

**PREDICTION OF ELECTROSTATIC  
DISCHARGE SOFT ERROR ON TWO-WAY  
RADIO USING SIMULATION AND IMMUNITY  
SCANNING TECHNIQUE**

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DISCHARGE SOFT ERROR ON TWO-WAY  
RADIO USING SIMULATION AND IMMUNITY  
SCANNING TECHNIQUE**

by

**ROSNAH ANTONG**

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of the requirements for the degree  
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# TABLE OF CONTENTS

	Page
<b>ACKNOWLEDGEMENTS</b>	ii
<b>TABLE OF CONTENTS</b>	iv
<b>LIST OF TABLES</b>	vii
<b>LIST OF FIGURES</b>	ix
<b>LIST OF ABBREVIATIONS</b>	xvi
<b>ABSTRAK</b>	xix
<b>ABSTRACT</b>	xxi
<b>CHAPTER ONE – INTRODUCTION</b>	
1.1 Introduction	1
1.2 Problem statement	3
1.3 Thesis Objectives	6
1.4 Research Scopes	6
1.5 Outline of the Thesis	7
<b>CHAPTER TWO – LITERATURE REVIEWS</b>	
2.1 Introduction	9
2.2 ESD Event	9
2.3 ESD Failure Modes	11
2.4 ESD Models and ESD System	15
2.5 ESD Level Test Specifications	18
2.6 ESD System Level Test	23
2.7 Electromagnetic field exposure	27
2.7.1 Propagation of Electromagnetic Energy	28
2.7.2 Electromagnetic Interference	30
2.8 Previous Research	32

2.9	Chapter Summary	59
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### **CHAPTER THREE – INTRODUCING OF ESD ON TWO-WAY RADIO**

3.1	Introduction	62
3.2	ESD Failure of Radio	66
3.3	ESD Susceptibility Test	68
3.4	3D Simulator CST	72
3.5	Radio 3-D Modeling	73
3.6	Poynting Vector, Dosimetry and $S_{twa}$	78
3.7	Summary	86

### **CHAPTER FOUR – METHODS AND MATERIALS**

4.1	Introduction	87
4.2	Methodology of ESD Soft Error failure Prediction	87
4.3	ESD Pulse Validation	91
4.3.1	ESD Gun	91
4.3.2	AC Current Probe	93
4.3.3	Measurement Setup	94
4.3.4	Simulation Setup	95
4.4	ESD Susceptibility Level Test	96
4.5	ESD Susceptibility Scanning	100
4.6	ESD Simulation Setup	102
4.7	Setup of 3D modeling Accuracy	108
4.7.1	Voltage Measurement setup of passive attenuator	108
4.7.2	Voltage Measurement setup on MAKO IC	110
4.8	Summary	112

### **CHAPTER FIVE – RESULTS AND DISCUSSION**

5.1	Introduction	113
5.2	ESD Pulse Validation	113
5.3	ESD Susceptibility Level of Radio	115
5.4	ESD Susceptible Scanning	119
5.5	ESD Modeling Correlation	120
	5.5.1 Voltage measurement of Attenuator	120
	5.5.2 Voltage measurement of complete radio	120
5.6	EM Field Strength distribution and $S_{twa}$	123
5.7	$S_{twa}$ Limit and ESD failure Prediction	135
5.8	Overall Findings and Summary	139

## **CHAPTER SIX – CONCLUSION**

6.1	Summary of the work	141
6.2	Recommendation for Future Work	142

<b>REFERENCES</b>	143
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## **APPENDICES**

