

ANALYSIS OF DIGITAL COMMUNICATION SYSTEMS IN  
IMPULSIVE ATMOSPHERIC RADIO NOISE AND  
DESIGN OF AN OPTIMUM RECEIVER

BY

VIRANDER KUMAR JAIN

THESIS SUBMITTED TO  
THE INDIAN INSTITUTE OF TECHNOLOGY DELHI  
FOR THE AWARD OF THE DEGREE OF  
DOCTOR OF PHILOSOPHY

DEPARTMENT OF ELECTRICAL ENGINEERING  
INDIAN INSTITUTE OF TECHNOLOGY, DELHI

JULY 1981

CERTIFICATE

This is to certify that the dissertation "Analysis of Digital Communication Systems in Impulsive Atmospheric Radio Noise and Design of an Optimum Receiver", which is being submitted by Virander Kumar Jain for the award of the degree of Doctor of Philosophy to the Indian Institute of Technology, New Delhi, is a record of bona-fide research work.

This dissertation has reached the standard fulfilling the requirements of the regulations relating to the degree. The results obtained in this dissertation have not been submitted to any other university or Institute for the award of any degree or diploma.

S. N. Gupta

(S. N. GUPTA)

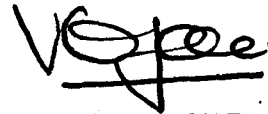
Department of Electrical Engineering  
Indian Institute of Technology,  
NEW DELHI-16

## ACKNOWLEDGEMENT

The author wishes to express his deep sense of gratitude to Dr. S.N. Gupta, Assistant Professor for his continuous guidance and encouragement during the course of this research work. The author expresses his appreciation and thanks to the other faculty members of I.I.T., Delhi for their invaluable help from time to time, particularly Dr. H.M. Gupta, Assistant Professor of the Electrical Engineering Department. A word of thanks is also due to my colleagues Dr. P. Mohana Shankar and Mr. S.P. Uttam of the Electrical Engineering Department for their help throughout the whole work.

The author is grateful to the Director General, All India Radio for allowing the author to pursue his doctoral research work on a part-time basis and permitting to submit the thesis.

The author expresses his appreciation and thanks to Mr Harish Bhatia for the typing work. Finally, the author wishes to thank all others who directly or indirectly rendered timely help on various occasions.



(VIRANDER KUMAR JAIN)  
Research Department, All India Radio  
I.P.Estate, Ring Road  
New Delhi - 2

ABSTRACT

Digital communication systems have been steadily assuming greater and greater importance because of the simpler implementation techniques and, of course, their inherent merits. The impulsive noise plays a significant role in digital communication systems design and performance. At tropical latitudes, the atmospheric radio noise, when in impulsive form, is the principal source of interference. In view of this, the study of digital communication in the presence of impulsive noise assumes significance. One such problem has been studied and the results of investigations presented in the thesis.

In the present analysis and design, the model of atmospheric radio noise is assumed to be Poisson or generalized shot noise model with a specific nongaussian amplitude distribution which is reported to be in excellent agreement with the observations. The receiver structure is taken to be the optimum receiver for Gaussian noise. The choice of the receiver structure is governed by the fact that most of the time it is the Gaussian noise that interferes with the signals. However, when impulsive noise occurs, though it may be the main source of interference, the receiver structure continues to be same. The impulse rates considered are those which are normally encountered in practice. The summary of the work carried out is as given below:

Evaluation of the performance of baseband polar signals, ASK, PSK and FSK signals in both the binary and m-ary forms and with both coherent and noncoherent detection and DPSK signal with polarity coincidence correlator receiver is carried out. In the baseband case, the evaluation has been extended to the case of the combined continuous and impulsive noise in different proportions. The effect of intersymbol interference is also included in the analysis of baseband and DPSK systems.

In all the above cases, the probability of error versus the signal-to-noise<sup>ratio</sup> curves are plotted for different impulse rates and for comparison, error probability curves in continuous noise are also drawn. The implications and significance of these results are also given. The results presented are for varying levels of intersymbol interference and for varying proportions of continuous and impulsive noise power wherever applicable.

Nonlinear processing techniques leading to an optimum receiver and a locally optimum receiver are given. Attainable improvement and practical difficulties in the implementation of nonlinear characteristics are also indicated. Performance results are given and compared with other available noise reduction techniques. Channel capacity in this form of noise is also evaluated.

## TABLE OF CONTENTS

	page
ABSTRACT	1
LIST OF FIGURES	iii
LIST OF SYMBOLS	vi
<b>CHAPTER 1 : ATMOSPHERIC NOISE IN COMMUNICATION SYSTEMS</b>	
1.1 Introduction	1
1.2 Merits of digital systems	5
1.3 Factors affecting digital systems performance	6
1.4 Significance of noise	7
1.5 Classification of noise	8
1.5.1 Source basis	8
1.5.2 Characteristic basis	11
1.6 Description of atmospheric radio noise (ARN)	13
1.7 ARN models	22
<b>CHAPTER 2 : SYSTEM PERFORMANCE AND NOISE REDUCTION TECHNIQUES</b>	
2.1 Introduction	25
2.2 Performance of digital systems	25
2.3 Description of intersymbol interference (ISI)	34
2.4 Noise reduction techniques	37
2.4.1 Impulse noise cancellers	38
2.4.2 Linear devices	39

2.4.3	Nonlinear processing	40
2.4.4	Nonparametric method	43
2.4.5	Signal design through coding and redundancy	44
CHAPTER 3 :	PROBLEM FORMULATION AND NOISE MODEL	
3.1	Problem formulation	45
3.2	Noise model	47
3.3	Characteristic and joint probability density functions	51
CHAPTER 4 :	ANALYSIS OF BASEBAND SYSTEM	
4.1	Introduction	55
4.2	Probability density function of noise	56
4.3	Error probability analysis in impulsive ARN with ISI	56
4.4	Error probability analysis in impulsive ARN and continuous noise with ISI.	61
4.5	Conclusions	65
CHAPTER 5 :	ANALYSIS OF ASK, PSK AND FSK SYSTEMS	
5.1	Introduction	75
5.2	Noise probability density function	76
5.3	Error probability analysis	77
5.3.1	Coherent ASK system	78
5.3.2	Noncoherent ASK system	83
5.3.3	Coherent PSK system	91
5.3.4	Noncoherent PSK system	99

5.3.5	Coherent FSK system	104
5.3.6	Noncoherent FSK system	106
5.4	Conclusions	113
CHAPTER 6 : ANALYSIS OF DPSK SYSTEM		
6.1	Introduction	116
6.2	Error probability analysis of DPSK signal with PCC receiver in impulsive ARN and ISI	118
6.3	Conclusions	121
CHAPTER 7 : OPTIMUM RECEIVER FOR IMPULSIVE ATMOSPHERIC RADIO NOISE		
7.1	Introduction	125
7.2	Detection of known signals in noise	128
7.3	Receiver operating characteristic and error probability	136
7.4	Channel capacity	138
7.5	Conclusions	141
CHAPTER 8 : CONCLUSIONS		142
APPENDIX : PROBABILITY DENSITY FUNCTION OF THE PCC RECEIVER OUTPUT		148
REFERENCES		151
CURRICULUM VITAE		
LIST OF PUBLICATIONS BY THE AUTHOR		