AN IMPULSIVE NOISE ANALYSER USING AMPLITUDE PROBABILITY DISTRIBUTION (APD) FOR BROADBAND WIRED COMMUNICATION

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A thesis submitted in
fulfilment of the requirements for the award of the
Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
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OCTOBER 2011

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This thesis is especially dedicated to my beloved wife Fatimah Binti Ibrahim, son Adam Danish and daughters Nur Aqilah and Nur Afiqah.

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ACKNOWLEDGEMENT

Many people have contributed directly or indirectly to the completion of this thesis and their assistance is gratefully acknowledged. First of all, I would like to express my gratitude to my supervisor, Prof. Dr. Mohd. Zarar Bin Mohd. Jenu for giving me the opportunity to work on this research. His willingness to teach attitude and unfailing patient has been a great motivation for me to excel in my work. Without his guidance and invaluable time spent with me in this research work, this thesis would not have been completed successfully.

I would also like to express my thanks and gratitude to my company Telekom Research and Development Sdn Bhd (TMRND) and Telekom Malaysia Berhad for sponsoring the research grant under project reference number of RDTC07-0673. I would also express my appreciations to the EMC and Power Quality members at TMRND especially to my superior Mr. Annuar Mohd Ramli and my colleague Mr. Wan Razli Wan Abdullah who supported me a lot in completing my laboratory and experimental work.

Special thanks dedicated to my wife Fatimah Binti Ibrahim and my children Adam Danish, Nur Aqilah and Nur Afiqah for always being there and giving me a lot of moral support as well as encouragement and accompanied me going through all the ups and downs. My appreciation and thanks to my friends as well for their constructive ideas, comments and critics throughout my research work.

Last but not least, I would like to thank GOD or ALLAH SWT for giving me this wonderful privilege to work on my research and the lesson I have learned along the way. Surely it is an experience which will prove invaluable later in life. Needless

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to say, without all the above help and support, the writing and production of this thesis would not have been possible. Thank you.

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ABSTRACT

Electromagnetic interference or noise which is of impulsive nature is known to affect data communication performance. It is useful to correlate the characteristics of the noise with the bit error probability (BEP). The amplitude probability distribution (APD) has been proposed within CISPR for characterisation of the impulsive noise. However, there is no analyser available to perform direct measurement of the noise within the bandwidth of asymmetric digital subscriber line (ADSL2+) communication. This research presents a novel development of APD analyser for measurements of impulsive noise emission and its impact on ADSL2+ communication. A unique noise APD pattern is obtained from each measurement of noise emission from different electrical and electronic appliances. It is vital to have correct measurement set-up, signal power level, sampling rate, sample points and filter characterisation in order to acquire accurate data representation of the noise patterns. The APD graph is generated by the analyser using the APD algorithm method which employs the envelope sampling technique from actual probability. The noises are characterised using α-stable distribution which exhibits its own distinct APD parameters. The APD curve can be related with the single modulation scheme communication channel performance for estimation of bit error probability. The analyser has been developed successfully with dynamic range of 70 dB higher than the 60 dB CISPR 16 requirement, 0.02 dB amplitude resolution compared to 0.25 dB CISPR 16 requirement and 0.59 dB amplitude accuracy compared with the CISPR 16 standard of +/- 2.7 dB. In addition, the limits for noise in copper cable have been proposed for estimating the severity of the interference towards digital communication performance in ADSL2+ system. An advantage of the analyser is its ability to not only record the noise but the ability to regenerate back the noise which can be used for further analysis. In conclusion, the analyser can provide a

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comprehensive platform for impulsive noise interference verification towards ADSL2+ communication performance.

