

**UNIVERSITY OF MORATUWA  
SRI LANKA.**

UNIVERSITY OF MORATUWA  
SRI LANKA

**ESTIMATION OF PROPAGATION CHARACTERISTICS  
IN THE FM ENVIRONMENT**



*Submitted in partial fulfilment for the Degree of Master of Engineering in  
Electronics and Telecommunications*

**E.N.P.K.Ratnapala**

621.38 "02"

671.396

um Thesis Coll.

University of Moratuwa



77709

**December 2002**

77709

77709

# DECLARATION

---

The work presented in this dissertation has not been submitted for the fulfillment of any other Degree



University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

Handwritten signature of E.N.P.K. Ratnapala in black ink, written over a dashed horizontal line.

E.N.P.K.Ratnapala  
Candidate

Handwritten signature of Prof (Mrs.) I.J. Dayawansa in black ink, written over a dashed horizontal line.

Prof (Mrs.) I.J. Dayawansa  
Supervisor

Handwritten signature of Dr (Mrs.) Dileeka Dias in black ink, written over a dashed horizontal line.

Dr (Mrs.) Dileeka Dias  
Supervisor

## DEDICATION

---

*To my loving parents who knew I could do it long before I did it*

*To my wife Deepika, for her boundless patience and understanding*



University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## ACKNOWLEDGEMENTS

---


The concentrated effort of many individuals has brought this project a reality. I offer my sincere appreciation to all those involved in this project.

I am deeply indebted to Prof. (Mrs) I.J. Dayawansa for her encouragements and moral support to get this project off the ground and guiding me throughout to achieve the expected outcome. She took time from her busy schedule to patiently review a manuscript that at times appeared endless and chaotic. I sincerely thank her for meticulous proofreading.

I am also grateful to Dr. (Mrs) Dileeka Dias for her encouragements, valuable comments, advices and suggestions to make this effort successful.

I thank Dr. J.A.K.S. Jayasinghe for his technical criticisms and valuable comments provided at periodical reviews.

My appreciation also goes to Telecommunications Regulatory Commission of Sri Lanka for providing me the opportunity, sophisticated equipment and software tools required for this undertaking.

I extend my gratitude to  University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations MBC Networks (Pvt) Ltd for providing data and related information on their VHF/FM transmission and keeping all transmission parameters unchanged during the period of study so that meaningful field strength measurements have been possible.

Finally, although I am unable to mention individually I owe much thanks and appreciation to all others, who enthusiastically contributed aid and support in many significant ways.

## ABSTRACT

---

Electromagnetic Compatibility (EMC) analysis involved in the planning process of a FM broadcasting service is an intricate and complex procedure, which is dependant fully on the propagation prediction models. For these predictions theoretical and empirical models are used. But the applicability, approach, complexity and the accuracy of each of these models can differ by a wide margin, producing lack of confidence and higher degree of uncertainty. Therefore choosing a model for a specific EMC Analysis with the required accuracy is of primary concern.

Most of these models have been developed in many parts of the world. Stringent validation of these models as distinct to the Sri Lankan environment is an essential requirement by testing on locally collected data. But apparently due to the extent of measurement and analysis facilities required this had been a minority activity.

In this research work the applicability of generally acceptable empirical and theoretical propagation models such as free space ( $L_F$ ), plane earth ( $L_p$ ), modified plane earth ( $L'_p$ ), Max ( $L_F, L_p$ ), Max ( $L_F, L'_p$ ), ITU PN 370-6, FCC are compared for their performance for typical rough and irregular terrain commonly found in Sri Lanka by observing the received signals of FM sound broadcast transmissions originating from Nuwara Eliya and Colombo.

The results show that theoretical model Max ( $L_F, L'_p$ ), is the most accurate model for FM broadcast environment in Sri Lanka. It is seen that this model, yields most accurate results even in irregular terrain with Epstein Peterson diffraction correction.

