

Dr. Purnima K Sharma
Dr. Dinesh Sharma
Prof. R.K. Singh

Development of Field Propagation Model for Urban Area



Anchor Academic Publishing

disseminate knowledge

Sharma, Purnima K, Sharma, Dinesh, Singh, R.K.: Development of Field Propagation Model for Urban Area, Hamburg, Anchor Academic Publishing 2017

PDF-eBook-ISBN: 978-3-96067-626-3

Druck/Herstellung: Anchor Academic Publishing, Hamburg, 2017

Bibliografische Information der Deutschen Nationalbibliothek:

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.d-nb.de> abrufbar.

Bibliographical Information of the German National Library:

The German National Library lists this publication in the German National Bibliography. Detailed bibliographic data can be found at: <http://dnb.d-nb.de>

All rights reserved. This publication may not be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publishers.

Das Werk einschließlich aller seiner Teile ist urheberrechtlich geschützt. Jede Verwertung außerhalb der Grenzen des Urheberrechtsgesetzes ist ohne Zustimmung des Verlages unzulässig und strafbar. Dies gilt insbesondere für Vervielfältigungen, Übersetzungen, Mikroverfilmungen und die Einspeicherung und Bearbeitung in elektronischen Systemen.

Die Wiedergabe von Gebrauchsnamen, Handelsnamen, Warenbezeichnungen usw. in diesem Werk berechtigt auch ohne besondere Kennzeichnung nicht zu der Annahme, dass solche Namen im Sinne der Warenzeichen- und Markenschutz-Gesetzgebung als frei zu betrachten wären und daher von jedermann benutzt werden dürften.

Die Informationen in diesem Werk wurden mit Sorgfalt erarbeitet. Dennoch können Fehler nicht vollständig ausgeschlossen werden und die Diplomica Verlag GmbH, die Autoren oder Übersetzer übernehmen keine juristische Verantwortung oder irgendeine Haftung für evtl. verbliebene fehlerhafte Angaben und deren Folgen.

Alle Rechte vorbehalten

© Anchor Academic Publishing, Imprint der Diplomica Verlag GmbH
Hermannstal 119k, 22119 Hamburg
<http://www.diplomica-verlag.de>, Hamburg 2017
Printed in Germany

Table of Contents

List of Figures	vi
List of Tables	xi
List of Abbreviations	xiii
1. Introduction	1
1.1. Historical Overview	1
1.2. Cellular Radio Concept	4
1.2.1. Frequency Reuse	6
1.3. Concept of Handoff	8
1.4. Concept of Trunking	9
1.5. Statement of Problem	9
1.6. Thesis Motivation	10
1.7. Literature Review	10
1.7.1. Related Work	15
1.7.1.1. Field Propagation Path Loss Models	15
1.7.1.2. Effect of Climatic Conditions on Radio Communication	17
1.7.1.3. Effect of Climatic Condition on Link Budget	19
1.8. Contribution of Thesis	21
1.9. Outline of Thesis	22
1.10. Benefits of Thesis	23
2. Field Propagation Path Loss Models	25
2.1. Background of Field Propagation Models	25
2.2. Radiated and Received Power	26
2.2.1. Radiated Power	26
2.2.2. Radiation Resistance And Received Power	29
2.2.3. Friis Transmission Equation	30
2.3. Propagation Path Loss	32
2.3.1. Causes of Path Loss	32
2.4. Mobile Radio Propagation Environment	33
2.4.1. Reflection	34
2.4.2. Refraction	34
2.4.3. Diffraction	34
2.4.4. Scattering	35
2.5. Field Propagation Path Loss Models	36
2.5.1. Indoor Field Propagation Models	36
2.5.2. Outdoor Field Propagation Models	36
2.5.2.1. Empirical Models	36
2.5.2.2. Deterministic Models	37

2.5.2.3. Stochastic Models	37
2.6. Empirical Model	37
2.6.1. Free Space Path Loss Model	38
2.6.2. Lee Path Loss Model	39
2.6.3. Cost 231 Walfish-Ikegami (W-I) Model	40
2.6.4. Egli Path Loss Model	40
2.6.5. Okumura Model	41
2.6.6. Hata Model	43
2.6.7. Cost 231 Model	43
2.6.8. ECC-33 Path Loss Model	44
2.6.9. Bullington Model	45
2.6.10. Epstein-Peterson Model	45
2.6.11. Stanford University Interim (SUI) Model	45
2.6.12. Walfisch- Bertoni Model	47
2.6.13. Longley Rice Model	47
2.7. Conclusion	48
3. Methodology for Field Data Collection, Analysis & Its Simulation in MATLAB	49
3.1. Introduction	49
3.2. Data Collection Tools	50
3.2.1. Nemo	50
3.2.2. Aligent	51
3.2.3. Pioneer	52
3.2.4. X-Tel	52
3.2.5. TEMS	53
3.3. Introduction to TEMS Investigation	54
3.4. GSM Parameters and Their Range	55
3.4.1. Handoff	55
3.4.2. Rx Level	57
3.4.3. Rx Quality	58
3.4.4. Speech Quality Index (SQI)	58
3.5. Requirements for Field Measurement	58
3.5.1. Hardware Requirement	59
3.5.2. Software Requirement	59
3.5.3. Specification of Hardware and Software	60
3.6. Assembling /Installation /Setup Procedure	63
3.6.1. Plugging In Phones and Data Card	63
3.6.2. Plugging In GPS Unit	63
3.6.3. Configuring TEMS Investigation for Data Collection	63
3.6.4. Test Procedure	68
3.7. Various Issues During Measurement	78
3.7.1. Overshooting	78

