

TABLE OF CONTENTS

1. INTRODUCTION	1
1.1. MOTIVATION	1
1.2. PROBLEM STATEMENT	1
1.3. RESEARCH QUESTIONS	2
1.4. HYPOTHESES	3
1.5. RESEARCH OBJECTIVES	3
1.5.1. GENERAL OBJECTIVE	3
1.5.2. SPECIFIC OBJECTIVES	3
1.6. CONTRIBUTIONS OF THIS WORK	4
1.7. PUBLICATIONS	5
1.8. OUTLINE OF THE THESIS	7
2. BACKGROUND.....	8
2.1. INCOHERENT SCATTER RADAR	8
2.2. ISR FACILITIES	9
2.3. ISR MEASUREMENTS.....	11
2.4. ISR ANALYSIS METHODS	13
2.5. RECEIVED POWER	14
2.6. PLASMA LINE	15
2.7. TEMPERATURE-ION COMPOSITION AMBIGUITY.....	17
3. METHODOLOGY	20
3.1. SIMULATION METHODS.....	20
3.1.1 IMPLEMENTATION OF THE INCOHERENT SCATTER RADAR MODEL	20
3.1.2. NOISE ADDITION SCHEME.....	20
3.1.3. PLASMA PARAMETERS ESTIMATION METHOD.....	22
3.1.4. NON-LINEAR LEAST SQUARES OPTIMIZATION ALGORITHM USED.....	25
3.1.5. ADDITION OF PLASMA LINE INFORMATION.....	26
3.1.6. MONTE CARLO SIMULATIONS OF PLASMA PARAMETERS.....	26
3.1.7. UNIFORMLY SELECTED INITIAL PARAMETERS.....	27
3.1.8. SIMULATION OF INACCURACY OF INITIAL PARAMETERS	28
3.1.9. SIMULATION OF UNCERTAINTY OF <i>A-PRIORI</i> KNOWN PARAMETERS	29
3.2. STATISTICAL ANALYSIS.....	30
3.2.1. DETERMINATION OF CONVERGENCE	30
3.2.2. DETERMINATION OF CORRECTNESS.....	32
3.2.3. CLUSTERING ALGORITHM.....	33
3.2.4. PROBABILITIES OF CONVERGENCE AND CORRECTNESS	35
4. DETERMINATION OF THE IMPACT OF THE INACCURACY ON THE INITIAL PARAMETERS.....	36
4.1. ACCURATE INITIAL GUESS	36
4.2 INCREASING THE UNCERTAINTY OF INITIAL PARAMETERS.....	38
4.3 PROPOSED ESTIMATION TECHNIQUE.....	40
5. ANALYSIS OF THE TEMPERATURE-ION COMPOSITION AMBIGUITY PROBLEM.....	41
5.1. AMBIGUOUS ION COMPOSITION ESTIMATE	41

5.2. UNCERTAINTY OF THE ION COMPOSITION ESTIMATE	42
5.3. PROBABILITY RESULTS OF PLASMA LINE INFORMATION ADDITION.....	44
5.4. RELATIONSHIPS BETWEEN ESTIMATION ERRORS OF PARAMETERS.....	48
5.4.1. ESTIMATED ERRORS OF FOUR PARAMETERS (N_e , T_e , T_i , AND p).....	49
5.4.2. ESTIMATED ERRORS OF THREE PARAMETERS (T_e , T_i , AND p) GIVEN A PRIORI N_e	50
5.4.3. ESTIMATED ERRORS OF TWO PARAMETERS (T_i AND p) GIVEN A PRIORI N_e AND T_e/T_i	51
5.4.4. ESTIMATED ERRORS OF TWO PARAMETERS (T_i AND p) GIVEN A PRIORI N_e AND T_e	52
5.4.5. VERIFICATION OF WALDTEUFEL ANALYTICAL FORMULATION.....	53
6. DETERMINATION OF THE MOST RELEVANT A-PRIORI KNOWN PARAMETERS	55
6.1. AMBIGUOUS ION COMPOSITION ESTIMATE	55
6.2. UNCERTAINTY OF THE ION COMPOSITION ESTIMATE	57
6.3. PROBABILITY RESULTS OF SINGLE PARAMETER ADDITION.....	58
6.4. RELATIONSHIPS BETWEEN ESTIMATION ERRORS OF PARAMETERS.....	60
6.4.1. ESTIMATED ERRORS OF FIVE PARAMETERS (N_e , T_e , T_i , V_i , p).....	61
6.4.2. ESTIMATED ERRORS OF FOUR PARAMETERS (N_e , T_e , T_i , AND p) GIVEN A PRIORI V_i	62
6.4.3. ESTIMATED ERRORS OF FOUR PARAMETERS (T_e , T_i , V_i , AND p) GIVEN A PRIORI N_e	63
6.4.4. ESTIMATED ERRORS OF FOUR PARAMETERS (N_e , T_i , V_i , AND p) GIVEN A PRIORI T_e/T_i	64
6.4.5. ESTIMATED ERRORS OF FOUR PARAMETERS (N_e , T_i , V_i , AND p) GIVEN A PRIORI T_e	65
6.4.6. ESTIMATED ERRORS OF FOUR PARAMETERS (N_e , T_e , V_i , AND p) GIVEN A PRIORI T_i	66
7. DETERMINATION OF THE IMPACT OF THE UNCERTAINTY OF A-PRIORI KNOWN PARAMETERS	67
7.1. PROBABILITY RESULTS OF PLASMA LINE INFORMATION ADDITION WITH UNCERTAINTY	67
7.2. USE OF <i>IN SITU</i> SENSORS.....	69
7.3. STATIONARITY OF UNAMBIGUOUS RADAR MEASUREMENTS	70
8. CONCLUSIONS.....	71
8.1. SUMMARY OF THE THESIS WORK	71
8.2. IMPROVEMENTS TO THE ISR TECHNIQUE	72
8.3. FUTURE WORK.....	73
GLOSSARY	74
BIBLIOGRAPHY	75
ANNEXES	84
ANNEX 1. THE INCOHERENT SCATTER SPECTRUM.....	84
ANNEX 2. STANDARD ISR ESTIMATION TECHNIQUE.....	91
ANNEX 3. THE LEVENBERG-MARQUARDT OPTIMIZATION ALGORITHM.....	93
ANNEX 4. THE EXPECTATION MAXIMIZATION ALGORITHM.....	98