### **APPENDIXA – FULL 3D MODELING FOR TWO-WAY RADIO**

### **APPENDIXB – POYNTING VECTOR DERIVATION**

### **APPENDIXC – IEC 61000-4-2 SPECIFICATION**

### **LIST OF PUBLICATIONS**

## LIST OF TABLES

	Page
Table 1.1: Recent history of ESD testing of electronic product (Hoolihan (2014))	2
Table 1.2: Comparison of different approach of ESD failure prediction	5
Table 2.1: IEC 61000-4-2 severity level and test voltages (AG (2002))	22
Table 2.2: IEC 61000-4-2 waveform parameters (AG (2002))	23
Table 2.3: HBM robustness obtained by simulation and by measurement with and without external capacitor on vehicle with IC1 (Caignet <i>et al.</i> (2015))	41
Table 2.4: HBM robustness obtained by simulation and by measurement with and without external capacitor on vehicle with IC2 (Caignet <i>et al.</i> (2015))	41
Table 2.5: Comparison results of (a) Measured voltage level of IC pins (b) Simulated voltage level of IC pins before and after improvement (Kim <i>et al.</i> (2010))	42
Table 2.6: Comparison results of (a) Measured voltage level of IC pins (b) Simulated voltage level of IC pins before and after improvement (Kim <i>et al.</i> (2010))	43
Table 2.7: Summary of related work comparison	60
Table 2.7: Summary of related work comparison	61
Table 3.1: Type of radio design	66
Table 3.2: Criticality versus consequences of part in radio modeling	75
Table 3.3: Comparison of quantity part in actual radio versus modeling	76
Table 4.1: Comparison between original and improved radio	97
Table 4.2: ESD susceptible level test setup with different conditions	97
Table 4.3: GCAI contact pins arrangement	99
Table 4.4: ESD discharge voltage applied in ESD simulation	107
Table 5.1: Comparison of rise time and magnitude of ESD current pulses	115



Table 5.2:	Summary of ESD failure observation in different radio condition	116
Table 5.3:	Results of ESD test on original radio at "Close housing" with shield	116
Table 5.4:	Results of ESD test on improved radio at 'close housing' with shield	116
Table 5.5:	Results of ESD test on original radio at 'open housing' with shield	117
Table 5.6:	Results of ESD test on improved radio at 'open housing' with shield	117
Table 5.7:	Results of ESD test on original radio at 'open housing' without shield	118
Table 5.8:	Results of ESD test on improved radio at 'open housing' without shield	118

## LIST OF FIGURES

	Page
Figure 1.1:	Four approaches use in ESD failure prediction 4
Figure 2.1:	Separated material with imbalance charges via triboelectric (NXP (2010)) 10
Figure 2.2:	(a) Human Metal Model (b) ESD circuitry (c) ESD pulse waveform (Voldman (2012)) 11
Figure 2.3:	Basic type of ESD failure modes - (a) Direct discharge into circuit (b) Direct discharge into the ground system (c) Indirect discharge (Ott (2011)) 14
Figure 2.4:	Simplified lumped element for HBM (Lou (2008)) 15
Figure 2.5:	Simplified lumped circuit for MM (Lou (2008)) 16
Figure 2.6:	Simplified CDM lumped circuit (Lou (2008)) 17
Figure 2.7:	Requirement of ESD robustness (IndustrialCouncil (2010)) 18
Figure 2.8:	Table top of ESD test setup per IEC 61000-4-2 (Instruments (2012)) 19
Figure 2.9:	Simplified circuit of ESD gun generator (Compatibility (2008)) 21
Figure 2.10:	Type of discharge tips used in ESD test (a) Air discharge (b) Contact discharge (Compatibility (2008)) 21
Figure 2.11:	IEC 61000-4-2 current waveform at 2 kV discharge voltage (AG (2012)) 23
Figure 2.12:	Device level test method (a) Basic circuit diagram for HBM and MM (b) Comparison of 2 kV HBM, 200 V MM and 500 V CDM current waveforms at long times (Ashton (2006)) 24
Figure 2.13:	Comparison of IEM, HBM and CDM current waveforms (Ashton (2006)) 25
Figure 2.14:	ESD path from interconnect to IC (Colby (2000)) 26
Figure 2.15:	(a) The keyboard is connected to PC (b) The ESD gun hits the backside of the PC case to test the ESD system level susceptibility of a keyboard in the PC system (Ker and Sung (2001)) 26