3.7.2. Bad Quality	78
3.7.3. Bad Coverage	78
3.7.4. Missing Neighbor	78
3.7.5. Dropped Calls	78
3.7.6. Blocked Calls	79
3.7.7. Handover Failure and Delay	79
3.8. Data Analysis and Simulation Tools	79
3.8.1. MapInfo	80
3.8.2. MATLAB	80
3.9. Conclusion	84
4. Performance Analysis of Different Field Propagation Models	85
4.1. Introduction	85
4.2. Field Collected/ Measured Data From Drive Test at South Haryana Region	85
4.3. Received Signal Strength and Path Loss in Different Areas	87
4.4. Comparison Between Field Measured Data and Propagation path Loss Models in South Haryana	88
4.5. Comparative Analysis Between Free Space Path Loss Model and Field Measured Path Loss	92
4.6. Comparative Analysis Between W-I Path Loss Model and Field Measured Path Loss	95
4.7. Comparative Analysis Between Lee Path Loss Model and Field Measured Path Loss	100
4.8. Comparative Analysis Between Egli Path Loss Model and Field Measured Path Loss	103
4.9. Comparative Analysis Between Bertoni Path Loss Model and Field Measured Path Loss	105
4.10. Comparative Analysis Between Okumura Path Loss Model and Field Measured Path Loss	109
4.11. Comparative Analysis Between Cost 231 Path Loss Model and Field Measured Path Loss	113
4.12. Comparative Analysis Between Ecc33 Path Loss Model and Field Measured Path Loss	115
4.13. Comparative Analysis Between Sui Path Loss Model and Field Measured Path Loss	120
4.14. Comparative Analysis Between Hata Path Loss Model and Field Measured Path Loss	123
4.15. Conclusion	126
5. The Effect of Climatic Conditions on Field Propagation Model	127
5.1. Introduction	127
5.1.1 Related Work	127
5.2. Climatic Conditions of Narnaul (Haryana), India	128
5.2.1 Geographical Location & Climate of Narnaul (Haryana)	129

5.3. Comparison & Field Data Collection During Different Climate Conditions	133
5.4. Development of Propagation Path Loss Model By Considering Different Climatic Conditions	139
5.4.1. Effect of Summer	139
5.4.2. Effect of Winter	140
5.4.3. Effect of Rain	140
5.4.4. Effect of Fog	142
5.5. Comparative Analysis of Field Measured Data, Okumura Model and Developed Okumura Model	143
5.6. Validation of Developed Okumura Path Loss Model	149
5.6.1. By Taking Reference Model	151
5.6.1.1. Fog Attenuation Reference Model	151
5.6.1.2. Rain Attenuation Reference Model	152
5.6.2. By Applying The Developed Model in Another City	156
5.7. Conclusion	161
6. Cell Coverage Area And Effect On Link Budget Due To Climatic Conditions	163
6.1. Introduction	163
6.2. Coverage Area	164
6.3. Link Budget and Its Calculations	166
6.3.1. Important Parameters of Link Budget Calculations	169
6.3.1.1 Receiver Sensitivity	169
6.3.1.2 MS Sensitivity	169
6.3.1.3 BTS Sensitivity	169
6.3.1.4 MS & BTS Antenna Gain	170
6.3.1.5 Diversity Gains	170
6.3.1.6 Feeder & Connector Loss	170
6.3.1.7 Pre Amplifier & Booster	170
6.3.1.8 Interference Degradation Margin	171
6.3.1.9 Polarization Loss	171
6.3.2. Uplink Budget And Coverage Area	172
6.3.2.1. Transmitting End	172
6.3.2.2. Receiving End	173
6.3.3. Down Link Budget And Coverage Area	174
6.3.3.1 Transmitting End	174
6.3.3.2. Receiving End	175
6.4. Effect of Climatic Conditions on Link Budget	177
6.4.1. Calculation of Link Budget & Coverage Area in Summer and Winter	177
6.4.2. Calculation of Link Budget and Coverage Area in Heavy Fog (visibility=30m)	179

6.4.3. Calculation of Link Budget and Coverage Area in Heavy Rain (100mm/hr)	181
6.4.4. Calculation of Link Budget and Coverage Area Including All Climatic Effects in Narnaul (Haryana, India).	183
6.5. Conclusion	185
7. Conclusion And Future Work	187
7.1. Results & Conclusion	187
7.2. Future Work	190
References	191
Appendices	207

LIST OF FIGURES

Figure No.	Description	Page No.
1.1	Year Wise Development of Wireless Communication	2
1.2	Global Growths of Mobile and Fixed Subscribers	3
1.3	Illustration Showing the Importance of Accurate Coverage Estimation in Cellular Networks as Compared to Early Land to Mobile System	5
1.4	First Generation Cellular Phone of 1924	6
1.5	Concept of Frequency Reuse	7
1.6	Illustration of Frequency Reuse Concept	8
1.7	Basic of Handoff	8
2.1	The Hertzian Dipole	26
2.2	Voltage Induced at the Receiver Antenna	30
2.3	Illustration of Wireless Communication Showing Path Loss	32
2.4	Phenomenon of Reflection and Refraction	34
2.5	Diffraction in Sharp Edge	35
2.6	Wave is Scattered by a Small Obstacle	35
2.7	Example of Free Space Communication	38
2.8	Median Attenuation Relative to Free Space $A_{mu}(f,d)$ Over a Quasi-smooth Terrain	42
2.9	Correction Factor G_{area} for Different Types of Terrain	42
3.1	User Interface of Nemo Drive Test Tool	50
3.2	E7478A Drive Test System with E6455C IMT2000 Digital Receiver (Agilent Data Collection Tool)	51
3.3	Pioneer Data Collection Tool	52
3.4	Window of XTEL's Data collection Tool	53
3.5	Test Principle Illustrations	59
3.6	TEMS Test Kit used for test drive	60
3.7	TEMS window	64
3.8	Equipment Configuration Windows in TEMS	65
3.9	Equipment Configuration Window	66
3.10	Cell Data Configuring Window	67
3.11	Example of loading of Cell File in Narnaul (South Haryana)	68
3.12	Five basic objects of Map info	81
3.13	Illustration of Map Layer	82
3.14	The Default MATLAB Desktop	83

