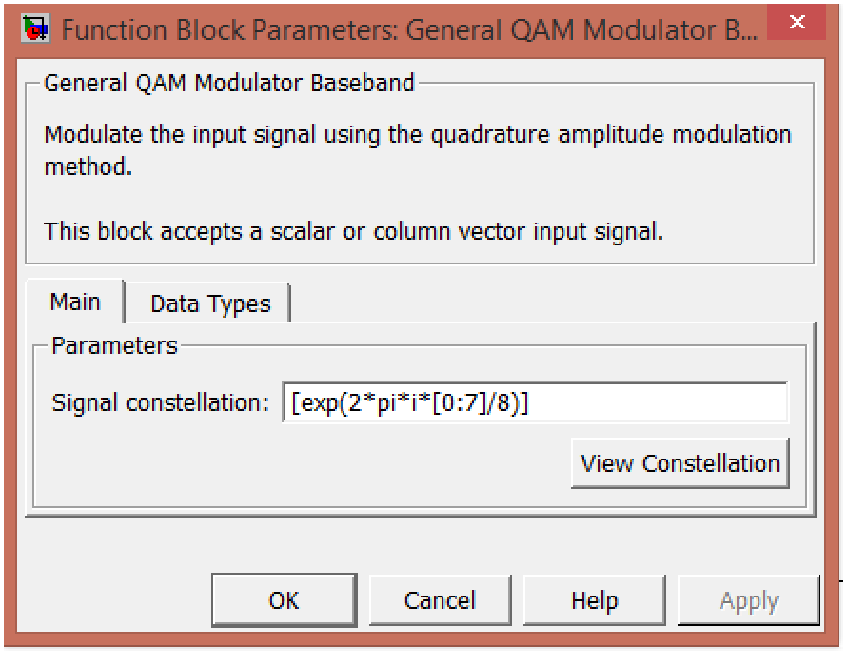
5. Deinter_leaver

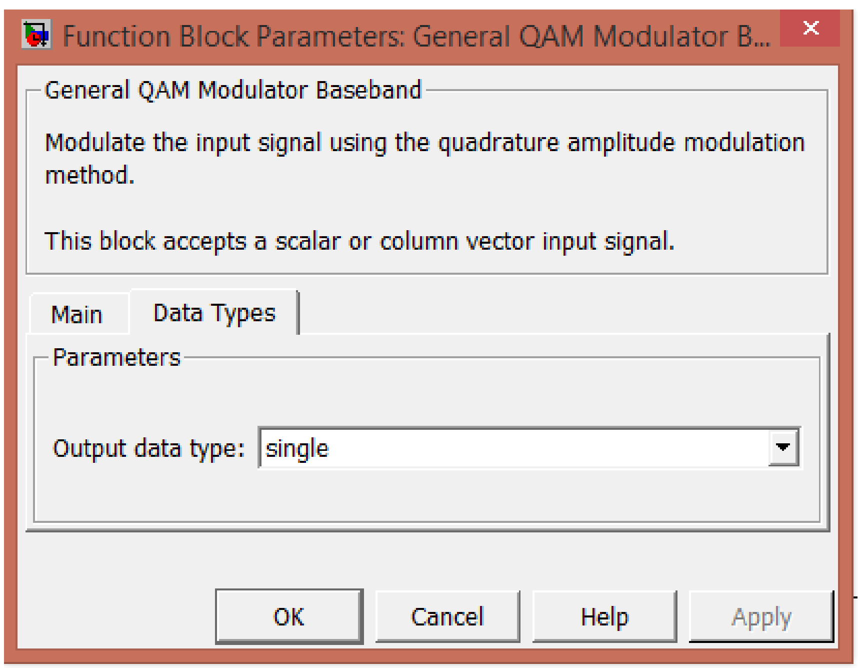


6. QPSK Modulator

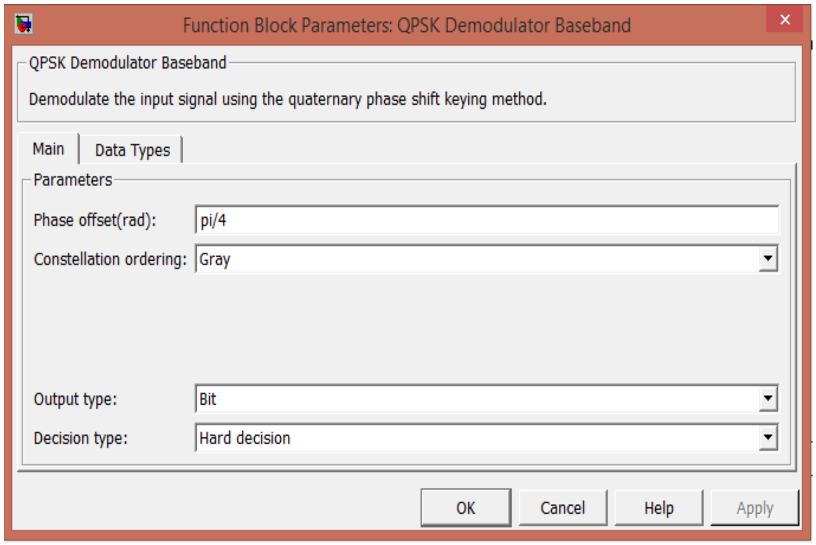


7. QAM Modulator

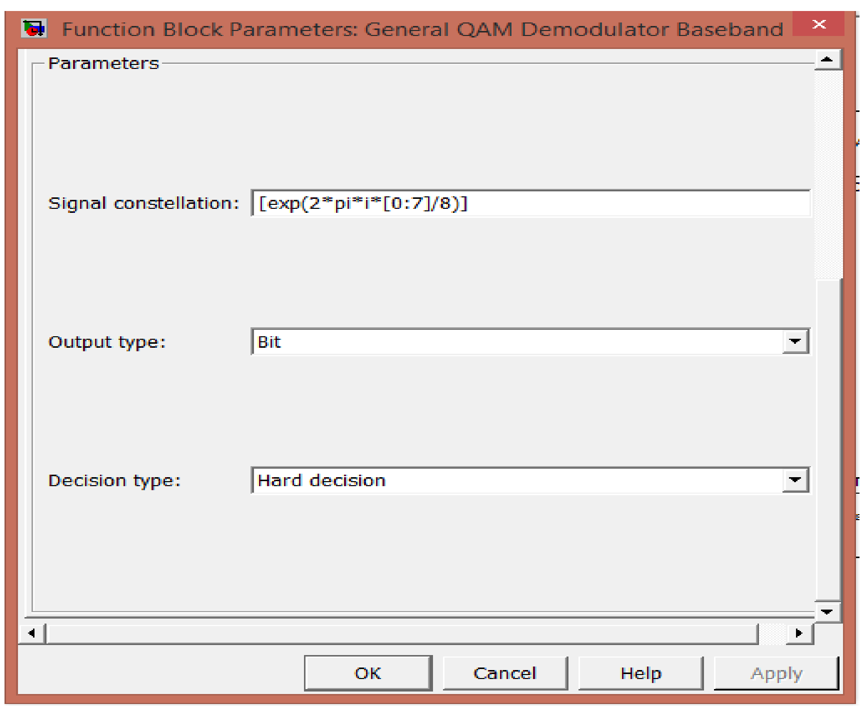




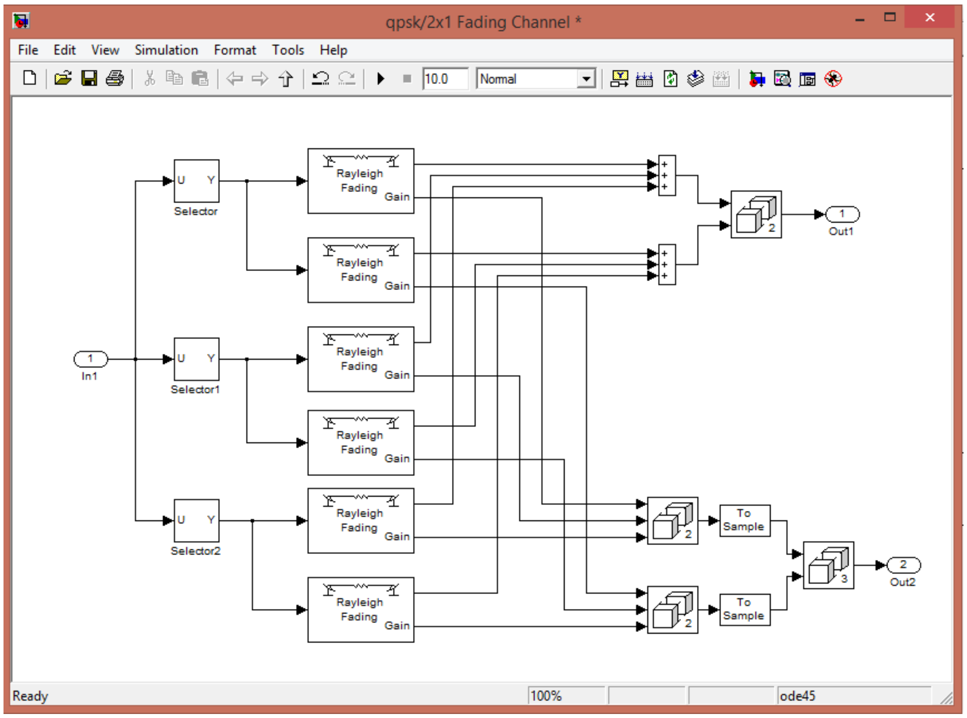
8. QPSK Demodulator



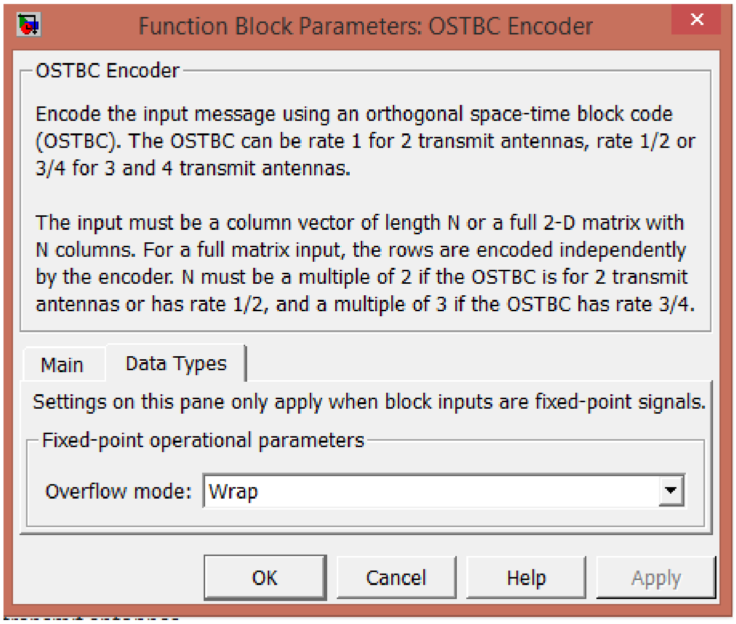
9. QAM Demodulator



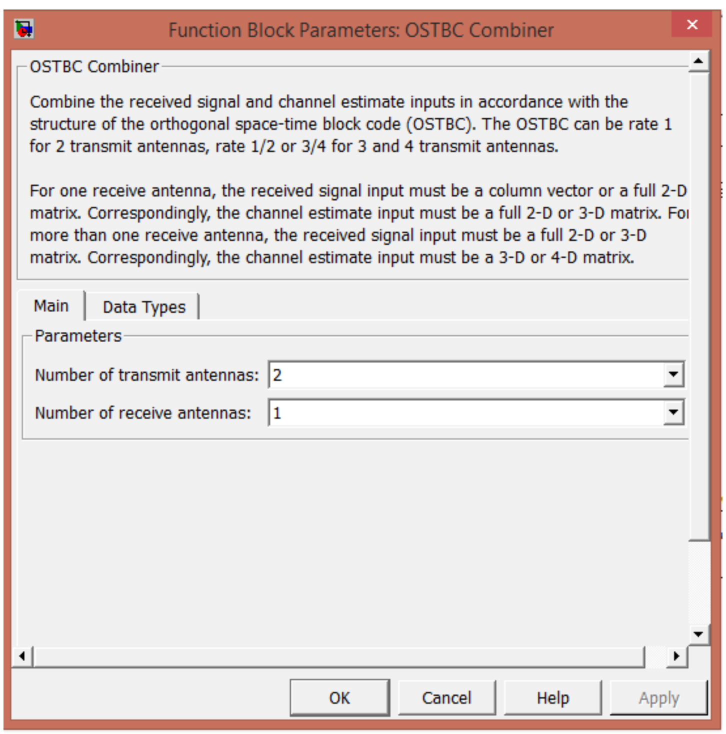
10.Fading Channel



11.OSTBC Encoder



12.OSTBC Combiner



Appendix (B)

To obtain the curve in figure 14 execute SISO Soft Decision in AWGN Channel curve code

```
