# MITIGATION OF AM INTERFERENCE IN DIGITAL TRANSMISSION

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**A project report submitted as partial fulfillment of the requirements for the award of the Master Degree of Electrical Engineering**

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**MARCH, 2004**

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*For My Mother Asiah Binti Jumali,*

*My Father Sulaiman Bin Naim,*

*And My Fiancé Noor Azradiana Binti Zahari with Love,*

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## ACKNOWLEDGEMENT

I would like to express my gratitude to my supervisor, Professor Dr Mohd Zarar Bin Mohd Jenu for his guidance and help rendered throughout this project. His willingness to teach attitude and unfailing patience has been a great motivation for me to excel in my work. Without his guidance and invaluable time spent, this thesis would not have been completed successfully.

To Mrs. Rosila, Mr. Nazri, Mr. Aizan and others whose name could not be mentioned here one by one. Your encouragement and concern is greatly appreciated.

Finally, I would like to thank God for giving me this wonderful privilege to work on my project and entire lesson I've learned along the way. Surely it is an experience which will prove invaluable later in life.


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## ABSTRACT

The plain-old-telephone-system (POTS) is now increasingly used to carry high-speed data such as for Internet purpose. However, problem can occur if the telephone network is in close proximity to an AM radio transmitter, transmitting high power signal at a frequency which overlaps the bandwidth of the Internet transmission. The interfering electromagnetic field can induced enough current and voltage in the telephone network and causing significant data errors. This report presents a study on the effects of high-powered AM transmission at 576 kHz on a digital transmission system. A GTEM Cell was used to generate the 576kHz electric field intensity varying from 1V/m to 15 V/m with 80% amplitude modulation. The electric field is imposed on a section of the cable and the Bit Error Rate (BER) is noted using Data Tools 5000. Shielding technique was employed using four conducted materials (soft steel, hard steel, aluminum and copper) in order to test the attenuation of the electric field reaching the cable. Measured results showed that copper ($\sigma = 5.87 \times 10^7$ S/m, $\mu_r = 1$) can reduce up to 70% of the BER. The relationship between electric field $|\vec{E}|$ and BER for copper is expressed as

$BER = 2 \times 10^{-5} e^{0.399|\vec{E}|} + 2.48 \times 10^{-5}$, indicating that the BER increases exponentially with the magnitude of the applied electric field. It is obvious from the work done in this project that any network situated near a high-powered electromagnetic field transmitter should employ a good shielded cabling system. It is recommended that further study need to be carried out to find ways of mitigating the effects of the interfering field such filtering and grounding.

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# ABSTRAK

Penggunaan plain-old-telephone-system (POTS) pada masa kini semakin meningkat terutama untuk membawa data kelajuan tinggi seperti Internet. Walau bagaimanapun, masalah akan timbul sekiranya sistem ini terletak berhampiran pemancar radio AM yang memancarkan isyarat dengan kuasa tinggi terutama pada frekuensi yang bertaut dengan lebarjalur penghantaran Internet. Gangguan medan elektromagnet boleh menghasilkan arus dan voltan ke dalam rangkaian telefon dan menyebabkan kesilapan data. Tesis ini menerangkan kesan kuasa tinggi penghantaran AM pada 576 kHz keatas sistem penghantaran digital. GTEM Cell digunakan untuk menghasilkan 576 kHz keamatan medan elektrik diantara 1V/m hingga 15 V/m dengan 80% perubahan amplitud. Medan elektrik dikenakan keatas sebahagian kabel penghantaran dan Kadar Kesilapan Bit (BER) dicatat menggunakan Data Tools 5000. Kaedah pelindung digunakan dengan empat bahan pengalir (besi lembut, besi keras, aluminium dan kuprum) untuk menguji keamatan medan elektrik yang menghampiri kabel. Keputusan ujikaji menunjukkan kuprum ($\sigma = 5.87 \times 10^7$ S/m, $\mu_r = 1$) dapat mengurangkan sehingga 70% BER. Hubungan antara medan elektrik $|\vec{E}|$ dan BER untuk kuprum ialah

$BER = 2\times10^{-5}e^{0.399|\vec{E}|} + 2.48\times10^{-5}$ , menunjukkan bahawa BER meningkat secara eksponen dengan peningkatan magnitud medan elektrik. Ujikaji yang dijalankan menunjukkan dengan jelas bahawa setiap sistem yang berdekatan dengan pemancar medan elektromagnet kuasa tinggi mesti menggunakan kaedah pelindung kabel yang baik. Adalah dicadangkan bahawa kajian lebih mendalam harus dibuat untuk mancari cara mangatasi gangguan medan elektrik seperti kaedah penapis dan pembumian.