Figure 2.16:	The measured $V_{DD}$ and $V_{SS}$ voltage waveform on the IC in a keyboard when the ESD gun with a negative 2 kV ESD voltage hits the backside of the PC case (Ker and Sung (2001))	27
Figure 2.17:	EM wave (Caignet <i>et al.</i> (2015))	28
Figure 2.18:	EM wave in near field and far field regions (OSHA (2013))	30
Figure 2.19:	ESD immunity scanning result lead to soft error failure due to induced voltage on the sensitive nets (a) Sensitive nets at lower TLP kV (b) Measured induced noise voltage (Muchaidze <i>et al.</i> (2008))	33
Figure 2.20:	Arduino Leonardo board (Yang (2016))	34
Figure 2.21:	$I - V$ curve measurement and simulation result (Yang (2016))	35
Figure 2.22:	IC soft error block diagram before adding 10 $\Omega$ resistor (Yang (2016))	36
Figure 2.23:	Measurement and simulation results (Yang (2016))	36
Figure 2.24:	Result of soft error threshold after adding 10 $\Omega$ resistor (Yang (2016))	37
Figure 2.25:	(a) Simplified schematic of the system (b) Simplified integrated circuit model with ESD protection from measurement and input and output buffer from IBIS model (Monnereau <i>et al.</i> (2012))	38
Figure 2.26:	Transient simulations of the output voltage when the ESD stress occurs on a low level of the output (Monnereau <i>et al.</i> (2012))	39
Figure 2.27:	Evaluation of the failure probability as a function of the external decoupling capacitor, clock frequency and ESD pulse amplitude (Monnereau <i>et al.</i> (2012))	39
Figure 2.28:	Wunsch and Bell curve of the IC (Caignet <i>et al.</i> (2015))	40
Figure 2.29:	ESD current distribution on mobile phone at 1.8 ns (Kim <i>et al.</i> (2010))	42
Figure 2.30:	Proposed method to predict induced noise voltage at IC pin (a) Experimental setup (b) Induced noise voltage (Lee <i>et al.</i> (2011))	43
Figure 2.31:	Comparison of (a) Measured waveform (b) simulated waveform of Address line (Lee <i>et al.</i> (2011))	44

Figure 2.32:	A bridge where two conductive filaments cross each other. A port 1 that contains of the break-through parameters is shown as a red cone (Hekkala <i>et al.</i> (2012))	44
Figure 2.33:	(a) Illustration of the mobile device under test (b) Switch model (Hekkala <i>et al.</i> (2012))	45
Figure 2.34:	(a) Voltage at various bridge locations. (b) Current through the switches (Hekkala <i>et al.</i> (2012))	46
Figure 2.35:	Display images before and after ESD stress (a) Before and after ESD zapping (b) SEM picture for permanent damage in the source driver after ESD stress of Air discharge of 6 kV (Ko <i>et al.</i> (2012))	47
Figure 2.36:	(a) The ESD path from panel surface to ground through the damaged thin gate oxide transistors in source driver IC (b) Sketch of parasitic NPN bipolar consists of NWELL (AVDD), PWELL (VGL) and NWELL (VDD) (Ko <i>et al.</i> (2012))	48
Figure 2.37:	(a) The layout image of VCOM ESD cell and its adjoining memory block (b) Well formation sketch creates parasitic NPN bipolar between the I/O and memory core (Ko <i>et al.</i> (2012))	49
Figure 2.38:	(a) Suggested scheme to mitigate VDD node potential (b) Simulation result of current density at t time of maximum VDD (Ko <i>et al.</i> (2012))	50
Figure 2.39:	Measurement setups of the effect EM to ESD failure (a) ESD current measurement setup (b) Setup of EM immunity test (Lim <i>et al.</i> (2013))	51
Figure 2.40:	Result of current spreading vs. Immunity test (a) Current spreading (b) Immunity test (Lim <i>et al.</i> (2013))	51
Figure 2.41:	Numerical model of ESD test setup (Caniggia and Maradei (2007))	52
Figure 2.42:	(a) Test setup for ESD current calibration and (b) ESD generator configuration model in MWS (Caniggia and Maradei (2007))	52