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ABSTRAK

Gangguan elektromagnet atau hingar merupakan sifat dedenyut asli diketahui berupaya menjejaskan prestasi data komunikasi. Adalah amat berguna untuk mengaitkan ciri-ciri hingar dengan keberangkalian ralat bit (BEP). Keberangkalian agihan amplitud (APD) telah dicadangkan di dalam CISPR sebagai salah satu cara pengukuran pancaran hingar elektromagnet. Bagaimanapun, tidak terdapat penganalisis yang mampu mengukur hingar didalam lebar jalur komunikasi talian digit elektronik (ADSL2+). Penyelidikan yang dijalankan membentangkan hasil untuk memajukan alatan penganalisis APD bagi pengukuran terus pancaran dedenyut hingar dan hentaman terhadap komunikasi ADSL2+. Pelbagai corak unik ganguan akan didapati daripada setiap pengukuran pelbagai jenis peralatan elektik dan elektronik. Adalah amat penting semasa di dalam proses pengukuran penentuan cara pengukuran yang betul, kadar kuasa isyarat, kadar sampel, takat sampel dan ciri penapis elektronik di dalam mendapatkan hasil data tepat yang mewakili corak-corak hingar. Hasil graf APD didapati daripada alatan penganalisis APD yang menggunakan algoritma APD dimana sampel liputan pancaran hingar dikira daripada kebarangkalian sebenar. Ciri-ciri gelombang radiasi akan mengunakan kaedah taburan $\alpha-$stable yang mepunyai parameter-parameter tersendiri. Lengkung APD yang terhasil boleh dikaitkan dengan skema komunikasi modulatan tunggal dan kadar anggaran pretasi kebarangkalian ralat bit. Penganalisis telah berjaya dimajukan dengan julat dinamik 70 dB tinggi dari 60 dB spesifikasi CISPR 16, 0.02 dB peleraian amplitud berbanding 0.25 dB keperluan CISPR 16 dan 0.59 dB ketepatan amplitud berbanding +/- 2.7 dB piawai CISPR 16. Tambahan, had hingar pada kabel tembaga telah dicadangkan bagi anggaran keterukan gangguan pada pretasi digit komunikasi sistem ADSL2+. Satu kelebihan penganalisis APD bukan hanya boleh mengukur hingar tetapi berupaya menghasilkan semula pancaran hingar yang telah diukur bagi tujuan menganalisa dengan lebih mendalam. Dalam kesimpulan,

penganalisis ini akan menjadi satu pelantar bagi pengesahan gangguan pancaran hingar buatan manusia terhadap pretasi komunikasi ADSL2+.

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LIST OF SYMBOLS/ ABBREVIATIONS

γ	-	Dispersion Parameter
α	-	Impulsiveness Parameter
β	-	Beta Constant Parameter
ADC	-	Analog to Digital Converter
AC	-	Alternate Current
APD	-	Amplitude Probability Distribution
AM	-	Amplitude Modulation
ADSL	-	Asymmetric Digital Subscriber Line
AWGN	-	Additive White Gaussian Noise
AWG	-	Arbitrary Wave Generator
BPSK	-	Binary Phase Shift Keying
BEP	-	Bit Error Probability
BER	-	Bit Error Rate
CDF	-	Cumulative Density Function
CISPR	-	Comité International Spécial des Perturbations Radioélectriques
CW	-	Continuous Wave
DC	-	Direct Current
DSL	-	Digital Subscriber Line
DSP	-	Digital Signal Processing
DSLAM	-	Digital Subscriber Line Access Multiplexer
DMT	-	Discrete Multi Tone
EMC	-	Electromagnetic Compatibility
EMI	-	Electromagnetic Interference
ESM	-	Equivalent Static Noise Model

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EUT	-	Equipment Under Test
EN	-	Européen de Normalisation
FCC	-	Federal Communication Comission
FFT	-	Fast Fourier Transform
FIR	-	Finite Impulse Response
FPGA	-	Field Programmable Gate Array
GPS	-	Global Positioning System
GHZ	-	Giga Hertz
HSBB	-	High Speed Broadband
HDF	-	Hierarchical Data Format
HWS	-	Hierarchical Waveform Storage
HZ	-	Hertz
IEC	-	International Electrotechnical Commission
ISO	-	International Organization for Standardization
IF	-	Intermediate Frequency
IFD	-	Instantaneous Frequency Distribution
ITU	-	International Telecommunication Union
KHz	-	Kilo Hertz
LABVIEW	-	Laboratory Virtual Instrumentation Engineering Workbench
MHZ	-	Mega Hertz
MATLAB	-	Matrix Laboratory
OSP	-	On-board Signal Processing
PDF	-	Probability Density Function
PSD	-	Power Spectral Density
PSK	-	Phase Shift Keying
PXI	-	Modular Instrumentation Platform Designed for Measurement and Automation
PAM	-	Phase Amplitude Modulation
POTS	-	Plain Telephone Service
QAM	-	Quadrate Amplitude Modulation
RAM	-	Random Access Memory
RDSLAM	-	Remote Subscriber Line Access Multiplier