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## GLOSSARY OF ABBREVIATIONS

| | | |
|---|---|---|
| E | - | Electric Field (V/m) |
| B | - | Magnetic Flux (T) |
| f | - | Frequency (f) |
| H | - | Magnetic Field (H/m) |
| J | - | Current Density |
| $\mu_r$ | - | Relative Permeability |
| $\sigma_r$ | - | Relative Conductivity |
| S | - | Shielding Effectiveness |
| Z | - | Impedance (Ω) |
| AC | - | Alternating Current |
| ADSL | - | Asymmetric Digital Subscriber Line |
| AM | - | Amplitude Modulation |
| ATM | - | Asynchronous Transfer Mode |
| ATU | - | ADSL Terminal Unit |
| BER | - | Bit Error Rate |
| BERT | - | Bit Error Rate Tests |
| CB | - | Citizens Band |
| CE | - | Conducted Emission |
| CM | - | Common Mode |
| CO | - | Central Office |
| DC | - | Direct Current |
| DM | - | Differential Mode |
| DMT | - | Discrete Multi Tone |
| EMC | - | Electromagnetic Compatibility |
| EMI | - | Electromagnetic Interference |

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| | | |
|---|---|---|
| EMS | - | Electromagnetic Susceptibility |
| ESD | - | Electrostatic Discharges |
| EUT | - | Equipment under Test |
| FCC | - | Federal Communications Commission |
| FDD | - | Frequency Division Duplex |
| FEC | - | Forward Error Correction |
| FEXT | - | Far End Crosstalk |
| FFT | - | Fast Fourier Transform |
| FM | - | Frequency Modulation |
| GTEM | - | Gigahertz Transverse Electromagnetic |
| HF | - | High Frequency |
| JMLSE | - | Joint Maximum Likelihood Sequence Estimation |
| MMSE | - | Minimum Mean-Square Error |
| NEXT | - | Near End crosstalk |
| NID | - | Network Interface Device |
| POTS | - | Plain Analog Telephone Service |
| RF | - | Radio Frequency |
| RFI | - | Radio Frequency Interference |
| RT | - | Remote Terminal |
| SNR | - | Signal to Noise Ratio |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

The widespread use of electronic circuits for communication, computation, automation and other purposes makes it necessary for diverse circuits to operate in close proximity. All too often, these circuits affect each other adversely. Electromagnetic interference (EMI) has become a major problem for circuit designers, and it is likely to become more severe in the future. The large number of electronic devices in common use is partly responsible for this trend. In addition, the use of integrated circuits and large-scale integration has reduced the size of electronic equipment. As circuitry has become smaller and more sophisticated, more circuits are being crowded into less space, thus increasing the probability of interference.

Today's equipment designers need to do more than just make their systems operate under ideal conditions in the laboratory. Besides that obvious task, they must also make sure the equipment will actually work in the "real world" with other

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equipment nearby. This means that the equipment should not be affect by external noise sources, and should not it be a source of noise to the environment. Electromagnetic compatibility (EMC) should be a major design objective. Figure 1.1 shows four aspects of EMC issues.

*"The ability of device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment is called EMC".* [1]