## LIST OF FIGURES

---

1.1	Stereophonic multiplex signal	3
1.2	Radio frequency protection ratios (dB)	5
1.3	Location probability of field strength	7
1.4	Time probability of field strength	8
3.1	Antennas located on smooth, spherical earth under line of sight condition	14
3.2	Knife edge diffraction	17
3.3	The variation of diffraction loss with diffraction parameter	18
3.4	Bullington diffraction construction	18
3.5	Epstein Peterson diffraction construction	19
3.6	Deygout diffraction construction	19
4.1	ITU land path propagation curves for 50% of time, 50% of locations for 50m-terrain roughness	21
4.2	Terrain roughness $\Delta h$	22
4.3	FCC propagation curves applicable for FM broadcasting	23
5.1	Measuring equipment configuration	25
5.2	(a) Horizontal radiation pattern in linear field scale	27
	(b) Vertical radiation pattern	27
5.3	Locations of transmitting station and test sites	27
5.4	Clearance angle	28
6.1	Median field strength variation with distance	33
6.2	Probability density function of error	33
6.3	Cumulative distribution function of error	34
6.4	Field strength contours	35

6.5	Trend line in comparison with theoretical models	36
6.6	Trend line in comparison with empirical models	36
6.7	Morphological losses for different clearance angle ranges	38
6.8	Variation of morphological loss with clearance angle	39
6.9	Bullington diffraction construction	40
6.10	Epstein Peterson diffraction construction	40
6.11	Deygout diffraction construction	41
6.12	Estimated values of mean error for different models	42



University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## LIST OF TABLES

---

1.1	Typical transmitting sites, power levels and antenna directivities	6
4.1	Values of $c$ for different zones for VHF and UHF band	22
5.1	Particulars of reference transmission (Colombo)	26
5.2	Particulars of reference transmission (Nuwara Eliya)	29
6.1	Diffraction loss by Bullington diffraction correction	40
6.2	Diffraction loss by Epstein Peterson diffraction correction	41
6.3	Diffraction loss due to individual obstruction	41
6.4	Diffraction loss of other obstacles with respect to main edge	42
6.5	Prediction comparisons in irregular terrain	43
6.6	Error comparisons in irregular terrain	44



University of Moratuwa, Sri Lanka  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)



# CONTENTS

---

	<i>Page No</i>
<b>1. INTRODUCTION</b>	1
1.1 Background	1
1.2 Standards of VHF/FM sound broadcasting service	3
1.3 FM broadcasting operation in Sri Lanka	5
1.4 Estimation of propagation characteristics	7
1.5 Objectives of the project	8
<b>2. FM BROADCASTING ANTENNAS AND RADIATION</b>	10
2.1 Radiation pattern plots	10
2.2 Antenna pattern distortion	12
<b>3. THEORETICAL PROPAGATION PREDICTION MODELS</b>	13
3.1 Free space propagation	13
3.2 Propagation over curved reflecting surface and Plane earth model	13
3.3 Other models	16
3.4 Diffraction loss due to irregular terrain	17
<b>4. EMPIRICAL MODELS</b>	21
4.1 ITU-PN 370-6	21
4.2 FCC method	23
<b>5. OBSERVATIONS</b>	25
5.1 Test equipment configuration	25
5.2 Propagation over rough terrain under line-of- sight conditions	26

5.3 Effect of morphological factors	28
5.4 Propagation over irregular terrain	28
<b>6. CALCULATIONS AND RESULTS</b>	30
6.1 Computation of azimuth and distance	30
6.2 Propagation over rough terrain under line of sight conditions	30
6.3 Effect of morphological factors	36
6.4 Propagation over irregular terrain	39
<b>7. DISCUSSION</b>	46
7.1 Conclusion	47
<b>REFERENCES</b>	48
<b>APPENDIX 1</b>	49
<b>APPENDIX 2</b>	58
<b>APPENDIX 3</b>	60
<b>APPENDIX 4</b>	61
<b>APPENDIX 5</b>	70
<b>APPENDIX 6</b>	80
<b>APPENDIX 7</b>	82



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)