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presented by

Gregory Brian Robinson

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EFFECTS OF RADIO FREQUENCY NOISE ON COMMUNICATION CAPABILITIES OF ULTRA-HIGH FREQUENCY PASSIVE TRANSPONDER

By

Gregory Brian Robinson

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Packaging

2010

Abstract

EFFECTS OF RADIO FREQUENCY NOISE ON COMMUNICATION CAPABILITIES OF ULTRA-HIGH FREQUENCY PASSIVE TRANSPONDER

By

Gregory Brian Robinson

The adoption of RFID in supply chain management provides complex issues to be overcome in order to function accordingly. These include people, objects, and atmospheric disturbances. Signal interference impacts essential components such as read range and rate of a functioning system.

This research examined radio frequency (RF) noise in three separate buildings. The objective was to determine whether or not RF noise could affect the functionality between a reader and transponder. If RF noise is found at a specific frequency range, (i.e., UHF 902 to 928 MHz in the USA) and combined with certain physical environmental conditions, then this noise can become an interfering factor with an RFID UHF system.

This study identified the importance of these components by; one, measuring ambient background noise; and two, introducing additional noise to the test location and whether they varied slightly or dramatically, based on findings from three different locations.

The research found different locations having diverse physical make-ups had different effects from both ambient and identified RF noise. Furthermore, the environment with each location played a key role in the amount of interactions resulting in desired communication paths and non-desired paths due to the presence of external RF noise.

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TABLE OF CONTENTS

LIST OF TABLES vii

LIST OF FIGURES xiii

CHAPTER 1: INTRODUCTION 1

CHAPTER 2: LITERATURE REVIEW 6

SECTION 2.1: RFID USES 7

SECTION 2.2: TRANSPONDER TYPES 9

Subsection 2.2.a: Active Transponders 9

Subsection 2.2.b: Passive Transponders 9

Subsection 2.2.c: Semi-Active Transponders 10

SECTION 2.3: COMMUNICATION ISSUES 10

Subsection 2.3.a: Air Interface 10

Subsection 2.3.b: Transmitting Radio Frequency Signals 11

Subsection 2.3.c: High Frequency (HF) 12

Subsection 2.3.d: Ultra-High Frequency (UHF) 13

Subsection 2.3.e: Coupling Communication 14

Subsection 2.3.f: Reader-to-Tag Communication 15

Subsection 2.3.g: Tag-to-Reader Communication 16

SECTION 2.4: NOISE AND INTERFERENCE 17

Subsection 2.4.a: Radio Frequency Noise 17

Subsection 2.4.b: Destructive and Constructive Interference 19

Subsection 2.4.c: Presence of Radio Frequency Noise In The Environment 20

Subsection 2.4.d: Multiple Tag-to-Reader Interference 21

Subsection 2.4.e: Multiple Reader-to-Tag Interference 22

Subsection 2.4.f: Reader-to-Reader Interference 22

Subsection 2.4.g: Jamming Signals 24

SECTION 2.5: MEASURING RADIO FREQUENCY NOISE 24

Subsection 2.5.a :Radio Frequency Site Audit 24

Subsection 2.5.b: Voyantic Measurement Unit 27

Subsection 2.5.c: Interference Feature 27

Subsection 2.5.d: Backscatter Feature 28

Subsection 2.5.e: Threshold Feature 29

SECTION 2.6: SENSITIVITY UNITS 30

Subsection 2.6.a: Transmit Power 30

Subsection 2.6.b: Electric Field Strength 31

Subsection 2.6.c: Power on Tag Forward 31

Subsection 2.6.d: Theoretical Read Range Forward 32

SECTION 2.7: BACKSCATTER UNITS 32

Subsection 2.7.a: Backscatter Power 32

Subsection 2.7.b: Backscatter Signal Phase 33

Subsection 2.7.c: Differential Radar Cross-Section (Delta RCS) 33

Subsection 2.7.d: Power on Tag Reverse 33

Subsection 2.7.e: Theoretical Read Range Reverse 34

CHAPTER 3: METHODOLOGY **35**

SECTION 3.1: EQUIPMENT **36**
Subsection 3.1.a: Voyantic UHF RFID Measurement Unit 37
Subsection 3.1.b: Impinj Speedway Reader 38
Subsection 3.1.c: Statistical Counseling Center's Data Analysis Model 38

SECTION 3.2: ENVIRONMENTS/LOCATIONS **39**
Subsection 3.2.a: Location 1 39
Subsection 3.2.b: Location 2 40
Subsection 3.2.c: Location 3 41

SECTION 3.3: TESTING PROCEDURE **42**
Subsection 3.3.a: Set Up of Voyantic Measurement Unit 42
Subsection 3.3.b: Interference Feature 42
Subsection 3.3.c: Threshold Feature 43
Subsection 3.3.d: Backscatter Feature 43
Subsection 3.3.e: Set Up of Impinj UHF Reader (Identifiable RF Noise Source) 45
Subsection 3.3.f: Data Collection 45

SECTION 3.4: DATA ANALYSIS PROCEDURE **46**

CHAPTER 4: RESULTS **48**

SECTION 4.1: STATISTICAL ANALYSIS **49**
Subsection 4.1.a: Statistical Analysis. 49
Subsection 4.1.b: Check Statistical Assumptions 50
Subsection 4.1.c: Select Variance Co-valence Matrix for Repeated Measures 52
Subsection 4.1.d: Performing F-test for Significance 53
Subsection 4.1.e: Fit Final Model 54
Subsection 4.1.f: Plot Results 55

SECTION 4.2: THEORETICAL AND ACTUAL CONNECTIONS BETWEEN COMMUNICATION CAPABILITIES **56**

SECTION 4.3: SCENARIO 1 ..... **60**

SECTION 4.5: SCENARIO 2 ..... **79**

SECTION 4.6: NULL HYPOTHESIS FINDINGS **95**

CHAPTER 5: CONCLUSIONS **99**

SECTION 6.1: LOCATION 1 ..... **101**

SECTION 6.2: LOCATION 2 ..... **103**

SECTION 6.3: LOCATION 3 ..... **104**

SECTION 6.4: OVERALL CONCLUSIONS **104**

CHAPTER 6: FUTURE WORK **107**

APPENDIX A: Interference Graphs – Received Power (dBm) vs. Frequency Sweep (800 to 1,000 MHz) for All Locations from Tagformance **111**

APPENDIX B: Testing Layouts and Set up **118**

APPENDIX C: Mapped Locations of Nearby Cell Towers to Each Location **122**

APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D

APPENDIX E

APPENDIX F

APPENDIX D: Scenario 1 Tables – Presence of Ambient Radio Frequency Noise **125**

APPENDIX E: Scenario 2 Tables – Combination of Ambient and Identified RF Noise ... **162**

APPENDIX F: Location 1 – Michigan State University Auto-ID Research and Testing Center Office Area Tables and Figures **199**

APPENDIX G: Location 2 – Michigan State University School of Packaging Machine Lab Tables and Figures **227**

APPENDIX H: Location 3 – Michigan State University Engineering Building Basement Tables and Figures **255**

REFERENCES **283**

List of Tables

Table 1: UHF Frequencies throughout the World (Sanghera, 2007) 13

Table 2: Example of Excel data formatted to use in Statistical Analysis Software (SAS) 46

Table 3: Selecting the Most Appropriate Variance-Covalence Matrix 53

Table 4: Example of F-test Results 53

Table 5: Transmit Power (dBm) Scenario 1 Estimations 62

Table 6: Transmit Power (dBm) Scenario 1 Comparisons 64

Table 7: Scenario 1 – Sensitivity Unit Performance Summary at 924 MHz 76

Table 8: Scenario 1 – Backscatter Unit Performance Summary at 908, 912, 914, and 916 MHz 76

Table 9: Ideal Outcome Based on Causal Relationship for Sensitivity Units at 924 MHz 77

Table 10: Ideal Outcome Based on Causal Relationship for Backscatter Units at 908, 912, 914, and 916 MHz 77

Table 11: Scenario 1 – Number of Differences and Similarities for Operating Frequency Range 78

Table 12: Transmit Power (dBm) Scenario 2 Estimations 81

Table 13: Transmit Power (dBm) Scenario 2 Comparisons 83

Table 14: Scenario 2 – Sensitivity Unit Performance Summary at 906, 908, 922, and 924 MHz 94