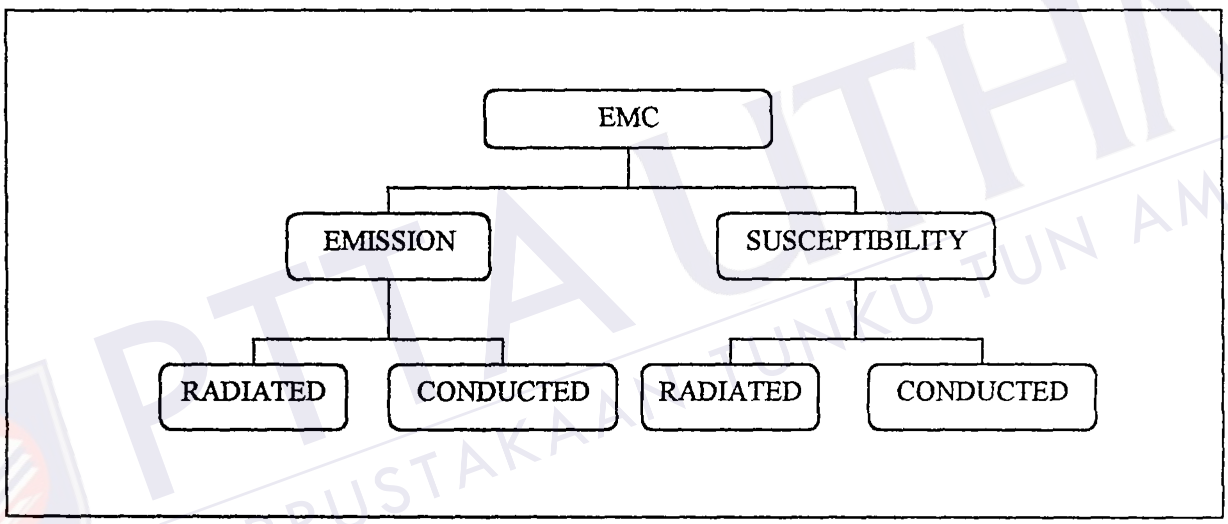


**Figure 1.1: Aspects of EMC [1]**

Interference can be eliminated or at least reduced by using many techniques such as shielding, grounding, filtering, separation, orientation, and cable design etc [2]. With all these method available, it should be remembered that noise usually could not be eliminated; but it could be minimized to the point where it no longer causes interference. A single unique solution to the noise reduction may not exist. Compromises are generally required, and which of the many alternative solutions is the best can be the subject considerable agreement.

## 1.2 Problem Statement

New digital technologies operate at high frequencies is an economical alternative to deliver broadband services over the existing copper access network. In order to be successful, digital transmission will have to deal with a number of impairments that exist in the local loop. The focus is on interference from and into radio users. Because digital signals contain frequencies up to several megahertz, these broadband signals are susceptible to more hostile noise conditions such as radio system. In this study we will discuss the interference and noise reduction techniques due to AM radio system that used 576 kHz frequencies; with 73dBm (20kW) power which happen into digital transmission.

## 1.3 Objectives

The project objectives are as follows: -

(i) To determine effect of high power AM signal in digital transmission

(ii) To identify the potential techniques in reducing the electromagnetic interference.

(iii) To do experimental meası rements and testing on the performance of the mitigation techniques.

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## 1.4 Scope of Work

The scope of the project is as follows:

(i) Use base band modem mod. BM/EV and data tools 5000 to test interconnection cables, terminals and transmission lines for twisted pair cables

(ii) To do immunity measurement on the twisted pair cables using Gigahertz Transverse Electromagnetic Cell (GTEM Cell) with 576 kHz frequency of AM signal.

(iii) Only shielding technique is used.

(iv) Analysis the shielding concept with various materials and polarization.

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## 1.5 Importance of Project

(i) To understand the behavior of the electromagnetic interference due to AM transmission.

(ii) Propose to manufacturer to upgrade the twisted pair cable using shielded material in high electromagnetic interference area.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Introduction to Broadcast Signal

Radio communication is typically in the form of AM radio or FM Radio transmissions. The broadcast of a single signal, such as a monophonic audio signal, could be done by straightforward amplitude modulation or frequency modulation. A radio wave is an electromagnetic wave propagated by an antenna. Radio waves have different frequencies, and by tuning a radio receiver to a specific frequency (Figure 2.1) we can pick up a specific signal.

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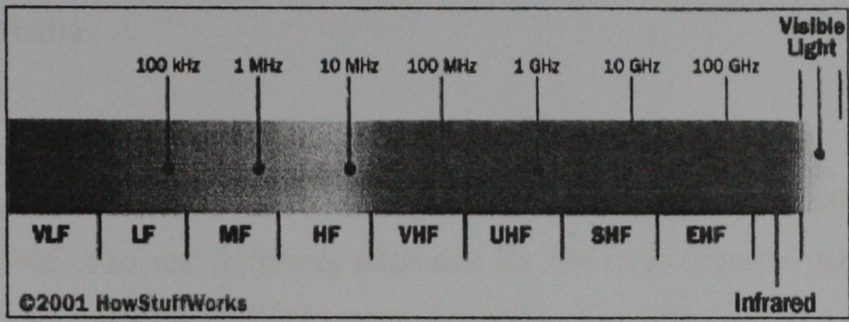