4.1	Selected Cell Sites for Field Data Collection	86
4.2	Derive Test Result in Cell id NNL001	87
4.3	Variation of Received Signal Strength (dBm) with Distance (Km.) in Three Different Areas of Five Different Cell ids	87
4.4	Variation of Path loss (dB) with Distance (Km.) in Three Different Areas of Five Different Cell ids	88
4.5	Comparison of field measured path loss and Predicted path loss with distance (Site id NNL001)	91
4.6	Comparison of field measured path loss and Predicted path loss with distance (Site id NNL002)	91
4.7	Comparison of Field Measured Path Loss and Predicted Path Loss With Distance (Site id NNL003)	92
4.8	M-file of Free Space Path Loss Model	93
4.9	Comparison Between Fields Measured Path Loss and Free Space Path Loss Model	93
4.10	Variation of Path Loss Between Free Space Path Loss and Practical Field Data for Two Adjacent Cells	94
4.11	Variation of Error Between Field Measured Data and Free Space Path Loss Model	95
4.12	M-file of W-I Path Loss Model	97
4.13	Comparison Between Field Measured Path Loss and W-I Path Loss Model	97
4.14	Variation of Path Loss Between W-I Path Loss and Practical Field Data for Two Adjacent Cells	98
4.15	Variation of Error Between Field Measured Data and W-I Path Loss Model	98
4.16	M-file of Lee path loss model	100
4.17	Comparison Between Field Measured Path Loss and Lee path loss model	100
4.18	Variation of Path Loss Between Lee Path Loss and Practical Field Data for Two Adjacent Cells	101
4.19	Variation of Error Between Field Measured Data and Lee Path Loss Model	101
4.20	M-file of Egli Path Loss Model	103
4.21	Comparison Between Field Measured Path Loss and Egli Path Loss Model	103
4.22	Variation of Path Loss Between Egli Path Loss and Practical Field Data for Two Adjacent Cells	104
4.23	Variation of Error Between Field Measured Data and Egli Path Loss Model	104
4.24	M-file of Bertoni Path Loss Model	105
4.25	Comparison Between Field Measured Path Loss and Bertoni Path Loss Model	107

4.26	Variation of Path Loss Between Bertoni Path Loss and Practical Field Data for Two Adjacent Cells	107
4.27	Variation of Error Between Field Measured Data and Bertoni Model	109
4.28	M-file of Okumura Path Loss Model Comparison Between Field Measured Path Loss and Okumura Path Loss Model	110
4.29	Variation of Path Loss Between Okumura Path Loss Model and Practical Field Data for Two Adjacent Cells	110
4.30	Variation of Error Between Field Measured Data and Okumura Path Loss Model	111
4.31	M-file of COST 231 path loss model	111
4.32	Comparison Between Field Measured Path Loss and COST 231 Path Loss Model	113
4.33	Variation of Path Loss Between Cost 231 Model and Practical Field Data for Two Adjacent Cells	114
4.34	Variation of Error Between Field Measured Data and Cost 231 Model	114
4.35	M-file of ECC 33 Path Loss Model	115
4.36	Comparison Between Field Measured Path Loss and ECC-33 Path Loss Model	117
4.37	Variation of Path Loss Between ECC-33 Path Loss Model and Practical Field Data for Two Adjacent Cells	117
4.38	Variation of Error Between Field Measured Data and ECC-33 Path Loss Model	118
4.39	M-file of SUI Path Loss Model	118
4.40	Comparison Between Field Measured Path Loss and SUI Path Loss Model	120
4.41	Variation of Path Loss Between SUI Path Loss Model and Practical Field Data for Two Adjacent Cells	120
4.42	Variation of Error Between Field Measured Data and SUI Path Loss Model	121
4.43	M-file of Hata Path Loss Model	121
4.44	Comparison Between Field Measured Path Loss and Hata Path Loss Model	123
4.45	Variation of Path Loss Between Hata Path Loss Model and Practical Field Data for Two Adjacent Cells	124
4.46	Variation of Error Between Field Measured Data and SUI Path Loss Model	124
4.47	M-file of Hata Path Loss Model	126
5.1	Geographical Map of Haryana	129
5.2	Average Rainy Days per Month in the Year 2011-2012	131
5.3	Average Rain Fall in Year 2011-2012	131
5.4	Satellite View & Climate (foggy day) of Narnaul	132