Table 15: Scenario 2 – Backscatter Unit Performance Summary at 900 and 902 MHz 94

Table 16: Scenario 2 – Number of Differences and Similarities for Operating Frequency Range 95

Table 17: Ideal Outcome Based on Causal Relationship for Sensitivity Units at 906, 908, 922, and 924 MHz 96

Table 19. de
20 and 202
Table 19. Ele
Table 20. Ele
Table 21. Ac
Table 22. Ad
Table 23. Th
Table 24. T
Table 25. A
Table 26. A
Table 27. A
Table 28. A
Table 29. A
Table 30. A
Table 31. A
Table 32. A
Table 33. A
Table 34. A
Table 35. A
Table 36. A
Table 37. A

Table 18: Ideal Outcome Based on Causal Relationship for Backscatter Units at 900 and 902 MHz 96

Table 19: Electric Field Strength (V/m) Scenario 1 Estimations 130

Table 20: Electric Field Strength (V/m) Scenario 1 Comparisons 132

Table 21: Absolute Power on Tag Forward (dBm) Scenario 1 Estimations 134

Table 22: Absolute Power on Tag Forward (dBm) Scenario 1 Comparisons ... 136

Table 23: Theoretical Read Range Forward (m) Scenario 1 Estimations 138

Table 24: Theoretical Read Range Forward (m) Scenario 1 Comparisons 140

Table 25: Absolute Backscatter Power (dBm) Scenario 1 Estimations 142

Table 26: Absolute Backscatter Power (dBm) Scenario 1 Comparisons 144

Table 27: Absolute Received Power (dBm) Scenario 1 Estimations 146

Table 28: Absolute Received Power (dBm) Scenario 1 Comparisons 148

Table 29: Absolute Delta RCS (dBsqm) Scenario 1 Estimations 150

Table 30: Absolute Delta RCS (dBsqm) Scenario 1 Comparisons 152

Table 31: Absolute Power on Tag Reverse (dBm) Scenario 1 Estimations 163

Table 32: Absolute Power on Tag Reverse (dBm) Scenario 1 Comparisons ... 165

Table 33: Theoretical Read Range Reverse (m) Scenario 1 Estimations 158

Table 34: Theoretical Read Range Reverse (m) Scenario 1 Comparisons 160

Table 35: Electric Field Strength (V/m) Scenario 2 Estimations 167

Table 36: Electric Field Strength (V/m) Scenario 2 Comparisons 169

Table 37: Absolute Power on Tag Forward (dBm) Scenario 2 Estimations 171

Table 38: Absolute Power on Tag Forward (dBm) Scenario 2 Comparisons ... 173

Table 39: Theoretical Read Range Forward (m) Scenario 2 Estimations 175

Table 40: Theoretical Read Range Forward (m) Scenario 2 Comparisons 177

Table 41: Absolute Backscatter Power (dBm) Scenario 2 Estimations 179

Table 42: Absolute Backscatter Power (dBm) Scenario 2 Comparisons 181

Table 43: Absolute Received Power (dBm) Scenario 2 Estimations 183

Table 44: Absolute Received Power (dBm) Scenario 2 Comparisons 185

Table 45: Absolute Delta RCS (dBsqm) Scenario 2 Estimations 187

Table 46: Absolute Delta RCS (dBsqm) Scenario 2 Comparisons 189

Table 47: Absolute Power on Tag Reverse (dBm) Scenario 2 Estimations 191

Table 48: Absolute Power on Tag Reverse (dBm) Scenario 2 Comparisons ... 193

Table 49: Theoretical Read Range Reverse (m) Scenario 2 Estimations 195

Table 50: Theoretical Read Range Reverse (m) Scenario 2 Comparisons 197

Table 51: Transmit Power (dBm) Location 1 Estimations 201

Table 52: Transmit Power (dBm) Location 1 Comparisons 202

Table 53: Electric Field Strength (V/m) Location 1 Estimations 204

Table 54: Electric Field Strength (V/m) Location 1 Comparisons 205

Table 55: Absolute Power on Tag Forward (dBm) Location 1 Estimations 207

Table 56: Absolute Power on Tag Forward (dBm) Location 1 Comparisons 208

Table 57: Theoretical Read Range Forward (m) Location 1 Estimations 210

Table 58: Theoretical Read Range Forward (m) Location 1 Comparisons 211

Table 59: Absolute Backscatter Power (dBm) Location 1 Estimations 213

Table 60: Absolute Backscatter Power (dBm) Location 1 Comparisons..... 214

Table 61: Absolute Received Power (dBm) Location 1 Estimations 216

Table 62: Absolute Received Power (dBm) Location 1 Comparisons 217

Table 63: Absolute Delta RCS (dBsqm) Location 1 Estimations 219

Table 64: Absolute Delta RCS (dBsqm) Location 1 Comparisons..... 220

Table 65: Absolute Power on Tag Reverse (dBm) Location 1 Estimations 222

Table 66: Absolute Power on Tag Reverse (dBm) Location 1 Comparisons.... 223

Table 67: Theoretical Read Range Reverse (m) Location 1 Estimations 225

Table 68: Theoretical Read Range Reverse (m) Location 1 Comparisons 226

Table 69: Transmit Power (dBm) Location 2 Estimations..... 229

Table 70: Transmit Power (dBm) Location 2 Comparisons 230

Table 71: Electric Field Strength (V/m) Location 2 Estimations..... 232

Table 72: Electric Field Strength (V/m) Location 2 Comparisons 233

Table 73: Absolute Power on Tag Forward (dBm) Location 2 Estimations 235

Table 74: Absolute Power on Tag Forward (dBm) Location 2 Comparisons.... 236

Table 75: Theoretical Read Range Forward (m) Location 2 Estimations 238

Table 76: Theoretical Read Range Forward (m) Location 2 Comparisons..... 239

Table 77: Absolute Backscatter Power (dBm) Location 2 Estimations 241

Table 78: Absolute Backscatter Power (dBm) Location 2 Comparisons 242

Table 79: Absolute Received Power (dBm) Location 2 Estimations 244

Table 80: Absolute Received Power (dBm) Location 2 Comparisons 245

Table 81: Absolute Delta RCS (dBsqm) Location 2 Estimations 247

Table 82: Absolute Delta RCS (dBsqm) Location 2 Comparisons 248

Table 83: Absolute Power on Tag Reverse (dBm) Location 2 Estimations 250

Table 84: Absolute Power on Tag Reverse (dBm) Location 2 Comparisons 251

Table 85: Theoretical Read Range Reverse (m) Location 2 Estimations 253

Table 86: Theoretical Read Range Reverse (m) Location 2 Comparisons 254

Table 87: Transmit Power (dBm) Location 3 Estimations 257

Table 88: Transmit Power (dBm) Location 3 Comparisons 258

Table 89: Electric Field Strength (V/m) Location 3 Estimations 260

Table 90: Electric Field Strength (V/m) Location 3 Comparisons 261

Table 91: Absolute Power on Tag Forward (dBm) Location 3 Estimations 263

Table 92: Absolute Power on Tag Forward (dBm) Location 3 Comparisons 264

Table 93: Theoretical Read Range Forward (m) Location 3 Estimations 266

Table 94: Theoretical Read Range Forward (m) Location 3 Comparisons 267

Table 95: Absolute Backscatter Power (dBm) Location 3 Estimations 269

Table 96: Absolute Backscatter Power (dBm) Location 3 Comparisons 270

Table 97: Absolute Received Power (dBm) Location 3 Estimations 272

Table 98: Absolute Received Power (dBm) Location 3 Comparisons 273

Table 99: Absolute Delta RCS (dBsqm) Location 3 Estimations 275

Table 100: Absolute Delta RCS (dBsqm) Location 3 Comparisons..... 276

Table 101: Absolute Power on Tag Reverse (dBm) Location 3 Estimations 276

Table 102: Absolute Power on Tag Reverse (dBm) Location 3 Comparisons.. 276

Table 103: Theoretical Read Range Reverse (m) Location 3 Estimations 276

Table 104: Theoretical Read Range Reverse (m) Location 3 Comparisons..... 276

List of Figures

Figure 1: Diagram of Backscatter Signal Transmission between a Reader and Transponder (Mayordomo, Berenguer, Garcia-Alonso, Fernandez, & Gutierrez, 2009). 15