**Figure 2.1: Radio frequency bands [2]**

Common frequency bands include the following:

(i) AM radio - 535 KHz to 1.7 MHz
(ii) Short wave radio - bands from 5.9 MHz to 26.1 MHz
(iii) Citizens band (CB) radio - 26.96 MHz to 27.41 MHz
(iv) Television stations - 54 to 88 MHz for channels 2 through 6
(v) FM radio - 88 megahertz to 108 MHz
(vi) Television stations - 174 to 220 MHz for channels 7 through 13

In the United States, the FCC (Federal Communications Commission) decides who is able to use which frequencies for which purposes, and it issues licenses to stations for specific frequencies.

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### 2.1.1 AM Radio

AM radio has been around a lot longer than FM radio. The first radio broadcasts occurred in 1906 or so, and frequency allocation for AM radio occurred during the 1920s (The predecessor to the FCC was established by Congress in 1927.). In the 1920s, radio and electronic capabilities were fairly limited, hence the relatively low frequencies for AM radio. Edwin Armstrong invented FM radio in order to make high-fidelity (and static-free) music broadcasting possible in 1939, but FM did not become popular until the 1960s "Radio waves" transmit music, conversations, pictures, and data invisibly through the air; often over millions of miles it happens every day in thousands of different ways. Even though radio waves are invisible and completely undetectable to humans, they have totally changed society.

When information broadcast from an AM radio station, the electrical image of the sound (taken from a microphone or other program source) used to modulate the amplitude of the carrier wave transmitted from the broadcast antenna of the radio station. This is in contrast to FM radio where the signal is used to modulate the frequency of the carrier [2].

The AM band of the electromagnetic spectrum is between 535 and 1605 kHz, and the carrier waves are separated by 10 kHz. A radio receiver can be tuned to receive any one of a number of radio carrier frequencies in the area of the receiver. This is made practical by transferring the signal from the carrier onto an intermediate frequency in the radio by a process called heterodyning. In a heterodyne receiver, most of the electronics is kept tuned to the intermediate frequency so that only a small portion of the receiver circuit must be retuned when changing stations.

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Figure 2.2 shows AM radio that uses electrical image of a sound source to modulate the amplitude of a carrier wave. At the receiver end in the detection process, that image is stripped back off the carrier and turned back into sound by a loudspeaker.