Figure 2.43:	Comparison of measured transient tip current versus simulation and IEC standard (Caniggia and Maradei (2007))	53
Figure 2.44:	(a) E-field sensor model (b) Meshing of E-field (c) H-field sensor model (d) Meshing of H- field (Caniggia and Maradei (2007))	54
Figure 2.45:	Transfer function of (a) E-field probe (b) E-field probe (Caniggia and Maradei (2007))	54
Figure 2.46:	Radiated E-field at distance of (a) 15 cm and (b) 45 cm (Caniggia and Maradei (2007))	55
Figure 2.47:	Radiated H-field at distance of (a) 15 cm and (b) 45 cm (Caniggia and Maradei (2007))	55
Figure 2.48:	Tri-axial near magnetic field probe (a) shielded loop and (b) triaxial probe (Fukui <i>et al.</i> (2013))	56
Figure 2.49:	Measurement setup and measured area (a) vehicle interior and (b) vehicle side (Fukui <i>et al.</i> (2013))	56
Figure 2.50:	TMeasurement result of vehicle interior field distribution (a) Electric field (b) Magnetic field (c) Real part of Poynting vector (d) Imaginary part of Poynting vector (Fukui <i>et al.</i> (2013))	57
Figure 2.51:	Simulation result (a) Electric field (b) Magnetic field (c) Real part of Poynting vector (d) Imaginary part of Poynting vector (vehicle interior field distribution) (Fukui <i>et al.</i> (2013))	58
Figure 2.52:	Simulation at f=400 MHz (a) Real part of Poynting vector (b) Imaginary part of Poynting vector (Fukui <i>et al.</i> (2013))	58
Figure 3.1:	Basic two-way radio communication (Hamuniverse.com (2000))	63
Figure 3.2:	Simplified two-way radio block diagram	64
Figure 3.3:	Connection between external radio and internal board define as ESD critical paths	65
Figure 3.4:	Two-way radio assembly	66
Figure 3.5:	ESD test with contact discharge mode	67
Figure 3.6:	Different states of radio display (a) Radio turns ON with no failure (b) Radio display hang and (c) Radio reset	68
Figure 3.7:	ESD Immunity Scanning system	70

Figure 3.8:	The induced current causing a failure (b) ESD induction schematic (Instruments (2008))	71
Figure 3.9:	Digitizing approach used in CST MWS (Technology (2011))	73
Figure 3.10:	Meshing of sphere with different approaches (a) Staircase approximation (b) PBA (Technology (2011))	73
Figure 3.11:	(a) Port location for IBIS on PCB/flex layout (b) Schematic diagram with IBIS model	77
Figure 3.12:	Illustration of time-weighted-average power density ( $S_{av}$ )	80
Figure 3.13:	Time sample of $t_1$ and $t_2$ (a) Total Poynting vector, $S_T$ (b) Time-weighted average power density, $S_{rwa}$	85
Figure 3.14:	Illustration of EM field coupling to sensitive IC through air (Instruments, 2008)	86
Figure 4.1:	Illustration of ESD failure prediction in radio development cycle	88
Figure 4.2:	Flowchart of ESD failure prediction methodology	90
Figure 4.3:	ESD gun (a) Simulator (Hire (2008)) (b) ESD gun circuitry (Eng (Eng))	92
Figure 4.4:	(a) ESD gun circuit diagram (b) Setting of ESD model	93
Figure 4.5:	Circuit of current probe (Tektronix (2000))	94
Figure 4.6:	Measurement setup of actual ESD pulse validation	95
Figure 4.7:	Simulation setup of ESD pulse validation with exciting rectangular waveform at port 2	96
Figure 4.8:	Radio with open housing	97
Figure 4.9:	Radio with 'close housing' condition	98
Figure 4.10:	Radio with 'close housing' condition	99
Figure 4.11:	'open housing' condition without digital shield	100
Figure 4.12:	ESD susceptibility scanning on radio ('open housing' condition)	101
Figure 4.13:	ESD discharge voltage setting	101
Figure 4.14:	Block diagram of complete ESD modeling	102
Figure 4.15:	MAKO IC on the PCB	103
Figure 4.16:	Cross section view (a) PCB with BGA IC (b) PCB without IC model	103