Figure 2: An example of The Voyantic Interference Feature. 28

Figure 3: An example of The Voyantic Backscatter Feature with 30 Trials..... 29

Figure 4: An example of The Voyantic Threshold Feature with 30 Trials 30

Figure 5: The Voyantic Tagformance Kit Components. 37

Figure 6: Location 1 – The Michigan State University Auto-ID research and Testing Center (MSU AIRTC) 30

Figure 7: Location 2 – The Packaging Building Machine Lab, Front View..... 40

Figure 8: Location 2 – The Packaging Building Machine Lab, Right Side View.. 40

Figure 9: Location 3 – The Engineering Basement, Front/Left View..... 41

Figure 10: Location 3 – The Engineering Basement, Rear View 41

Figure 11: Example of Data Distribution 51

Figure 12: Example Box Plots Comparing Locations..... 52

Figure 13: Scenario 1 – Transmit Power (dBm) vs. Frequency (MHz) 61

Figure 14: Scenario 1 – Electric Field Strength (V/m) vs. Frequency (MHz) 66

Figure 15: Scenario 1 – Absolute Power on Tag Forward (dBm) vs. Frequency (MHz)..... 67

Figure 16: Scenario 1 – Theoretical Read Range Forward (m) vs. Frequency (MHz)..... 68

Figure 17: Scenario 1 – Absolute Backscatter Power (dBm) vs. Frequency (MHz) 69

Figure 18: Scenario 1 – Absolute Received Power (dBm) vs. Frequency (MHz) 70

Figure 19: Scenario 1 – Absolute Delta RCS (dBsqm) vs. Frequency (MHz)..... 71

Figure 20: Scenario 1 – Absolute Power on Tag Reverse (dBm) vs. Frequency (MHz)..... 72

Figure 21: Scenario 1 – Theoretical Read Range Reverse (m) vs. Frequency (MHz)..... 73

Figure 22: Scenario 2 – Transmit Power (dBm) vs Frequency (MHz). 80

Figure 23: Scenario 2 - Electric Field Strength (V/m) vs. Frequency (MHz) 85

Figure 24: Scenario 2 - Absolute Power on Tag Forward (dBm) vs. Frequency (MHz)..... 86

Figure 25: Scenario 2 - Theoretical Read Range Forward (m) vs. Frequency (MHz)..... 87

Figure 26: Scenario 2 - Absolute Backscatter Power (dBm) vs. Frequency (MHz) 88

Figure 27: Scenario 2 - Absolute Received Power (dBm) vs. Frequency (MHz) 89

Figure 28: Scenario 2 - Absolute Delta RCS (dBsqm) vs. Frequency (MHz)..... 90

Figure 29: Scenario 2 - Absolute Power on Tag Reverse (dBm) vs. Frequency (MHz)..... 91

Figure 30: Scenario 2 - Theoretical Read Range Reverse (m) vs. Frequency (MHz)..... 92

Figure 31: Scenario 1 - Location 1 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)..... 112

Figure 32: Scenario 2 - Location 1 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)..... 113

Figure 33: Scenario 1 - Location 2 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)..... 114

Figure 34: Scenario 2 - Location 2 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)..... 115

Figure 35: Scenario 1 - Location 3 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)..... 116

Figure 36: Scenario 2 - Location 3 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)..... 117

Figure 37: Location 1 - Michigan State University Auto-ID Research and Testing Center..... 119

Figure 38: Location 2 - School of Packaging Machine Lab 120

Figure 39: Location 3 - Engineering Building Basement 121

Figure 40: Location of Cell Towers Around Location 1 123

Figure 41: Location of Cell Towers Around Locations 1 and 2 124

Figure 42: Location 1 - Transmit Power (dBm) vs. Frequency (MHz) 200

Figure 43: Location 1 - Electric Field Strength (V/m) vs. Frequency (MHz) 203

Figure 44: Location 1 - Absolute Power on Tag Forward (dBm) vs. Frequency (MHz) 206

Figure 45: Location 1 - Theoretical Read Range Forward (m) vs. Frequency (MHz) 209

Figure 46: Location 1 - Absolute Backscatter Power (dBm) vs. Frequency (MHz) 212

Figure 47: Location 1 - Absolute Received Power (dBm) vs. Frequency (MHz) 215

Figure 48: Location 1 - Absolute Delta RCS (dBsqm) vs. Frequency 218

Figure 49: Location 1 - Absolute Power on Tag Reverse (dBm) vs. Frequency (MHz) 221

Figure 50: Location 1 - Theoretical Read Range Reverse (m) vs. Frequency (MHz) 224

Figure 51: Location 2 - Transmit Power (dBm) vs. Frequency (MHz) 228

Figure 52: Location 2 - Electric Field Strength (V/m) vs. Frequency (MHz) 231

Figure 53: Location 2 - Absolute Power on Tag Forward (dBm) vs. Frequency (MHz) 234

Figure 54: Location 2 - Theoretical Read Range Forward (m) vs. Frequency (MHz) 237

Figure 55: Location 2 - Absolute Backscatter Power (dBm) vs. Frequency (MHz) 240

Figure 56: Location 2 - Absolute Received Power (dBm) vs. Frequency (MHz) 243

Figure 57: Location 2 - Absolute Delta RCS (dBsqm) vs. Frequency (MHz) 246

Figure 58: Location 2 - Absolute Power on Tag Reverse (dBm) vs. Frequency (MHz) 249

Figure 59: Location 2 - Theoretical Read Range Reverse (m) vs. Frequency (MHz) 252

Figure 60: Location 3 - Transmit Power (dBm) vs. Frequency (MHz) 256

Figure 61: Location 3 - Electric Field Strength (V/m) vs. Frequency (MHz) 259

Figure 62: Location 3 - Absolute Power on Tag Forward (dBm) vs. Frequency (MHz) 262

Figure 63: Location 3 - Theoretical Read Range Forward (m) vs. Frequency (MHz) 265

Figure 64: Location 3 - Absolute Backscatter Power (dBm) vs. Frequency (MHz) 268

Figure 65: Location 3 - Absolute Received Power (dBm) vs. Frequency (MHz) 271

Figure 66: Location 3 - Absolute Delta RCS (dBsqm) vs. Frequency (MHz) 274

Figure 67: Location 3 - Absolute Power on Tag Reverse (dBm) vs. Frequency (MHz) 277

Figure 68: Location 3 – Theoretical Read Range Reverse (m) vs. Frequency (MHz) 280

Chapter 1: Introduction

This chapter focuses on a growing topic of interest concerning transponder performance in UHF RFID systems in the presence of radio frequency noise. A brief discussion on influential people and special equipment will set up further discussion on how testing began. This chapter discusses the lack of publications surrounding noise and interference, why radio frequency noise is important, how transponder performance is affected by noise, and what hypotheses were tested in order to determine significance differences between communication capabilities.

This research topic began by measuring RF power levels of an interrogation zone at various geological areas within the Michigan State University (MSU) Auto-Identification Research and Testing Center (AIRTC). Coordinated by Robert H. Clarke, Ph.D, the MSU AIRTC researches topics related to auto-identification including process control, inventory management, barcoding, RFID and other applications. Power measurement testing eventually led to interest in spectrum analyzers for more accurate measurements than what was used in previous tests.

Continued interest in the topic of RF power led to an opportunity from a company with a new measurement device called the Voyantic Measurement Unit. This device was designed by Voyantic Ltd Staff, led by CEO Jukka Voutilainen and CTO Jesse Tuominen. It was borrowed by the AIRTC as part of a starting kit trial. This device provided an opportunity to further test RF power levels but also provided an Interference Feature that monitored ambient and identified RF signals within the 800 to1,000 Megahertz (MHz) band.

But how does power measurement relate to RFID application and the impact of noise in and around packaging? There has been an increasing interest and usage of radio frequency identification (RFID) technology in supply chain management.