5.5	Average Fog Hours per Day in Year 2011-2012	132
5.6	Variation of Path Loss in Different Climatic Conditions	133
5.7	Error between Measured Data and Okumura Model in Winter	136
5.8	Error between Measured Data and Okumura Model in Summer	136
5.9	Error between Measured Data and Okumura Model in Heavy Fog Climate	137
5.10	Error between Measured Data and Okumura Model in Heavy Rain Climate	137
5.11	Illustration of Collision of Atoms and Molecules	139
5.12	Effect of Sun in Frequency Spectrum	140
5.13	Effect of Rain on Radio Waves	141
5.14	Comparison Between Field Measured Data, Okumura and Developed Okumura Path Loss Model in Winter Climate	143
5.15	Comparison Between Approximated 4 th Degree Polynomial Curve of Field Measured data, Okumura and Developed Okumura Path Loss Model in Winter Climate	144
5.16	Comparison Between Field Measured Data, Okumura and Developed Okumura Path Loss Model in Summer Climate	144
5.17	Comparison Between Approximated 4 th Degree Polynomial Curve of Field Measured Data, Okumura and Developed Okumura Path Loss Model in Summer Climate	145
5.18	Comparison Between Field Measured Data, Okumura and Developed Okumura Path Loss Model in Heavy Fog Climate	145
5.19	Comparison Between Approximated 4 th Degree Polynomial Curve of Field Measured Data, Okumura and Developed Okumura Path Loss Model in Heavy Fog Climate	146
5.20	Comparison Between Field Measured Data, Okumura and Developed Okumura Path Loss Model in Heavy Rain Climate	146
5.21	Comparison Between Approximated 4 th Degree Polynomial Curve of Field Measured Data, Okumura and Developed Okumura Path Loss Model in Heavy Rain Climate	147
5.22	Variation of Error Between Field Measured Data, Okumura and Developed Okumura Model in Winter	147
5.23	Variation of Error Between Field Measured Data, Okumura and Developed Okumura Model in Summer	148
5.24	Variation of Error Between Field Measured Data, Okumura and Developed Okumura Model in Foggy Climate	148

5.25	Variation of Error Between Field Measured Data, Okumura and Developed Okumura Model in Winter	149
5.26	Comparison Between Developed Fog Attenuation and Reference Fog Attenuation Model	151
5.27	Difference Between Developed and Reference Fog Attenuation Model	152
5.28	Comparison Between Developed Rain Attenuation and Reference Rain Attenuation Model	153
5.29	Difference Between Developed and Reference Rain Attenuation	153
5.30	Comparison Between Developed Okumura Model and Field Data Taken (Hisar, Haryana, INDIA) in winter season	156
5.31	Comparison Between Developed Okumura Model and Field Data Taken (Hisar, Haryana, INDIA) in summer season	156
5.32	Comparison between Developed Okumura Model and Field Data Taken (Hisar, Haryana, INDIA) in Heavy Fog Condition	157
5.33	Comparison between Developed Okumura Model and Field Data taken (Hisar, Haryana, INDIA) in Heavy Rain Condition	157
5.34	Error between Developed Okumura Model and Field Data taken (Hisar, Haryana, INDIA) in Winter Condition	158
5.35	Error between Developed Okumura Model and Field Data taken (Hisar, Haryana, INDIA) in Summer Season	158
5.36	Error between Developed Okumura Model and Field Data taken (Hisar, Haryana, INDIA) in Heavy Fog Condition	159
5.37	Comparison between Developed Okumura Model and Field Data taken (Hisar, Haryana, INDIA) in Heavy Rain Condition	159
6.1	Illustration of Link Budget in Mobile Communication	164
6.2	Methodology Used for Prediction of Optimum Coverage Area	166
6.3	Uplink & Downlink Budget	168
6.4	Mast Head Amplifier	171
6.5	Uplink Budget & Flow Chart (Uplink Budget)	173
6.6	Downlink Budget & Flow Chart (Downlink Budget)	174

LIST OF TABLES

Table No.	Description	Page No.
1.1	Evolution of The WLAN Standards	4
2.1	The Parameter Values of Different Terrain for SUI Model	46
3.1	Range of SQI	58
3.2	Some TEMS Supported Mobile Phone's Feature	61
3.3	Signal Strength Measurements at Base Station NNL001 in Month of January (Winter)	70
3.4	Signal Strength Measurements at Base Station NNL011 in Month of May (Summer Temperature:47 ⁰ C)	71
3.5	Signal Strength Measurements at Base Station NNL001 in Month of July (Heavy Rain)	72
3.6	Signal Strength Measurements at Base Station NNL001 in Month of December (Winter Heavy Fog Condition)	73
3.7	Signal Strength Measurements at Base Station Hisar in Month of January	74
3.8	Signal Strength Measurements at Base Station Hisar in Month of May	75
3.9	Signal Strength Measurements at Base Station Hisar in Month of July	76
3.10	Signal Strength Measurements at Base Station Hisar in Month of December	77
3.11	Main Parts of MATLAB	83
3.12	Different Parts of MATLAB Window	84
4.1	Average Signal Strength Measurements	89
4.2	Average Path Loss Measurements	90
4.3	Error Between Measured and Free Space Path Loss Model	96
4.4	Error Between Measured and W-I Path Loss Model	99
4.5	Error Between Measured and Lee Path Loss Model	102
4.6	Error Between Measured and Egli Path Loss Model	106
4.7	Error Between Measured and Bertoni Path Loss Model	108
4.8	Error Between Measured Okumura Path Loss Model	112
4.9	Error Between Measured and Cost 231 Path Loss Model	116
4.10	Error Between Measured and ECC-33 Path Loss Model	119
4.11	Error Between Measured and SUI Path Loss Model	122
4.12	Error Between Measured and Hata Path Loss Model	125
5.1	Different Seasons of India	128
5.2	Various Climatic Regions of India	129
5.3	Rainfall Statistics for Haryana	130
5.4	Variation of Maximum and Minimum Temperature in Haryana	130
5.5	Average Signal Strength Measurements at Narnaul (Haryana)	134
5.6	Average Path Loss Measurements at Narnaul (Haryana)	135
5.7	Error Between Okumura Path Loss Model and Field Data	138
5.8	Error Between Measured, Okumura and Developed Okumura Model	150