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RMS	-	Root Mean Square
RF	-	Radio Frequency
SMC	-	Synchronization and Memory Core
SNR	-	Signal to Noise Ratio
UMTS	-	Universal Mobile Telecommunications System
VDSL	-	Very High Bit Rate Digital Subscriber Line
VCCI	-	Voluntary Control Council for Interference by Information Technology Equipment

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CHAPTER 1

INTRODUCTION

1.1 General

The technology of digital electronic systems and appliances are rapidly evolving for many applications. A household today has more electrical appliances than it did for the past ten years. Therefore the unintentional electromagnetic radiations from modern electronic systems have become increasingly difficult to control. Electromagnetic compatibility (EMC) has emerged as a branch of science and engineering concern to fulfill the needs of studying the relation between the immunity of electrical and electronic appliances toward electromagnetic interference and at the same time ensuring equipment to generate interference within specified limits.

Nowadays, the use of digital radio communication has become essential in human life. It has become a cultural necessity of an innovative lifestyle and entertainment tools. For example, devices like GPS navigator is equipped in middle - end and high-end modeled vehicles. Besides that the internet is an important tool for a global system of interconnected computer networks of academic, business and government networks are accessible by using medium of communication through copper wires, fiber-optic cables, wireless connections and other technologies. Understanding on the relations between the interference of electronic or electrical equipments and digital communication have become essential since the interference affect the communication system's capacity, robustness, reliability and availability. The interference phenomenon is called intersystem interference and is an inevitable in reality.

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Current EMC standards cover all areas of interference and immunity in terms of radiation or conduction. All these standards and measurement set-up are well defined and illustrated in international standards (IEC, ISO, CISPR) and national standards (FCC, EN, VCCI). However, question arises whether current standards do consider the perspective of digital communication which mainly concerns the bit error probability of data received. The existing emission limits and requirements have been developed to protect analog amplitude modulated radio services. These limits are defined as the maximum allowable level of the measured peak and quasi-peak values of the radiated emission from the interference sources. However, the levels measured by the peak and quasi-peak detectors do not correlate with the impact of the interference source on a digital radio system [1]. The reason is that both detectors have been developed during the era of analog systems. Consequently, current electromagnetic compatibility analysers use these two detectors, which originally simulate human hearing perception of the disturbances on analog radio receivers [2].

The electromagnetic noises are the main elements to be studied in this research. The well known noise is called Additive White Gaussian Noise (AWGN), which exhibits an instantaneous level that varies following a normal random process of mean zero and variance equal to its mean power. Samples from this AWGN are independent, and they have a plain power spectrum with the same contributions in all the frequencies. AWGN does not represent a major problem in digital communication systems, as long as the mean power of the desired received signal is higher compared with the mean power of the noise itself. The other type of noise is called impulsive noise. This noise is not easily traceable. This noise is appearing unexpectedly as pulses of high amplitude. Typically the impulsive noises can be classified according to its origin such as natural noise and man-made noise. Most of the man-made noise originated from various electrical or electronic devices. These electrical or electronic devices are commonly co-located to the digital equipment communications system. As for digital communications, the impulsive noise is harmful because each pulse may causes bursts of bit errors and loss of

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synchronization. As the occurrence of noise pulses and its amplitude is so unpredictable, it makes it difficult to build digital communication systems that can avoid the effects of impulsive noise [3]. David Middleton [4]-[11] has divided the impulsive noise into three categories of bandwidth as listed below. Impulsive emissions mostly fall in Class B category.

(i) Class A: Impulsive noise with a bandwidth smaller than that of the receiver.

(ii) Class B: Impulsive noise with a bandwidth larger than that of the receiver.

(ii) Class C: A case that comprises Class A and Class B.

Two of the most popular and promising methods which presented a connection between the interferences and the performance of digital communication systems in term of bit error probability (BEP) are root mean square (RMS) detector, which uses existing standard detector [12]-[15], and amplitude probability distribution (APD), in which the information about the noise envelope statistics is obtained from the IF-filter. Both techniques successfully presented a connection between the interferences with the performance of digital communication and suggested possible new radiated emission standards. The BEP is the probability that the digital receiver makes an error in the decision of what kind of data bit that has been received.