Radio frequency (RF) noise can be generated by an unintended source, often a device that normally does not emitted a signal at all (Thomas, & McLain, 2009). There has been a lack in open discussion about RF noise in the RFID

world. The difference between noise and interference is often blurred when discussing RFID. The term "noise" can be defined as an unwanted electrical wave or energy that is present in a signal/location (Sanghera, 2007). Some literature refers to the term "interference" but not many discuss the topic in great detail as it relates to RFID technology. Interference can be defined as the superposition of two or more waves, which results in the creation of a new wave pattern (Brown, Patadia, Dua, & Meyers, 2007). RF interference has been a known source of interference for electronic devices for years (Hallas, 2009). The two terms are treated as meaning the same meaning; however, this is not always accurate for many RFID applications.

RFID systems can be prone to complications just like other technologies. Complications can occur for a number of reasons such as installation issues, environmental effects (i.e., metal or liquid-based objects), RF noise, and size of interrogation zone. Any of these can cause serious performance issues for the system. Thus, every RFID application requires a customized setup based on the number of potential complications that exist in a location. Implementation is critical to the accuracy and efficiency of an ultra-high frequency (UHF) RFID system. A pre-installation site survey can help identify some potential complications with the RFID system (Sweeney, 2007). This site analysis should be conducted at locations such as packaging facilities, office buildings, and research laboratories.

RF noise can be the cause of a number of different effects on the system's operation capabilities (transmitting, receiving, and energy gathering). Working

under the assumption that RF noise will likely be present in most environments, concern for how it could affect the communication capabilities of that system is justifiable. When the term interference is used during troubleshooting in a manufacturing plant, for example, it normally refers to UHF RF waves experiencing difficulties with metals or liquid-based substances somehow obstructing the signal's path between the reader and transponder. Seldom do people refer to the possibility that the system's inability to work appropriately could be due to the amount of RF noise within the operating frequency.

The main objective of this study is to provide quantitative information on the influence of RF noise upon the operation of an RFID system. Communication capabilities in general consist of transmitting and receiving signals between the reader and transponder. RF noise is not easily detected and can be virtually impossible to locate if knowledge and appropriate equipment are lacking. When RF noise overlaps with the operating frequency of the system, it may disrupt the consistency/frequency rate of detectable backscatter response signals from the transponder, or interfere with the transmitted signals from the reader before they reach the transponder. Even in a situation where RF noise is present, there may not be an interfering effect on system operation. Since RF noise consists of a mixture of different radio frequency waves at various frequencies, it is possible that the degree of overlap between them and the operating frequencies (i.e. UHF 902 – 928 MHz) is negligible.

This study is to identify and quantify the effects of RF noise on a UHF passive transponder installed in different environments. To that end, two

scenarios will be used; one in which only ambient RF noise is present and one in which the same ambient RF noise is combined with noise produced by an identifiable/known source. In order to test and evaluate these objectives, the following null hypotheses were developed.

Hypotheses

- **Hypothesis 1**: The presence of ambient radio frequency noise within the operating frequency range of an ultra-high frequency radio frequency identification system will NOT have an effect on the communication capability of a passive transponder.
- **Hypothesis 2**: Introducing additional radio frequency noise from an identified source, within the focused operating frequency range of 902 to 928 MHz, for a given location will NOT have an effect on the communication capabilities of a passive transponder.
- **Hypothesis 3**: The surrounding environment in which a radio frequency identification system is implemented will NOT have an effect on the communication capabilities of a passive transponder.

Chapter 2: Literature Review

This chapter will set the stage for understanding the importance of RF noise. This section provides detailed background information on topics ranging from transponder types to measuring RF noise. The different communication capabilities will be defined and discussed in engineering and conceptual aspects. RF noise can play a key role in an RFID system operation. Other related concepts include transmitting and receiving, communication types, interference, and measuring performance.

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RFID systems consist of a transponder, reader antenna(e), reader, and a computer (middleware). Data is exchanged between transponder and reader through wireless connections operating within the same frequency (Xiao, Yu, Wu, Ni, Janecek, & Nordstad, 2007). These components are utilized to create unique systems for specific applications.

RFID Uses

RFID technology has been around for many years, however, new application and innovations have made it a top 10 innovative technology in the past 25 years (Top 25: Innovations, 2005). Businesses looking for cost savings and mandates declared by Wal-Mart and Department of Defense (DoD) pushed growth in RFID. It continues to develop as a technology with increasing interest in supply chain management systems. This interest has also fueled the growth of research and testing center to develop standards and practices to produce application solutions, however, there are few plug and play solutions that apply to all invested parties (Singh, McCartney, Singh, & Clarke, 2007).

RFID has been accepted in three main areas; transportation and distribution, manufacturing, and security (Singh, McCartney, Singh, & Clarke, 2007). Other areas of interest include animal tagging, waste management attendance, tracking, and road tolls. Some areas of application are not as dependable as some expect them to be. Accidental shipping, mislabeling, and loss/theft still occur (Singh, McCartney, Singh, & Clarke, 2007).

A German retailing chain by the name of Metro opened a "store of the future" that implemented RFID tags in their inventory management system to create a store entirely dependent on RFID-tagged shelf items. These smart shelves were designed to provide information on product quantities, create self-servicing information kiosks and Smart Scales. The main focus of this trial run was to display how to cut expenses with the technology (Kanellos, 2003). However, trials such as this created excitement about the potential of this technology thus, increased the hype around it.

Over-the counter (OTC) medication labels have been equipped with external tags behind them. This is used in inventory management and security from theft/counterfeiting. Similar ideas have been applied to OTC before "smart labels". Electronic article surveillance (EAS) tags are a subdivision of RFID technology, and are commonly used as an anti-theft device (Bix, Sansgiry, Clarke, Cardoso, & Shringarpure, 2004). These tags are applied directly to the outside of packages. This can cause problems with covering essential product information contained on the labeling of the package. Studies conducted on this issue conclude that these external tags do obstruct essential information required by law (Bix, Sansgiry, Clarke, Cardoso, & Shringarpure, 2004). Therefore, RFID tags that are placed behind a paper label helps eliminate that issue.

To understand more about the operation of an RFID system, it is necessary to understand the components that can be affected by RF noise.

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Transponder Types

Three basic types of transponders are commonly used with RFID systems: passive, semi-passive, and active. Each type of transponder can be used for a number of applications.

Active Transponders

Active transponders are equipped a battery power source for initiating communication by transmitting their own signal. The addition of this battery source to the transponder eliminates the need for a wakeup signal from the reader (Sanghera, 2007). Active transponders depend on the battery to function. The life span of the battery is will vary depending on the usage of the transponder. The battery allows for the transmitted signal from the transponder to travel longer distance at high signal strength. This internal power source allows the transponder to operate in two different ways: it can either stay actively transmitting its signal all the time, or wake up only when it receives a signal from the reader. Active transponders have the ability to transmit a signal over a distance of 100 feet (Garfinkel & Rosenberg, 2006). The memory capacity of this type is generally larger than that of semi-passive and passive types due to their larger overall size (Sanghera, 2007).

Passive Transponders

A passive transponder does not have a battery power source, and, thus, relies on the power from the reader to activate the chip (Weisman, 2002). This provides an advantage in terms of the lifespan of this transponder compared to

an active type. Passive transponders have low data throughput and require energy from the reader to function (Weisman, 2002). It must be in the interrogation zone of the reader in order to operate, limiting the read range of the transponder compared to the longer range of an active type. Depending on the size of the chip, the memory capacity varies from 1 bit to several kilobytes (Sanghera, 2007).

Semi-passive Transponders

Semi-passive transponders contain attributes of both active and passive transponders. They contain their own battery source similar to active transponders, however, this power source is not used to initiate communication, and it is only used to operate the circuitry. The transponder still needs to gather adequate power from the reader in order to communicate to the reader. The advance for semi-passive types is a longer read distance than passive types because of the battery. Operation is dependent on battery life. The lifespan of this type is intermediate between that of passive and active transponders (Sanghera, 2007).

Communication Issues

Air Interface

Specific parameters for air interface communication have been set according to the International Organization for Standardization (ISO) 18000-6 for the 860 – 980 MHz frequency range. This ISO standard defines common terms and provides technical specifications to promote compatibility among RFID

equipment. Communication between the reader and transponder is based on modulation. Carrier/reader modulation is done by data transmission in pulses at different time intervals. The time between two intervals results in successful delivery of data. The reader uses an "interrogator talks first" method, which means it must attempt communication with the transponder first. The transponder must receive a decodable command from the reader before transmitting a response. Tag modulation occurs when the transponder switches between one of several states. The 'space state' is considered the normal condition, with the transponder being energized and ready to receive and decode data. The 'mark state' is a stand-by alternative created by switching antenna configuration. The more antennae used in configuring a system, the more channels of communication are needed to avoid interfering with each other (ISO, 2004).