5.9	Error Between Fog Attenuation and Reference Model	154
5.10	Error Between Rain Attenuation and Reference Model	155
5.11	Error Between Measured Data (Hisar, Haryana, India) and Developed Okumura Model	160
6.1	Transmitter Side Specifications (Uplink)	172
6.2	Receiver Side Specifications (Uplink)	173
6.3	Transmitter Side Specifications (Down Link)	175
6.4	Receiver Side Specifications (Down Link)	175
6.5	Coverage Area Calculations in Summer & Winter	179
6.6	Coverage Area in Foggy Days	181
6.7	Coverage Area Calculation in Rainy Days	182
6.8	Coverage Area Calculations by Using Developed Okumura Model	184
7.1	Difference between Measured Field Data to Path Loss Model	188
7.2	Average Error between Currently Measured Data with Okumura and Developed Okumura Model	188
7.3	Coverage Area Calculations Taking Different Parameters	189

LIST OF ABBREVIATIONS

1G	First Generation wireless technology
2G	Second Generation wireless technology
3G	Third Generation wireless technology
1xDV	3G Extension of IS-95B: shared data and voice
1xDO	3G Extension of IS-95B: data only
1xEV	3G Extension of IS-95B: data with circuit-switched voice
1xRTT	3G Extension of IS-95B: one RF channel
ACELP	Adaptive Code Excited Linear Prediction
ADPCM	Adaptive Digital Pulse Code Modulation
AM	Amplitude Modulation
AMPS	Advanced Mobile Phone Service
BCCH	Broadcast Control Channel
BCH	Bose Chaudhuri Hocquenghem <i>also</i> Broadcast Channel
BoD	Bandwidth on Demand
BPSK	Binary Phase Shift Keying
BS	Base Station
BTS	Base Transceiver Station
CC	Convolution Code
CB	Citizens Band
CDMA	Code Division Multiple Access
CEPT	Conference of European Postal and Telecommunications Administrations
COST	Cooperative for Scientific and Technical Research
CT2	Cordless Telephone 2
CTIA	Telephone Industry Association
COST WI	COST Walfisch Ikegami
DCS	Digital Cellular System
DECT	Digital European Cordless Telephone
DQPSK	Differential Quadrature Phase Shift Keying
DS-CDMA	Direct-Sequence Code Division Multiple Access
EDGE	Enhanced Data Rate For GSM Evolution
EIRP	Effective Isotropic Radiated Power
EFR	Enhance Full Rate
ELF	Extremely Low Frequency
ETACS	Extended Total Access Communication System <i>also</i> European Total Access Cellular System
ETSI	European Telecommunications Standard Institute
EURO-COST	European Cooperative for Scientific and Technical Research
EHF	Extremely High Frequency
F/TDMA	Hybrid FDMA/TDMA
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Accesses
FL	Forward Link
FM	Frequency Modulation
FR	Full Rate

GAN	Global Area Network
GMSK	Gaussian Minimum Shift Keying
GFSK	Gaussian Frequency Shift Keying
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HF	High Frequency
HO	Hand Over
HR	Half Rate
HSCSD	High Speed Circuit Switched Data
HSPDA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
iDEN	Integrated Digital Enhanced Network
IMT	International Mobile Telecommunications
ITU	International Telecommunication Union
ITU-R	ITU's Radio communications sector
IS-54	EIA Interim Standard for U.S. Digital Cellular with Analog Control Channel
IS-95	EIA Interim Standard for U.S. Code Division Multiple Access
IS-136	EIA Interim Standard 136 –USDC with Digital Control Channel
ISDN	Integrated Services Digital Network
JTACS	Japanese Total Access Communication System
LF	Low Frequency
LOS	Line of sight
LTE	Long Term Evolution
MSE	Mean square error
MF	Medium Frequency
MS	Mobile Station
NIDS	Network Intrusion Detection System
NMT	Nordic Mobile Telephone
NLOS	Nonlineofsight
NTACS	Narrowband Integrated Services Digital Network
NTT	Nippon Telephone and Telegraph
OVSF	Orthogonal Variable Spreading Factor
PABX	Private Access Business Exchange
PDC	Personal Digital Cellular
PCNs	Personal Communication Networks
PN	Pseudo Noise
PCS	Personal Communication System
PSI-CELP	Pitch Synchronous Innovation CELP
QCELP	Quadrature Code Excited Linear Prediction
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RAN	<i>Radio Access Network</i>
RCELP	Residual Code Excited Linear Prediction
RL	Reverse Link

RPE-LTP	Regular Pulse Excited Long Term Prediction
SDCCH	Stand-alone Dedicated Control Channel
SQI	Speech Quality Index
SHF	Super High Frequency
TACS	Total Access Communication System
TCH	Traffic Control Channel
TDD	Time Division Duplex
TETRA	Terrestrial Trunked Radio
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunication System
VHF	Very High Frequency
VLF	Very Low Frequency
VSELP	Vector Sum Excited Linear Prediction
WCDMA	Wideband CDMA
WiMAX	Worldwide Interoperability for Microwave Access
WARC	World Allocation Radio Conference

CHAPTER 1

INTRODUCTION

In current era the wireless communication is spreading throughout the world rapidly. The wireless technology has covered each and every area in day to day life. This chapter discusses the historical overview and outline of the thesis along with expected outcome of the research work carried presently.