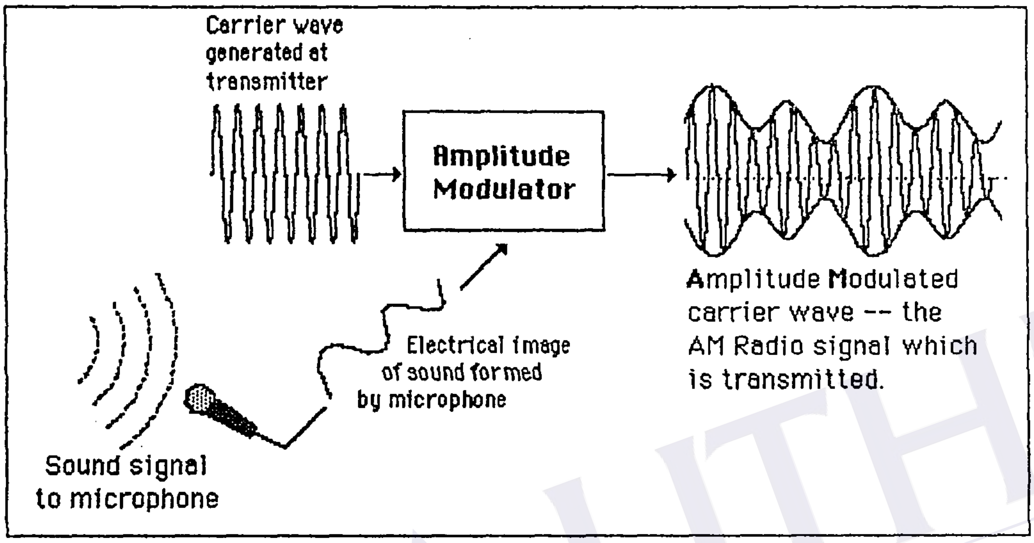


**Figure 2.2: AM radio carrier wave [3]**

## 2.2 Introduction to ADSL

Work on ADSL concept started at the end of 1980's and has gathered pace since with partially integrated production prototypes now appearing, capable of providing a high-bit-rate channel to customer while supporting a much lower bit rate from the customer. The most important feature of ADSL is that it can provide high speed digital services on the existing twisted pair copper network, in overlay and without interfering with the traditional analog telephone service (POTS: plain analog telephone service). ADSL thus allows subscribers to retain the analog services to which they have already used. Moreover, due to its highly efficient line coding technique, ADSL supports new broadband services on a single twisted pair.

The twisted pair copper access network has intended as a transmission medium for low-bandwidth analog voice signals. The twist improves the egress and ingress properties of the wire: it reduces the electromagnetic radiation from signals propagating over the wires as well as the pickup of unwanted signals when the wire is submerged in an electromagnetic field. In the past, paper was used as the insulator between the wires; today polyethylene is common. The wire pairs are combined in cables of different sizes ranging from a couple in the customer drop and distribution section to a few hundred pairs in the feeder section.

In the existing telephone networks, the carrier are commonly, 24-gauge twisted pair cable with bandwidth carrying capacity of such cables is about 1MHz. All along this, cables have been used for the purpose of voice communication. Normally, the range of signals requires the frequency is from 300Hz to 3600Hz, which mean the bandwidth is around 3300Hz wide. In the dial up modem, this limits the amount of information that could be transmitted, wasting about 99.7% of the bandwidth [3].

### 2.2.1 ADSL Technology

ADSL technology is an economical alternative to deliver broadband services over the existing copper access network. In order to be successful, ADSL transmission will have to deal with a number of impairments that exist in the local loop. The focus is on interference from and into radio users. Unlike voice band modems that operate in this frequency band, emerging high-speed digital transmission systems such as ADSL through this network uses much larger spectrum. Normally the bandwidth [1, 2, and 3] is 175 kHz for upstream traffic (from home) and about 900 kHz bandwidth for downstream traffic (to the home). Figure 2.3 shows ADSL spectral allocation for upstream and downstream bandwidth.

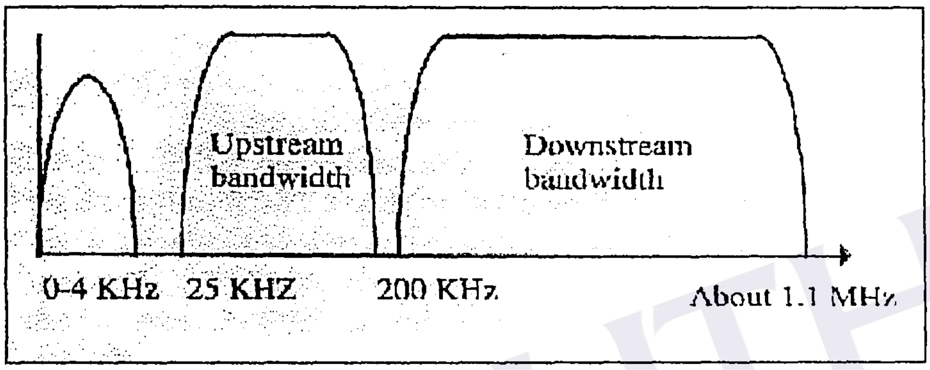


**Figure 2.3: ADSL Spectral allocation [3]**

Figure 2.4 shows a network reference model for ADSL. ADSL has to coexist with POTS on the same pair. A POTS-splitter consist a low pass filter and high pass filter separates the analog and telephone signal from the digital data signal. The high pass filter may be integrated with ATU (ADSL terminal Unit) at central office side (CO) or the remote terminal (RT) side located at costumer side. At the customer premises, the low pass filter is typically installed at the entrance of the home that is in the basement or in the NID (Network Interface Device).

The ADSL transmission system offers an asymmetric capacity to the subscriber. In the downstream direction, it provides a capacity up to 7 Mb/s, while in the upstream direction it provide up to 640 kb/s. In general the maximum ADSL data rate depends upon the distance covered, wire gauge and interference. Three types of data transport

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