Transmitting Radio Frequency Signals

When dealing with passive transponders, the transmission of RF signals/power becomes essential to the operation of the RFID system. RFID systems function by sending and receiving pulses from an antenna. This pulse is then transformed in to energy that is used to activate a transponder on an object. The transponder sends back a signal that is the reciprocal of the RF pulse received (Shirokov, 2009). RF power in any given environment is produced by a signal at a RF wave pitch ranging from 3 Hertz (Hz) to 300 Gigahertz (GHz). The transmission of outside signals can prevent the passive transponder from gathering enough signal power to generate a response (Sweeney, 2007). Broadcasting a transmission through airspace allows that signal to be transmitted

a certain distance from the source of the transmission. The transponder is can be limited outside factors such as the environment (Mayordomo, Ubarretxena, Valderas, Berenguer, & Gutierrez, 2007). Certain transponder types rely heavily on the presence of space to function properly. The term "free air" refers to space that is free of RF inhibitors such as RF-reflecting and -absorbing materials.

High Frequency (HF)

RFID operation signals can occupy a large range of different wave bands within the RF spectrum. The frequency band that a transponder requires for communication is referred to as the operating frequency (Glover & Bhatt, 2006). In the US, the two frequencies that have sparked the most interest in supply chains are high frequency and ultra-high frequency (UHF) wave bands. The HF band ranges from 3 to 30 Megahertz (MHz), with most RFID systems in this frequency band operating at 13.56 MHz. This frequency is available worldwide. The energy waves that are generated within the HF range can only maintain that frequency, at a specific concentration, to about a meter away from the signal source. The HF wavelength range from 10 meters (m) – 100 m provides an advantage because the waves are able to penetrate certain materials. Transponders operating in this frequency range have generated much interest for item-level tagging (Sanghera, 2007). HF transponders are suitable for limited read range applications.

Ultra High Frequency (UHF)

Radio energy is identified and described by the frequency and strength/power of the oscillation (Garfinkel, & Rosenberg, 2006).The UHF band ranges from 300 MHz to 3 GHz, but the specific frequency band allocated to RFID systems varies in different regions of the world (Table 1). This makes it difficult for UHF systems to become universally adopted in global supply chains worldwide.

Table 1: UHF Frequencies throughout the World (Sanghera, 2007)

Country	Frequency Band (MHz)	Maximum Watts Allowed
United States	902-928	4
Australia	918-926	1
Europe	865-868	2
Hong Kong	865-868	2
	920-925	4
Japan	952-954	4

UHF has the ability to broadcast electromagnetic (EM) waves over a much greater distance than HF. The UHF wavelengths range from 10 centimeters (cm) to 1 m, which provides the ability for these waves to travel farther without decaying, resulting in greater read ranges. However, it also limits the ability of these waves to penetrate materials such as metals and water-containing products (Sanghera, 2007). The long read range of UHF systems appeals to pallet-level and case-level tagging (Clarke, Tazelaar, Twede, & Boyer, 2006).

Coupling Communication

Passive transponders generally use one of two communication methods: inductive coupling and backscatter coupling. The term coupling refers to the transfer of energy from one source to another. Passive transponders use this coupling to gather power and transfer data.

Inductive coupling functions by generating a magnetic field, which limits the broadcasting range to close proximity to the reader (Weisman, 2002). Inductive coupling can operate using either a close coupling or a remote coupling. The difference between the two modes of operation is the distance the magnetic field can reach. Close coupling is limited to 1 cm in read range, whereas remote coupling has a range between 1 cm and 1 m. Inductive coupling is the method of communication usually used for applications such as low frequency and high frequency passive transponders (Brown, Patadia, Dua, & Meyers, 2007). Unlike inductive coupling, backscatter coupling as shown in Figure 1 focuses on the generation of an EM field that can be used to carry signals from the reader to the transponder at a much farther distance.

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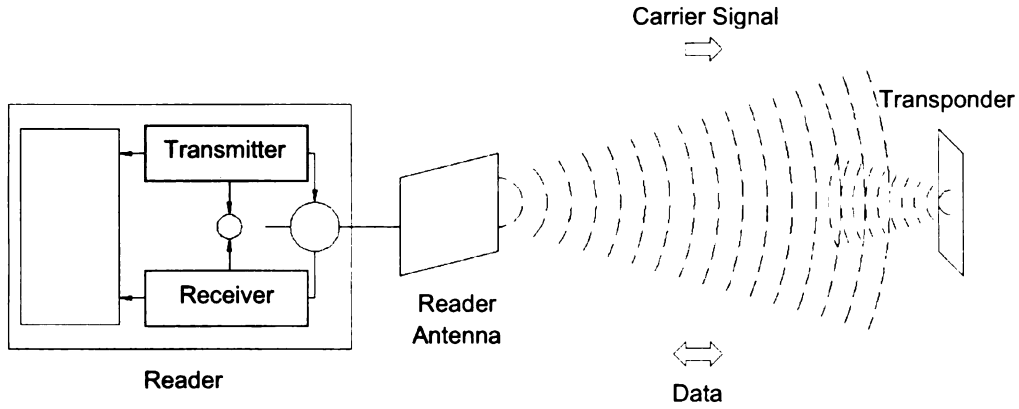

Figure 1: Diagram of Backscatter Signal Transmission between a Reader and Transponder (Mayordomo, Berenguer, Garcia-Alonso, Fernandez, & Gutierrez, 2009).

Both communication methods transmit signals through air space; however, this is more critical for backscatter coupling. The read field is generated by radiating EM waves from the reader's antenna; the direction and reach of this field creates the interrogation zone. This field contains energy and data from the reader that can be detected by a transponder. The signal is reflected back in the form of a backscatter signal when the EM field encounters a signal with at least half its own wavelength. This interaction is displayed by the carrier and response signals in Figure 1. The efficiency at which the transponder is able to convert the field's energy and signal to a response is determined by the response (Brown, Patadia, Dua, & Meyers, 2007).

Reader-to-Tag Communication

The interrogation zone in which the transponder is located provides an uplink communication system for the reader to deliver a decoded signal to the transponder. The communication process occurs when the reader's antenna

emits an electric field that contains a decoded RF signal, which creates an interrogation zone. The EM field is propagated by the transmitter inside the antenna performing multiple reflections and diffractions depending on the objects present in the environment (Sweeney, 2007; Shameli, et al, 2008). The interrogation zone is capable of generating energy that a passive transponder can gather to activate its integrated circuit (IC).

Tag-to-Reader Communication

A passive transponder needs to receive sufficient RF energy from a reader/interrogation zone in order to respond. This produces a reverse link communication system that decodes and replies to the reader's signal. In the case of a passive UHF transponder, communication was centered on modulated backscattered signals (McCarthy, Ayalew, Bulter, McDonnell, & Ward, 2009). Once the transponder is activated, it responds to the reader's transmission using backscatter coupling. For the passive transponder to respond, a specific threshold of energy must be collected through its antenna. Once this energy threshold is met, the transponder's IC can initiate a response by sending a decoded signal back to the reader (Lin, Lin, & Yuan, 2009). After a response signal is emitted from the transponder, the energy level of its IC will fall below the threshold for further response. In order to send out another response signal, the energy level needs to be replenished to the activation level. Generally, as long as the transponder is in the interrogation zone and is receiving an adequate amount of energy, the response signal can seem to occur continuously. In general, accurate transponder read ranges are measured within controlled environment to

ensure purity (Rao, Nikitin, & Lam, 2005). However, even with its much smaller size and energy threshold, the response communication signal is still susceptible to interference. Similar to reader-to-tag communication, absorption, reflection and refraction can also affect the response signal (Shameli, et al, 2008).