Figure 4.17:	Field probes assignment on MAKO IC	104
Figure 4.18:	Illustration of (a) Field probes (b) Poynting vector, $S_N$	104
Figure 4.19:	Radio modeling	105
Figure 4.20:	(a) Discretization of GCAI flex with $14 \mu$ mesh step (b) Discretization of main flex and PCB using $14 \mu$ mesh step	106
Figure 4.21:	ESD test modeling with ESD pulse injection at GCAI contact pin	107
Figure 4.22:	ESD Simulation using different models (a) Original radio (b) Improved radio	107
Figure 4.23:	Passive attenuator test board in (a) Actual (b) CST Simulation (Compatibility (2008))	109
Figure 4.24:	Loss factor calculation of attenuator (Compatibility (2008))	109
Figure 4.25:	Voltage measurement setup on passive attenuator	110
Figure 4.26:	Block diagram of voltage measurement on MAKO IC	111
Figure 4.27:	Voltage measurement setup during ESD system level	111
Figure 4.28:	Voltage measurement with the attenuator and ESD pulse injection at GCAI contact	112
Figure 4.29:	Attenuator and 10 mm coax cable solder to the PCB	112
Figure 5.1:	Comparison of ESD current pulse at 1 kV against IEC 61000-4-2	114
Figure 5.2:	ESD Failure symptoms on radio display (a) Radio display (b) Fail 001 (c) Blank display	115
Figure 5.3:	ESD susceptibility area on digital circuitry from top view	120
Figure 5.4:	Output voltage of attenuator (a) Block diagram of test setup (b) Comparison result	121
Figure 5.5:	(a) Block diagram of voltage measurement on complete radio (b) Simulation model	122
Figure 5.6:	(a) Measured voltage at port 2 (b) Comparison result between simulation and measurement	123
Figure 5.7:	Illustration of field probes on the PCB for EM field strength distribution	124
Figure 5.8:	Original radio at 5 kV, probe 1 (a) Magnitude of H-field (b) Magnitude of H-field (c) Poynting vector, $S_N$	125

Figure 5.9:	Original radio at 5 kV, probe 2 (a) Magnitude of H-field (b) Magnitude of H-field (c) Poynting vector, $S_N$	126
Figure 5.10:	Original radio at 5 kV, probe N=2 (a) Total Poynting vector, $S_N$ (b) Total time-weighted average power density, $S_{twa}$	127
Figure 5.11:	Comparison simulation result of original radio at different kV, N=15 probes (a) ESD current (b) Poynting vector	128
Figure 5.12:	Comparison simulation result of $S_{twa}$ of original radio at different kV, N=15 probes	128
Figure 5.13:	ESD simulation on (a) Original radio (b) Improved radio	129
Figure 5.14:	Comparison of ESD current between original and improved radio at 5 kV, N=15 probes	129
Figure 5.15:	Comparison between original and improved radio at 5 kV, N=15 probes (a) Poynting vector (b) $S_{twa}$	130
Figure 5.16:	Comparison result between original and improved radio at $t_1=0.6$ ns, 5 kV discharge voltage (a) Flow of simulated current (b) ESD current distribution on the MAKO IC	131
Figure 5.17:	Comparison result between original and improved radio at $t_2=4.0$ ns, 5 kV discharge voltage (a) Flow of simulated current (b) ESD current distribution on the MAKO IC	132
Figure 5.18:	Comparison result between original and improved radio at $t_3=8.0$ ns, 5 kV discharge voltage (a) Flow of simulated current (b) ESD current distribution on MAKO IC	133
Figure 5.19:	EM propagation (a) Single path on the original radio (b) Two paths on the improved radio	134
Figure 5.20:	Simulated $S_{twa}$ graph on improved radio (a) 8 kV (b) 11 kV	136
Figure 5.21:	$S_{twa}$ limit as ESD baseline in ESD simulation	138



## LIST OF ABBREVIATIONS

A/m	Ampere per meter
A/m	Ampere per meter
API	Amber Precision Instruments
BGA	Ball Grid Array
CDM	Charged Device Method
CLK	Clock
CMOS	Complementary Metal – Oxide Semiconductor
CST MWS	Computing Simulation Technology Microwave Studio
DUT	Device under Test
DFM	Design for Manufacturing
ECAD	Electronic Computer–Aided Design
EEPROM	Electrically Erasable Programmable
E-field	Electric Field
EM	Electromagnetic
EMC	Electromagnetic Compatibility (Ability of device to function in its electro magnetic environment without introducing disturbance to that environment or to other device)
EMI	Electromagnetic Interference
EMF	Electromagnetic Force
ESD	Electrostatic Discharge
ESDA	Electrostatic Discharge Association
ESDS	Electrostatic Discharge Sensitive
FCB	Flexible Circuit Board
FDTD	Finite–Differences Time-Domain