1.1 HISTORICAL OVERVIEW

Wireless communication is one of the most dynamic and vibrant areas of technology development in the communication field today. To give better understanding, it may be revert from literature of old days that the first outcome of communication started with origin of radio in the year 1680 by Newton's theory of composition of light. According to Newton, light is a composition of various colours and his theory brings the importance of light as a research area of study for many scientists. Later on in 1873, James Clerks Maxwell gave many laws to explain electro magnetism as a result of Poisson's equation using electrostatics, Gauss law equation using magneto statics, Ampere's law equation using electrodynamics, and Faraday law equation using magneto-dynamics. After his research, in the year 1888, Heinrich Rudolf Hertz practically verified the electromagnetism phenomena which Maxwell obtained mathematically [164].

Four years later, in the year 1892, A British scientist Sir William Crookes published a paper on telegraphic communication over long distances using tuned circuits. With the help of Crookes work, Guglielmo Marconi established a radio link over a distance of a small number of miles in 1895. It is the first revolution to the mobile radio industry. The communication with people on the move was made possible by this radio link. Two way radio communication links at frequencies of 30 to 40 MHz were designed from the middle of 1930s [174]. The radio communication gradually increased to include the metric, decimetric and centimetric wavelengths from the year 1930 to 1960 [187]. From the year 1970 frequency modulation was introduced in communication. The analog cellular systems were first developed by Bell Laboratories [186]. In 1979, an effort was made to launch and install first cellular system, i.e. Advanced Mobile Phone Service (AMPS) started at Chicago. Then in 1980 the High Capacity Mobile Telephone System (HCMTS) launched at Tokyo and the Nordic Mobile Telephone (NMT) launched in 1981 at Scandinavia. France's Radiocom 2000

was operational in 1985, similar to United Kingdom's Total Access Communication System (TACS) and Germany's C 450 systems [209]. In the early days of 1990s, low cost cordless system and it got remarkable growth rates. Among these systems cellular played an important role in such growth process, especially after the invention of international digital standards like Global System for Mobile Communications (GSM) and Code division multiple access (CDMA) system (IS-95) [184].

In general, the cellular systems in operation are divided into two categories: the first-generation analog systems and the second generation digital systems. At present, one can observe the quick growth of different types of wireless communication systems for example personal fixed & mobile, and land & satellite. These systems utilize a frequency band from 500 MHz up to 3 to 10GHz. The IMT-2000 third generation cellular mobile system was introduced in 2002. This system relies on cellular techniques and reuses the basic concepts of architecture, functionality and services of these systems [70], [187]. Generation wise the wireless communication is as shown in figure 1.1. The first-generation (1G) mobile systems were analogue, and commissioned in the 1980s. In the 1990s, second-generation (2G) digital mobile systems such as the GSM came in existence. The GSM standard is tremendously triumphant, providing the national as well as international coverage. So, GSM is nowadays the foremost mobile communication system [163].