Noise and Interference

Radio Frequency Noise

In the presence of noise the detection of any signal becomes increasingly difficult. Not only is a receiver attempting to receive the desired signal but will also unintentionally pick up noise from all over as well. Often times the designers are more interested in the amount of added noise from internal circuits. At the receivers input location, there will a certain amount of noise that is used to identify a noise floor. In order to compensate for this additional noise and receive signals dependably; the minimum detectable signal has to exceed the noise floor level by some signal-to-noise ratio (Rogers, & Plett, 2003).

RF noise can be classified as either internal or external noise. Both types of noise may affect the functionality of the system. Internal RF noise generally causes complications with the circuitry of the reader, the antenna, or the transponder's IC (Hickman, 1999). This noise can distort the reader's output signal causing distortion and limited signal amplitude (Roger & Plett, 2003). Crosstalk noise is a type of interference that occurs when coupling of EM energy between adjacent traces or printed circuit boards (PCB) occurs. The generated energy between PCB's will reduce the signal integrity of the main PCB. This can

cause instability within the main PCB circuitry. In order to reduce the amount and effect of crosstalk noise, the substrate that the PCB is placed on should take in consideration the sensitivities of the PCB (Sudo, Sasaki, Masuda, & Drewniak, 2004).

External RF noise comes from an outside source and may influence transmit signals, backscatter signals, and the size of the interrogation zone. External RF noise generally must be concentrated at a specific frequency in order to cause adverse effects on a system. This external noise can arise from three sources: atmospheric, galactic, and man-made.

Atmospheric noise is a result of lightning (electrical) storms in tropical areas. However, other sources include the aurora borealis and aurora australis. Atmospheric noise changes depending on the time of day, the season, the 11-year sunspot cycle, and the geographic location of the equipment. Atmospheric noise generally is a concern at frequencies up to 30 MHz (Hickman, 1999).

Since galactic noise is of cosmic origin, it rarely is a concern for RFID systems. It affects the frequency range of 3 MHz to 300 MHz. Similar to atmospheric noises, it varies depending on the season. It tends to be more noticeable when it coincides with man-made noise levels.

Man-made noise is unintentionally produced noise from a variety of sources. Electronic motors, light switches, and thermostats, for example, are capable of generating noise signal in pulses. Radiation from ISM (industrial, scientific and medical) RF generators used for diathermy, metal treatments, and

polythene sealing for example, can generate a continuous noise signal (Hickman, 1999). The definition of man-made noise is not supposed to include intentional RF noise such as jamming signals, however, these intentional transmissions can be considered noise until the source of the signal is known.

Destructive and Constructive Interference

There are generally two main types of interference; destructive and constructive. Interference takes place when one or more electromagnetic waves interact with each other at a given location. The outcome of this interference depends on their phase, amplitude, and polarization. Constructive interference occurs when the combined wave experiences an amplitude increase. Destructive interference has the reverse effect on the amplitude of the combined wave. Since destructive interference results in a decrease of the new wave's amplitude, there is a chance that the amplitude could be zero, or nearly zero. This type of interference is very important for passive transponders because they cannot harvest a sufficient amount of energy from these waves if signals are too low. This can lead to low amplitude locations in the interrogation zone or null spots (standing waves). This generally happens when two waves interact that are half a wavelength out of phase, resulting in elimination or cancellation of the signal (Sweeney, 2007).

Presence of Radio Frequency Noise in the Environment

RF noise is present virtually everywhere. Unless a given area is designed to shield or block out RF noise in general, it is safe to assume that there is some

sort of RF noise present in a given environment. This assumption is very important for a user of RFID technology, especially for those who are involved with implementing RFID systems for various applications. Every RFID system implementation has the potential to be different from another one even if utilizing the same equipment for the same application, but in another location. Thus, each implementation should be handled and assessed independently to ensure optimal efficiency and accuracy for that RFID system (Clarke, Tazelaar, Twede, & Boyer, 2005). This procedure is important to remember because other electronic devices could be sources of unidentified or ambient RF noise.

Since disturbances for communication capabilities can be caused by RF noise, awareness of its presence can help with troubleshooting. The surrounding environment itself is very important to consider, especially if a large amount of metal is present. In most cases, the combination of a non-RFID-friendly environment (in terms of surrounding materials) and RF noise in the operating frequency will increase the likelihood of interference with RFID communication. The existence of metal objects such as beams, equipment, products, electric motors, floors, and ceilings can introduce the possibility of absorption, reflection, refraction, and wave scattering that can ultimately lead to interference (Sanghera, 2007). Conductive materials such as metals tend to reflect waves at UHF frequencies without reducing the waves' overall energy. Water is generally a good reflector and a good attenuator (absorber) of electromagnetic waves (Sweeney, 2007). A good solution is to avoid metal objects in the interrogation zone if at all possible. Some adjustments of the distance from the antenna to the

transponder may be necessary in order to avoid or limit the effects of the reflected RF signals (Sanghera, 2007).

Interference can be cause by various aspects involved in the RFID application. The presence of RF noise is not the only contributing factor when it comes to interference. The positioning of a transponder that is attached to a product can play a critical role transponder readability. Products such as a package of refrigerated beef can cause the loss of communication between reader and transponder (Onderko, 2004). The interference generally does not come from the orientation of the transponder on the product. The material that the product contains or made of has a greater effect on the possibility of interference (Tazelaar, 2004).

Multiple Tag-to-Reader Interference

This type of interference occurs when multiple transponders within the interrogation zone of an RFID system are energized and attempt to respond to the reader at the same time. Referred to simply as tag interference, complications can occur when all transponders attempt to respond at the same time in a tightly enclosed area. This results in a massive amount of scattered, individual response signals from each transponder attempting to communicate with the reader, which makes the signals difficult to differentiate. In order to help correct this issue, complex anti-collision algorithms are necessary (Kim, Yook, Yoon, & Jang, 2008).

Multiple Reader-to-Tag Interference

Interference from multiple readers occurs when more than one reader operating at the same frequency attempts to activate and read the same transponder simultaneously. This is also referred to as the reader collision problem. This collision problem generally occurs in a dense reader environment that contains numerous readers attempting to identify or detect the transponder at the same time and in the same vicinity. The results can be of substandard accuracy and consistency, compared with valid reads. In an attempt to resolve this issue, Europe has introduced a "Listen before Talk" (LBT) provision for RFID systems (Leong, Ng & Cole, 2005). According to European Regulations, the reader has to listen and identify that a specific channel is not in use before that channel can be used to interrogate a transponder. However, this regulation could provide problems in an area with a large number of actively operating readers since a number of the communication channels may be occupied by a single reader, thus making them inactive to other readers who also operate in the same channels. This issue has raised doubt whether a global RFID initiative can ever be implemented (Leong, Ng & Cole 2005).

Reader-to-Reader Interference

This interference type is due to one reader's signal reaching the other readers and causing an altered effect on normal system operation. Reader-to-reader interference is distinct from the other two types of interference because it can occur even in the absence of intersecting points between interrogation

zones. The transmitted signals from a remote reader can be sturdy enough to obstruct the accuracy of the decoding process from the transponder (Kim, Yoon, Jang, & Yook, 2009). The transmission signal of the reader and the backscattered signal of the transponder exist on separate spectrum domains. Odd or even-numbered channels are designated for reader only transmissions, however, this does not terminate the threat of reader-to-reader interference (Kim, Yook, Yoon, & Jang, 2008). It can still have an effect on the backscattered signal from the transponders.

Minor interference can be increased in environments that contain multiple readers in a given area, such as warehouses. Reader-to-reader interference, also called reader collisions, can occur if a reader using the same channels simultaneously and at a certain distance causes other readers to stop reading transponders altogether. The environment can play a large role by magnifying the interference possibilities especially in an RF-noisy environment (Kim, Yoon, Jang, & Yook, 2009).

A number of studies have been conducted on the effects of reader-to-reader interference. Many of these studies focus on deriving an equation to reduce effects of other readers on a desired reader, or to identify a way of analyzing the effects of interference on a reader interrogation zone (Kim, Yoon, Jang, & Yook, 2009). Other studies have taken a different approach to solving the complex reader collision problem. A suggested solution to this problem is using a central cooperator (CC). It is a central communication hub that would mitigate the communication between tags and readers. The idea is to share

information among readers instead of individual reader attempting to receive the same data signal from a transponder at once (Wang, Wang, & Zhao, 2006).