FIT	Finite Integration Technique
Flex	Flexible Printed Circuit
FR4	Flame Resistant 4 (a glass fiber epoxy laminate)
GCAI	Global Communication Accessory Interface
GND	Ground
GPU	Graphics Processing Unit
GRP	Ground Reference Plan
GTL	Gunning Transistor Logic
HBM	Human Body Method
HCP	Horizontal Coupling Plane
H-field	Magnetic Field
IBIS	Input/Output Buffer Information Specification
IC	Integrated Circuit
IEC 61000–4–2	International Electrotechnical Commission (Part 4–2 Testing and Measurement techniques – Electrostatic discharge immunity test)
JEDEC	Joint Electron Device Engineering Council
kV	Kilovolt
LED	Light–emitting diode
MIC	Microphone
$\mu$	Micron
MM	Machine method
mm	Millimeter
ns	Nanosecond
ODB++	Open Database (CAD–to–CAM data exchange format used for electronic database of printed circuit board manufacturing)
PBA	Perfect Boundary Approximation

PCB	Printed Circuit Board
pF	Pico farads
PN	P–N type junction
ProE	Pro Engineer
ps	Picoseconds
RLC	Resistor, Inductor and Capacitor
SDRAM	Synchronous dynamic random–access memory
SPKR	Speaker
T	Tesla
TTL	Transistor–Transistor Logic
TLP	Transmission Line Pulse
ULC	Ultra Low Cost
V	Volt
V/m	Voltage per meter
VCP	Vertical Coupling Plan

# RAMALAN RALAT ANJAL NYAHCAS ELEKTROSTATIK

## RADIO DUA HALA MENGGUNAKAN SIMULASI DAN

### TEKNIK PENGIMBASAN IMUNITI

#### ABSTRAK

Nyahcas elektrostatik (ESD) merupakan faktor utama kepada kegagalan dan kerosakan radio komunikasi dua hala. Kegagalan ralat anjal seperti kegagalan logik, selak-atas atau tersalah set boleh berlaku disebabkan ESD secara berlebihan. Secara umumnya diketahui bahawa peranti-peranti Semikonduktor Pelengkap Oksida-Logam (CMOS) amat terdedah kepada ESD. Kegagalan CMOS yang disebabkan oleh ESD boleh juga menyebabkan radio dua hala ditetapkan semula atau berhenti berfungsi sepenuhnya. Lazimnya, kegagalan ini hanya boleh diketahui selepas radio dipasang and diuji. Melalui kajian ini, satu kaedah baru telah dicipta untuk menguji risiko ESD pada peringkat litar radio. Vektor Poynting digunakan untuk mengira kuasa yang diterima oleh litar bersepadu semasa berlakunya ESD. Melalui kaedah ini, radio dua hala telah dimodel secara 3-dimensi menggunakan piawai IEC 61000-4-2. Model ini dapat memberikan satu gambaran mengenai penyebaran arus ESD di dalam Papan Litar Tercetak (PCB) dan satah bumi. Kuasa purata berpemberat masa ( $S_{twa}$ ) yang dikira melalui produk silang di antara medan-E dan medan-H diguna secara meluas dalam permodelan, hasilnya nilai had maksimum sebanyak  $3.7 \text{ W/m}^2$  telah ditetapkan untuk meramal kegagalan ESD. Keputusan simulasi komputer menunjukkan persetujuan yang baik dengan nilai yang telah diukur di dalam had toleransi. Kajian ini mendapati bahawa radio yang diperbaharui menggunakan batang logam mempunyai  $S_{twa}$  kurang dari had maksimum berbanding radio asal. Kajian ini juga meramal kegagalan ESD akan berlaku pada 8 kV and 11 kV bagi radio asal dan diperbaharui masing-masingnya. Hasil kajian ini juga menghasilkan

satu skim baru bagi jurutera untuk menilai risiko ESD pada radio dua hala di peringkat PCB. Mengenalpasti komponen yang paling berisiko kepada ESD di peringkat awal juga bermakna kegagalan ESD dapat ditangani secukupnya sebelum pengeluaran secara besar-besaran.