1.2 Problem Statement

The digital subscriber line (DSL) technology has been widely used in Malaysia for accessing the broadband Internet. The DSL technology uses the existing local telephone network for transmitting high speed digital data. Service providers are able to provide the service at affordable service price since there is no cost of new cable layout. The DSL communication which is specifically a system that uses symmetric digital subscriber line (ADSL2+) system has covered almost 98% of broadband

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connections [16]. The unshielded nature of twisted telephone pair causes the ADSL2+ system to be vulnerable from electromagnetic interference of the man made noise [17]. As observed in Figure 1.1, around 30% of customers have lodged complains on the quality of ADSL2+ services. Up to now, there is no equipment available in the market that is able to analyze the interference within the bandwidth of ADSL2+ systems. This is because existing equipment manufacturers such as Rohde & Schwarz, Agilent and Anritsu are developing the test equipment for wireless and fiber communication system which have high potential market demands compared to ADSL2+ system. Therefore the ADSL service provider such as Telekom Malaysia needs to develop their own methodology and test equipment to fulfill their operation needs. The challenges to fulfill these requirements are to develop reliable and accurate test equipment which is useful in troubleshooting current problems. Many problems which are currently faced by the ADSL service provider cannot be answered which eventually lead to unsolved problems. Furthermore, these unsolved problems eventually affect the service quality performance of ADSL2+ system. Everyday complains are lodged by the customer service center and service providers are struggling to solve the current problems with limited tools capability. It is clear that there is an urgent need for an analyser which is able to characterise the noise that affect the performance services.

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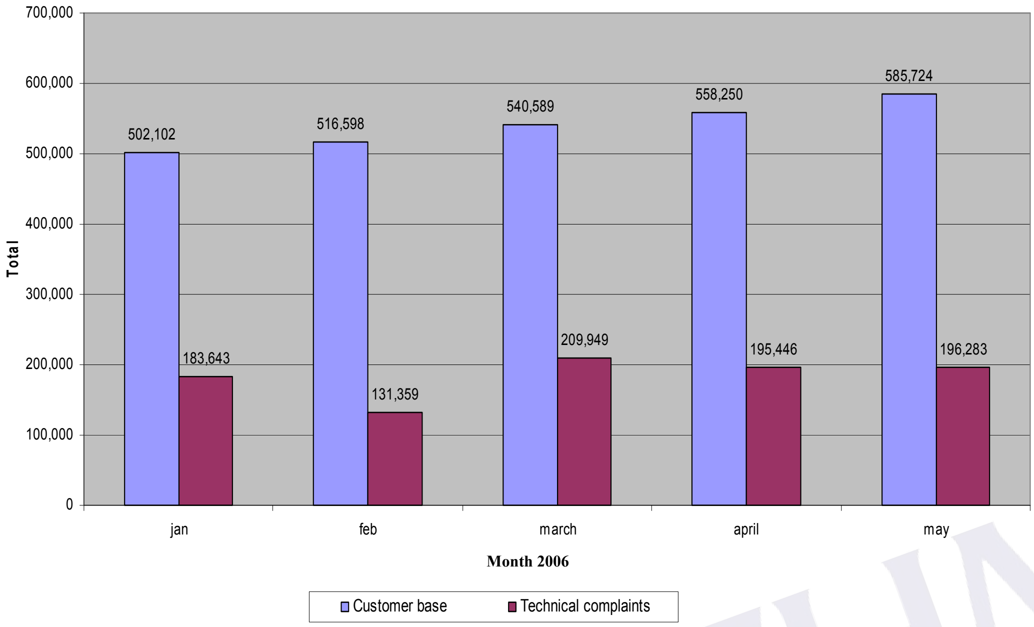

Figure 1.1: The ADSL2+ customer base and technical complains [18]

1.3 Aim of Research

The aim of this research is to develop and verify an amplitude probability distribution (APD) analyser to characterize the impulsive noise generated by various interference sources for evaluation of the bit error probability (BEP) for an asymmetric digital subscriber line (ADSL2+) system.

1.4 Objectives of Research

The objectives of this research are as follows:

(i) To develop a technique for impulsive noise interference measurement within the bandwidth of ADSL2+ system.

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