Jamming Signals

Jamming signals are often thought of as a signal used to disrupt an incoming transmission or signal. Normally, jamming signals are not aimed at interfering with a particular transmitted signal. Instead they are aimed at disrupting the receiver's ability to receive the signal. It is a common misconception that the transmission signal is disrupted, but that is not the case. It may seem the case because a radar system normally has its transmit and receive antennae at the same location and, often times, come from the same antenna (transceiver). This same strategy can be applied to a network of transceivers (Adamy, 2008). Another form of jamming signal is called deception jamming. Radar jamming signals use replicas of the targeted echo signal in order to confuse the radar system and complicate the system's ability to receive and decipher the true signal. This particular method is known as false target generation (Schuerger, & Garmatyuk, 2008).

Measuring Radio Frequency Noise

Radio Frequency Site Audit

When troubleshooting complications with a system, the possibility of interference based on EM or RF noise should be considered. This depends on a number of factors which include operating frequency of the system, strength of RF noise signal, and consistency, or how frequent the RF noise occurs.

Measuring RF noise has been a necessary and common procedure in site auditing. When conducting a RF site audit it is important to follow some guidelines around infrastructure assessment, RF characteristics, business process documentation, site survey report.

- Infrastructure Assessment

Know the area well. Obtain a blueprint layout of the entire facility. Notes should be kept on the size of the building and what materials were used to construct the floor, roof and walls. Identify personnel and equipment moving paths and locations of static equipment. Identify what type of product is used throughout the facility, include hazardous materials. This is necessary since the environment can have a large impact on the RFID interrogation zone (Brown, Patadia, Dua, & Meyers, 2007).

- RF Characteristics

Identifying sources of possible interference to an RFID system can begin without the use of a spectrum analyzer. Start by checking the operating frequency of the equipment. After locating suspected sources, a spectrum analyzer will help identify the difficult ones. Cell towers, two-way radios, and manufacturing equipment can all be sources for unidentified/ambient noise. Remember that cordless phones and mobile phones can operate at 900 MHz (Brown, Patadia, Dua, & Meyers, 2007). Many times the source of RF noise can be caused by "unintended emitters or devices that should not be radiating a signal" (Thomas, & McLain, 2009). Look for equipment

like electric motors, power jacks, and air-conditioners because they can all potentially produce harmonic interference. Do not focus solely on the operating frequency range of the RFID system; it is important to widen the search outside that frequency as well to identify other nearby signal spikes (Brown, Patadia, Dua, & Meyers, 2007).

- Business Process Documentation

Each RFID system requires an application specific installation depending on what the system need to accomplish. In order to implement a system properly, an understanding of how that task is currently done should be understood. This will allow the implementer a better idea how to integrate the RFID system and how to get the best results (Brown, Patadia, Dua, & Meyers, 2007).

- Site Survey Report

Document everything, even if it seems like a minor detail. This means that pictures, documents on current business procedures and answers to all questions asked should be documented to make sure that nothing was missed. This report will help design the best RFID system possible for that facility and application (Brown, Patadia, Dua, & Meyers, 2007).

Voyantic Measurement Unit

A company based in Espoo, Finland, Voyantic is the developer of the Tagformance RFID Measurement System, designed specifically to help tag

designers and manufacturers produce a better product (Tagformance, 2009). However, this system has been leveraged beyond its original purpose and is now being used at universities and research facilities. The Voyantic measurement unit can be used as a spectrum analyzer for detecting various signals within the UHF band range. Essential communication capabilities such as transmission of energy, response signals and distance are measured and calculated using a number of software features. The three main features of the system, Interference, Backscatter, and Threshold are discussed below.

Interference Feature

Interference measurements detect the given frequency range to reveal all inband RF activity. Ambient noise can be identified and compared to measurements from environments that provide additional noise from identified sources. This feature allows the user to monitor the amount of backscattered signals (RF noise) on a single frequency or a frequency sweep ranging from 800 to 1,000 MHz. Figure 2 is an example of a noise measurements in a given locations recorded by the Interference Feature. When a signal is detected, a spike occurs at that frequency on the graph as seen at 870 MHz, below.

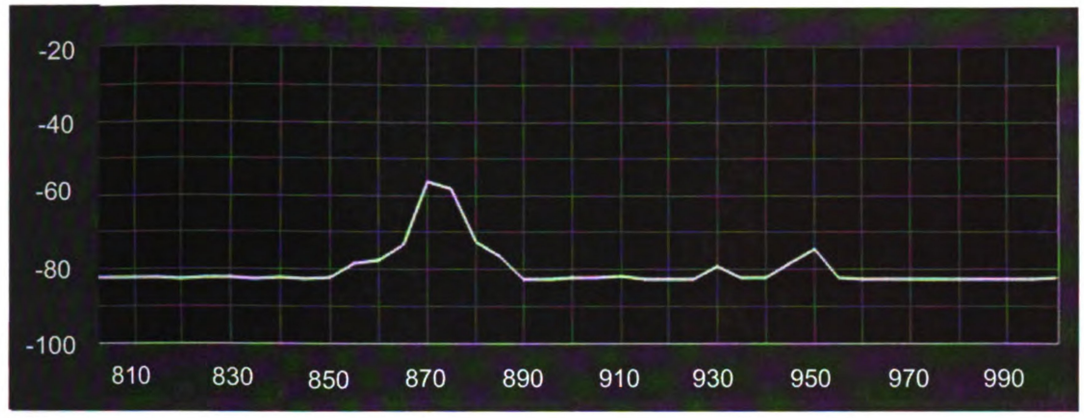

Figure 2: An example of The Voyantic Interference Feature.

A frequency evaluation allows the user to identify potential signs of reader-tag communication issues such as high levels of noise within operating frequencies for transponders. If conditions are right, an environment will have no noticeable levels of RF noise thus providing a noise-free environment similar to that of an anechoic chamber. This feature is useful for applications such as site surveys for manufacturing facilities and hospitals where interference from RF noise is a concern. It can also be used to monitor the channel allocation of nearby readers to identify free channel slots (Tagformance, 2010).

Backscatter Feature

Using the Backscatter feature, a power sweep within a selected frequency band will measure and plot a comparison between Sensitivity and Backscatter units (Figure 3). This feature provides a quick and easy way to compare sensitivity and backscatter units to identify potential interactions.

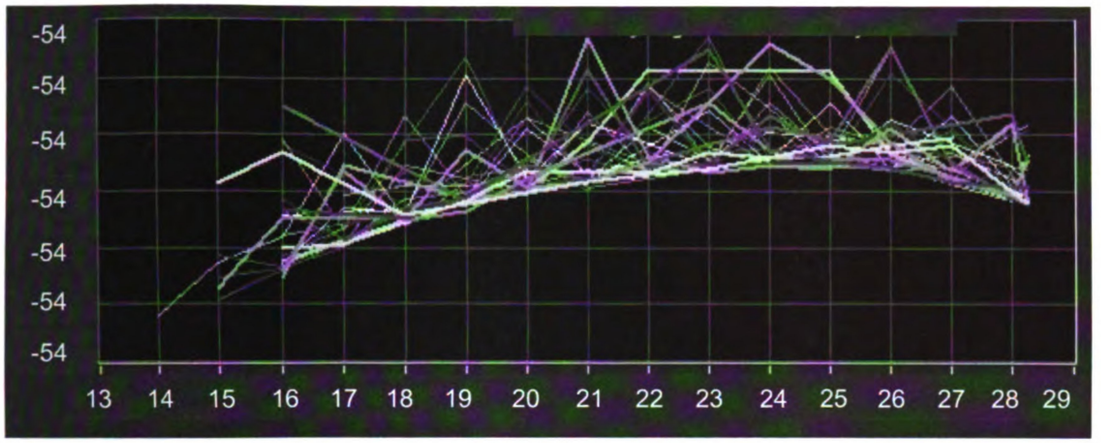

Figure 3: An example of The Voyantic Backscatter Feature with 30 Trials.

Under ideal conditions, at a single frequency, as transmit power increases, the backscatter power will also increase. Comparisons can be displayed on a graph of Sensitivity units against a Backscatter unit. Unlike a frequency sweep, comparisons are limited to a single frequency at a time. The final separate measurements must be taken at each desired frequency before analysis can take place (Tagformance, 2010).