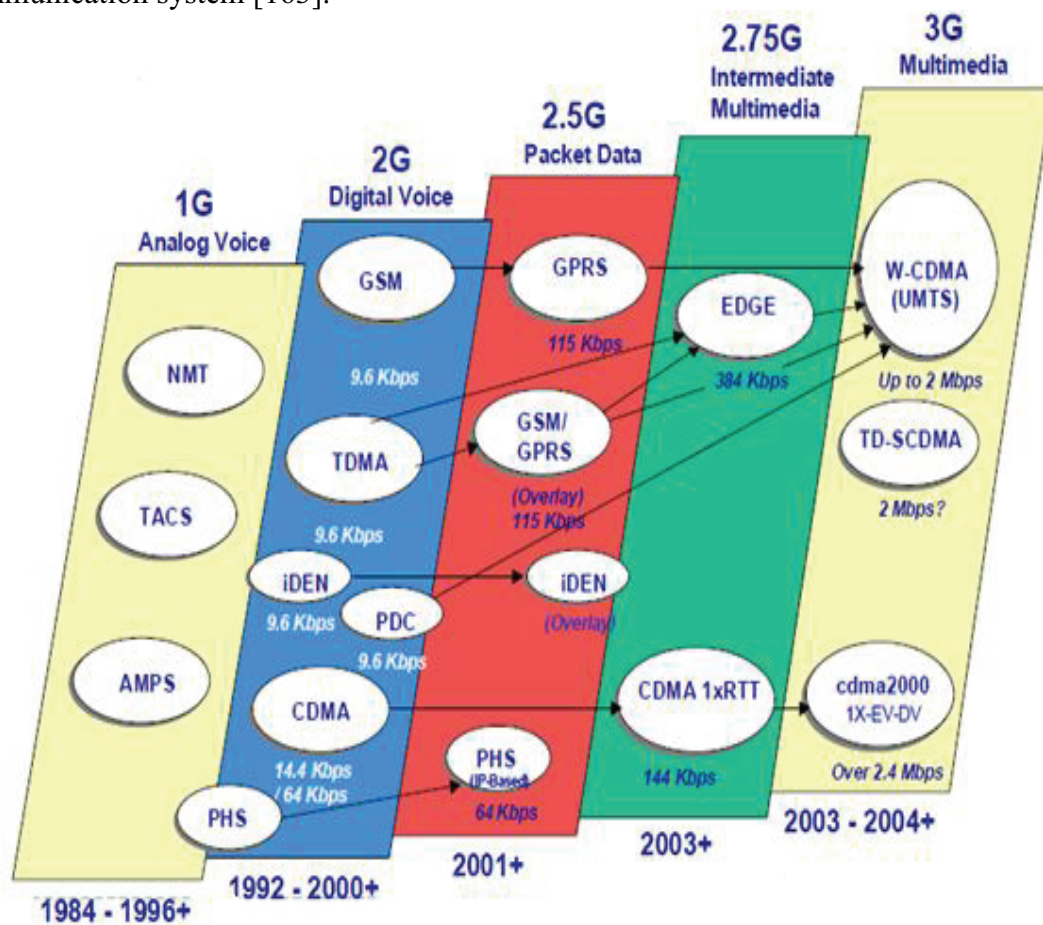


Figure 1.1 Year Wise Development of Wireless Communication

Wireless communication has gained incredible growth in the last few years. The first mobile contributions took place in the early 1980s, and the industry was blooming by 1987. However, the traditional phone technology was analogue. The business take-off by GSM (digital) technology occurred in 1992. In early 1991 hardly one in every thousand people had a mobile phone. But till the end of 2001, approximately 17% people got access of the mobile phone [106]. Within this period the number of countries using a mobile network increased tremendously from 3% to more than 90%. In 2002 the number of mobile subscribers leaves behind the number of fixed-line subscribers. Mobile subscribers outnumbered by 7% fixed line subscribers: Mobile subscribers (million): 1,157 and Fixed lines (million): 1,083. Since 2002, the fixed line technology declined, getting closer to the edge of obsolescence. The growth of mobile subscribers is depicted in figure 1.2. It is assumed that this growth will continue to rise, and by 2015 every person will have mobile subscription [163].

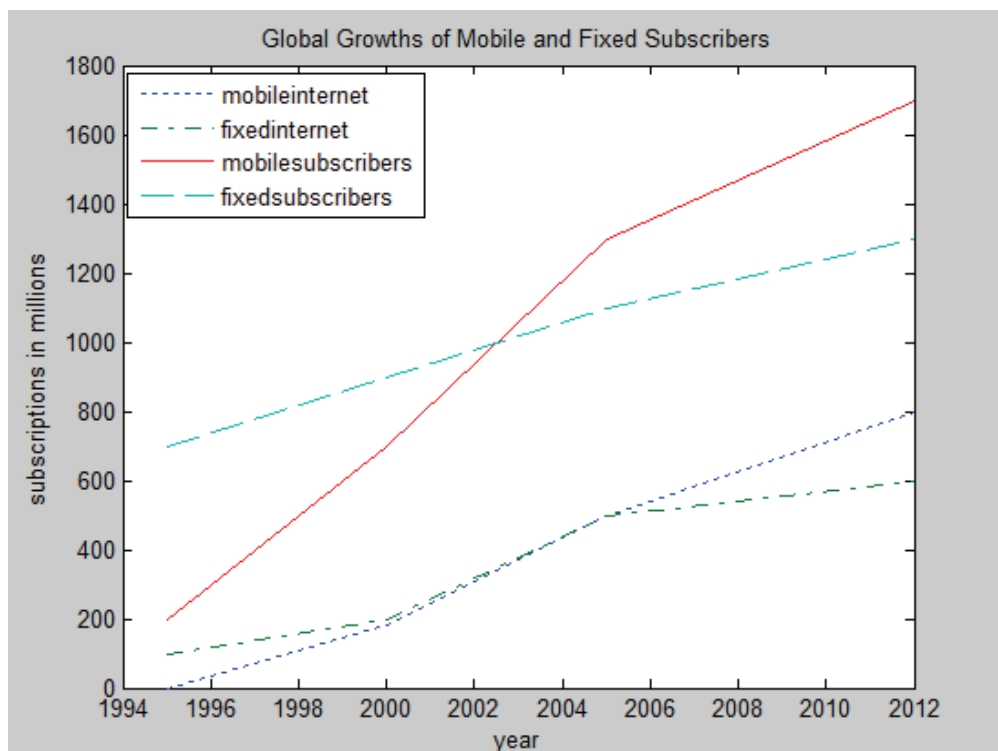


Figure 1.2 Global Growths of Mobile Subscribers

Other than mobile phone communications, Wireless Local Area Networks (WLANs), which came into existence in 1997 only, have also gained tremendous growth. The quick propagation of WLAN hotspots in public places like airport terminal has been amazing. In fact, WLANs have reached into homes, with the help of Digital subscriber line (DSL) and cable access modems resulting in the scenario where number of wireless Internet subscribers will go beyond the number of wired internet users in near future and shown in figure 1.2. The growth of wireless data systems is also seen in many new standards which have recently been developed or are currently under development [163]. Both 1G and 2G systems were intended mainly to offer voice

applications, and to support circuit-switched services [167]. However, GSM provides data communication services to users, but the data rates are restricted to only a few tens of kbps. In contrast, WLANs which were designed to offer fixed data network extension in the beginning provide Mbps data transmission rates. The WLAN standard – IEEE 802.11, known as Wi-Fi, was commissioned first time in 1997 and it offered 2 Mbps. Since then the standard has grown numerous times and keeps on increasing as per user requirement for higher bit-rates as shown in Table 1.1. Now days, WLANs can offer up-to 54 Mbps for the IEEE 802.11a/g, and Hiper LAN2 standards operating in the 2.4 GHz and 5 GHz license-free ISM bands. Though, WLANs are not able to provide the kind of mobility, which mobile systems can do [5], [163].