# **PREDICTION OF ELECTROSTATIC DISCHARGE SOFT ERROR ON TWO-WAY RADIO USING SIMULATION AND IMMUNITY SCANNING TECHNIQUE**

## **ABSTRACT**

Electrostatic discharge (ESD) is a major cause of failures and malfunctions in two-way communication radio. Soft error failures like logic error, latch-up and wrong reset can occur as a result of the excessive ESD. It is a well-known fact that the Complementary Metal-Oxide-Semiconductor (CMOS) devices are more susceptible to ESD. The failure of CMOS ICs due to ESD can also cause radio to reset or shutdown completely. Presently the failures are detected after the radio is built and tested only. In this research, new methodology is developed to assess the ESD risk of two-way radio at circuit level. Poynting vector is used to calculate the incident power received by susceptible integrated circuit during ESD. In doing so the two-way radio is modeled in 3-D using the IEC 61000-4-2 standard. The result provides a graphical means to visualize the propagation of ESD current in Printed Circuit Board (PCB) and ground plane. Time-weighted average power density ( $S_{Twa}$ ) calculated as a cross product between E-field and H-field was used extensively in the modeling, from which a maximum limit of  $3.7 W/m^2$ ,  $S_{Twa}$  was established for predicting ESD failures. It was observed that results obtained through computer simulation agree well with measured values within some tolerance limit. It was also discovered that the improved radio with metal bar is well above this limit compared to the original radio. It is also predicted that the soft error due to ESD would occur at 11 kV and 8 kV for improved and original radio respectively. Results from this study provide a new scheme for engineers to assess ESD risk of two-way radio at PCB level. Identifying most susceptible component to ESD allows radio failures to be addressed adequately before mass production.

## CHAPTER ONE

# INTRODUCTION

### 1.1 Introduction

Electrostatic discharge (ESD) is a discharge of electricity where a charge moves at different electrical potentials. ESD is a high voltage event which is generated from the released electrical energy through tribocharging or electrostatic induction. ESD can cause device failure during production, assembly, testing and at the user site. Among Integrated Circuit (IC) devices, Metal-Oxide-Semiconductor (MOS) is most susceptible to ESD damage (Unger (1981)). Complementary Metal-Oxide-Semiconductor (CMOS) IC can be very susceptible to system-level ESD stress although it has passed the component-level ESD specification (Yen and Ker (2007)). As ESD current is a source of system level failures, when the current flows through components or IC, it can cause a system failure (upset). The current induces electric fields (E) and magnetic fields (H) when travelling on the printed circuit boards (PCB), or any packaging components. This can lead to component malfunction and system failure (Voldman (2012)).

There are two types of ESD failure at system level – (i) ESD hard error failure (ii) ESD soft error failure. The hard error failure is commonly caused by physical destruction in interconnection inside a device or physical damage due to the high level of ESD current. The soft error failure is mainly caused by a logic error of IC such as glitches, abnormal interrupt request signal or signal inversions of the IC. The root cause of hard error failure is easily analyzed compared to soft error failure and it is traceable by finding the location of device breakdown. However it is difficult to find a root cause of ESD soft error failure because it is a temporary event and system is recovered after rebooting.

The history of electrostatic was not discovered until 600BC. Thales of Miletus began conducting experiments that involved charging amber by rubbing it with a piece of fur to observe an attraction to lightweight object such as fur and feather. In 1600, serious work in the field of electrostatic began with *De Magnete*, a book published by William Gilbert in the year 1600. Over the next several centuries, experiments by Gauss, Coulomb, Faraday and Franklin are established to understand the basis of electrostatics (Weitz (2015)).

From past history summarized in Table 1.1, the electrostatic discharge testing has evolved from a company based reliability test in the 1960s and 1970s to a performance test on electronic product. This requirement is that electronic products should operate normally when subjected to ESD phenomena by representing it in the real-world environment. The emphasis has switched from susceptibility of equipment to quote how immune a product to air-discharge and contact discharge from a portable ESD tester whose output is compliant with the latest international standard criteria (Hoolihan (2014)).

Table 1.1: Recent history of ESD testing of electronic product (Hoolihan (2014))

Decade	Event
1950s	– The electronic companies are concerned with the damage in electronic component and functional interruption of electronic products.
1960-1970	– Most companies started to use 5 kV then 7.5 kV discharge voltage as the passing level of ESD system level.
1980s	– The First International Electrotechnical Commission (IEC) Publication 801-2 was released in 1984 for air-discharge test method.
1990s	– Second edition of IEC 801-2 was released in 1991. Major change was to define the contact discharge mode as a preferred test method. – The first IEC 100-4-2 was released in 1995 for International Standard on Electrostatic Discharge Immunity test. It introduced Horizontal and vertical coupling planes on references. – Second edition of IEC 6100-4-2 was released in 2008 to replace the first edition in 1995. Key parameters of ED generator remain unchanged.