>> x=[0 5 10 15 20 25 30 40 ]
>> y=[0.4985 0.13567 0.002987 0.000001 0.000001 0.000001 0.000001 0.000001]
>> semilogy(x,y,'blue')
>> hold on
>> z=[0.4995 0.3995 0.2981 0.1000 0.04999 0.004876 0.000001 0.000001]
>> semilogy(x,z,'red')
>> grid
```

To obtain the curve in figure 15 execute SISO Hard Decision in AWGN Channel curve code

```
>>x=[0 5 10 15 20 25 30 40 ]
>> y=[0.5073 0.4085 0.208 0.103 0.000001 0.000001 0.000001 0.000001]
>> semilogy(x,y,'blue')
>> hold on
>> z=[0.6016 0.5987 0.5011 0.3005 0.1 0.006051 0.000001 0.000001]
>> semilogy(x,z,'red')
>> grid
```

Appendix (C)

To obtain the curve in figure 16 MIMO Hard andSoft Decision in Fading Channel with QPSK Modulator Curve code

```
>> x=[0 5 10 15 20 25 30 40]
>> y=[0.04995 0.005005 0.000001 0.000001 0.000001 0.000001 0.000001 0.000001]
>> semilogy(x,y,'blue')
>> hold on
>> z=[0.5095 0.04062 0.004014 0.000001 0.000001 0.000001 0.000001 0.000001]
>> semilogy(x,z,'red')
>> grid
```

To obtain the curve in figure 18 AeroMACS Performance curve code

```
>> x=[0 2 4 6 8 10 12]
>> y=[0.04085 0.005003 0.00004098 0.000001 0.000001 0.000001 0.000001]
>> semilogy(x,y,'blue')
>> grid
```