Table 1.1 Evolutions of the WLAN Standards

Year of Establishment	Standard of WLAN Standard	Frequency	Modulation	Bit rate
1997	IEEE 802.11	2.4 GHz	Frequency Hopping and direct spread spectrum	2 Mbps
1998	ETSI Home RF	2.4 GHz	Wideband Frequency Hopping	1.6 Mbps
1999	IEEE 802.11b	2.4 GHz	Direct Sequence Spread spectrum	11 Mbps
1999	IEEE 802.11a	5 GHz	OFDM	54 Mbps
2000	ETSI Hiper LAN2	5 GHz	OFDM Connection oriented	54 Mbps
2003	IEEE 802.11g	2.4 GHz	OFDM Compatible with 802.11a	54 Mbps

Wireless communication should be designed to attain high capacity with limited radio spectrum and it is possible by the Cellular radio concept, which is discussed in the following section.

1.2 CELLULAR RADIO CONCEPT

The concept of cells was introduced in early 1947 by Bell Laboratories in the US; they also gave a detailed proposal for a “High-Capacity Mobile Telephone System” integrating the cellular concept submitted by Bell Laboratories to the FCC in 1971. Still the first AMPS system was set up in Chicago in 1983 [56]. The old system was able to attain a large coverage by means of a simple, high power transmitter in a cell. Base station (BS) was put on the top of mountains or tall towers, so that it could cover a large area. The next Base station BS was put so far away that interference was not a concern. Wireless radio services just in terms of spectrum use alone pretence a much more difficult problem [33]. Severely, it bounds the number of users that could communicate at a time. These were noise-limited systems as numbers of users were limited. The Bell mobile system in New York City in the 1970s was able to communicate a maximum of twelve calls at a time over an area of thousand square

miles [125], [186]. The number of calls a mobile wireless system can handle at the same time is essentially determined by the total spectral allocation for that system and the bandwidth needed for transmitting signals used in managing a call. Cellular systems can handle a large number of users over a large geographic area within a limited frequency spectrum. High capacity is attained by using the concept of cell which is a small geographic area and for each cell a single base station is used. Using this concept the same radio channels can be reused by another base station situated some distance away. The entire coverage area can be partitioned into several cells [14]. A cell corresponds to the covering area of single BS transmitter or a small collection of many transmitters. The size of a cell is determined by the transmitter's power.

In this way a single, high power transmitter (large cell) is replaced by many low power transmitters (small cells) which cover only one cell area (a small portion of the service area) as shown in figure 1.3. For mobility a sophisticated switching technique called handoff is used which helps in establishing a call un-interrupted when the user shift, from one cell to another.

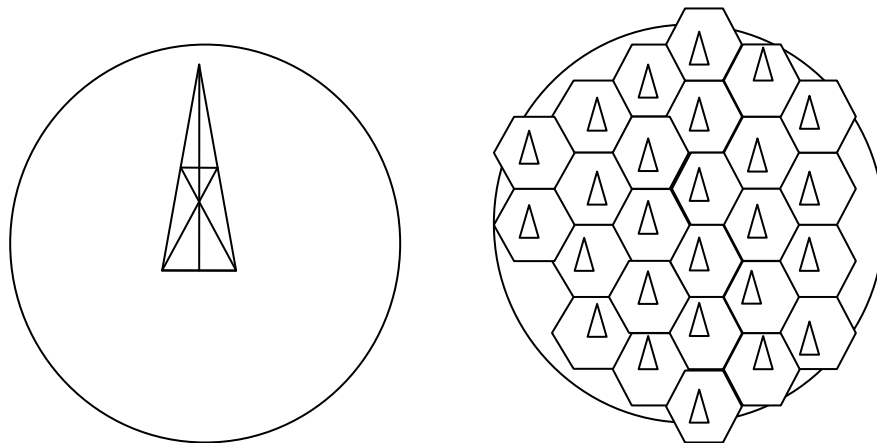


Figure 1.3 Illustrations Showing the Importance of Accurate Coverage Estimation in Cellular Networks as Compared to Early Land to Mobile System

Basic cellular system consists of mobile stations, base stations, and a mobile switching centre (MSC). Mobile switching centre (MSC) is also referred as mobile telephone switching office (MTSO) which manages the activities of the base stations and also connects the entire cellular system to the public switched telephone network (PSTN) [230]. It handles all billing and system maintenance functions. Each communication takes place via radio waves with one of the base stations and for the complete duration of call the mobile station may be handed-off to any number of base stations [231]. Mobile station consists of three units, first one is transceiver, second is an antenna, and third is control circuitry. Among all mobile users in the cell Base stations work as a bridge and helps in connecting the concurrent mobile calls via telephone lines or microwave links to the MSC. It contains a number of transmitters and receivers which concurrently manage full duplex communications. In general it has towers to support numerous transmitting and receiving antennas [232]. Cellular concept also depends on an intelligent allocation and reusability of channels all over a coverage

region. These systems are sometimes referred as narrow band systems as these use the concept of frequency reusability. The frequency reuse concept is given in the following section.



Figure1.4. First Generation Cellular Phone of 1924

1.2.1 Frequency Reuse

Cellular notion depends on an intelligent allocation and reusability of channels all over a coverage region. These systems are sometimes referred as narrow band systems as these use the concept of frequency reusability. A group of radio channels are assigned to each cellular base station (BTS) to be utilized within a cell. The design process contains selecting and assigning channel groups to all cellular BTS within a system [80]. Consider a cellular system has a total of S duplex channels available for use. If each cell is allocated a group of k channels, where $k < S$, and if the S channels are divided among N cells into unique and disjoint channel groups which each have the same number of channels, the total number of available radio channels can be expressed as

$$S = k N \quad (1)$$