Threshold Feature

Thresholds are levels or points above which something will take place and below which it will not. This particular feature operates by performing a sweep through a user-selected frequency range, power step (increase), and frequency step (increase) to detect the minimum required transmit power to energize a transponder at each frequency point. Figure 4 is a representative example of graphed data using this feature with a frequency range of 800 to 1,000 MHz, a power step of 1decibel (dB), a frequency step of 5 MHz.

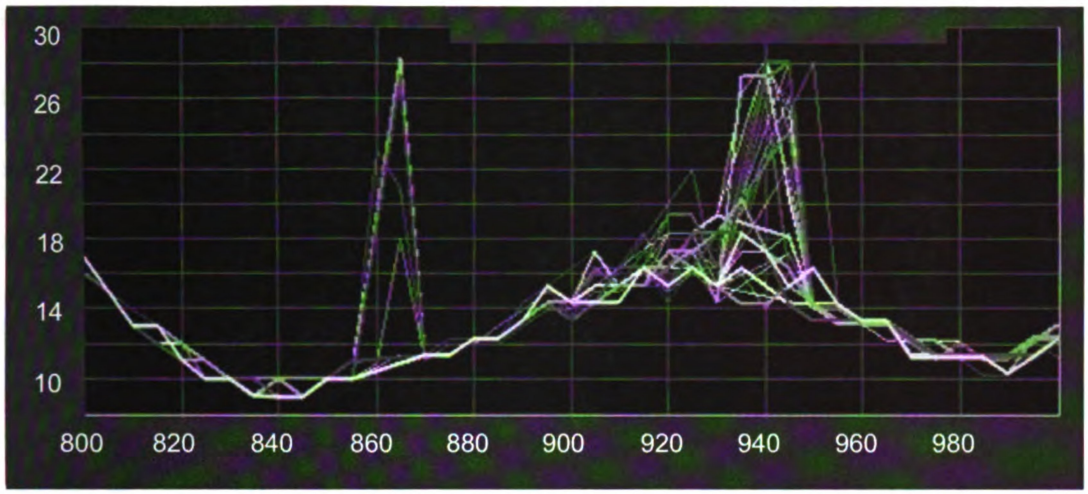

Figure 4: An example of The Voyantic Threshold Feature with 30 Trials.

Calculated values are expressed using Sensitivity and Backscatter measurement units. The main applications of this feature are to verify the performance and tuning of transponder designs, measure the detuning and achievable read range, and provide simulated and measured results (Tagformance, 2010).

Sensitivity Units

Sensitivity units can be broken out in multiple settings. These include Transmit Power, Electric Field Strength, Power on Tag Forward, and Theoretical Read Range Forward.

Transmit Power (dBm)

Identified as a sensitivity measurement unit, Transmit Power (TP) is the power output at the RF out-port of the reader (Tuominen, 2009). It determines the threshold limit of a transponder by measuring the power output necessary from the reader to activate it (Figure 4). This threshold limit will vary depending

on the frequency at which the measurement is taken. A transponder with a low sensitivity value (or threshold) means the necessary transmit power from the reader to energize it is minimized. The Tagformance unit's output measurements for transmit power range from 0 to 30 decibels measured in milliWatts (dBm).

Electric Field Strength (V/m)

Electric Field Strength (EFS) is the field strength at the transponder's location. This calculation is the minimum necessary field strength to activate a transponder (Tuominen, 2009). The electric field generated helps gather energy to energize the transponder. The field strength at the transponder coincides with the transmit power. High transmit power measurements generally have high electric field strength measurements. EFS values indicate how hard the transponder works in order to gather energy. Similar to transmit power, lower values generally means a more efficient connection between transmitted energy and harvesting it.

Power on Tag Forward (dBm)

This sensitivity unit refers to the uplink communication from the reader (antenna connection points) to the transponder. Power on Tag Forward (POTF) is the power at the transponder's location sent from the reader's transmit antenna (Tuominen, 2009). Similar to Transmit Power, Power on Tag Forward is often referred to as a more accurate depiction of the activation threshold for a transponder because it is calculated at the transponder's location rather than at the reader's out-port.

Theoretical Read Range Forward (m)

The Theoretical Read Range Forward (TRRF) means that the operating distance is limited to being able to activate the tag from distance. In this case, the TRRF is the maximum operating range (Tuominen, 2009). RF-reflections from floor, walls, structures, etc. can naturally affect the reach of the interrogation zone in all directions. This measurement is used as an estimation to how far the interrogation zone is able to reach out. The longer the read range, generally, the larger the interrogation zone will be.

Backscatter Units

Backscatter units can be broken out as well. Its settings include Backscatter Power, Backscatter Signal Phase, Differential Radar Cross-Section, Power on Tag Reverse, and Theoretical Read Range Reverse.

Backscatter Power (dBm)

Backscatter Power (BP) is a calculation of backscattered signal from the reader's RF in-port (Tuominen, 2009). Similar to the Transmit Power, the actual calculation is taken based from the response of an energized transponder. A significantly weaker signal in terms of strength compared to Transmit Power, Backscatter Power is measured in negative dBm. Backscatter Power (also referred to as Received Power (RP) in the Interference feature) can represent two quantities: response signal from a transponder and presence of noise.

Backscatter Signal Phase (degrees)

Backscatter signal phase is the phase difference between the transmitted signal and the received transponder response (Tuominen, 2009). This can be used to determine the transponders distance (how much does the phase change when frequency is increased) from the reader. If the transmitted signal and backscattered signal overlay each other they are said to be "in phase". However, if they do not overlay each other and are 180 degrees displaced they are "out of phase". This can be an indicator of how well the transmitted and received signals operate in the presence of each other.

*D*ifferential Radar Cross-Section (decibels per square meter, or dBsqm)

*D*ifferential Radar Cross-Section (Delta RCS) is a calculation of how effectively the transponder can turn incoming carrier power into its response to the reader (Tuominen, 2009). This calculation becomes vital when determining how well established the reader-to-tag communication is within the system. The higher the value, the more efficiently the transmitted signal is being received and, generally, the better the communication. A lower value can mean that the transmitted signal is not reaching the transponder at a high enough concentration thus, the transponder does not responding frequently.

Power on Tag Reverse (dBm)

This measurement calculation refers to the downlink communication from the tag to the reader (antenna connection points). Power on Tag Reverse (POTR) is the radiated backscatter signal power "sent" by the tag back to the

reader at the tag location (Tuominen, 2009). This measurement is a true indicator of the response strength from the transponder. Unlike Backscatter Power, this measurement has less of a chance to encounter external interference.

Theoretical Read Range Reverse (m)

The Theoretical Read Range Reverse (TRRR) value is an Electronic Product Code (EPC) globally specified quantity that tells what distance the backscatter signal strength would be sufficient for an average reader if the tag could always be activated. If the TRRR is larger than TRRF (it usually is), the tag is uplink limited (Tuominen, 2009). Unlike the TRRF, this calculation does not represent the range limit of the interrogation zone. Generally, as long as the transponder receives enough power, the backscattered signal can be received at a much further distance than the reach of the interrogation zone.

Chapter 3: Methodology

This chapter will provide details on the testing methods, equipment, locations, and procedures used for this study. This begins by discussing the equipment used during both testing scenarios. It is followed by the set up and running of scenarios in three separate locations. This chapter concludes with a discussion on the data analysis procedure.

Two separate UHF-based RFID systems (Voyantic Measurement Unit and Impinj Speedway) were used to analyze the functionality between the reader-to-transponder and transponder-to-reader communication capabilities. Three testing environments/locations were chosen, these being the MSU Auto-ID Research and Testing Center (Location 1), the MSU School of Packaging (Location 2) and the MSU Engineering Building (Location 3). Each location had different levels of RF noise and/or environmental surroundings, known as UHF inhibitors. To provide statistical validity for testing, 30 test trials were conducted for the two testing scenarios and each measurement unit. These two scenarios were: Scenario 1 – the measurement of ambient RF noise; and Scenario 2 – the combination of ambient and identified RF noise.

Equipment

Before any testing occurred, all equipment including the readers, antennae, transponder and cables were checked to make sure everything was in proper working order. Initial tests to choose an appropriately functioning transponder were conducted by recording the number of reads in a given time period of numerous transponders of the same model to find a consistent read rate between a number of the transponders. The transponder with the highest read rate was chosen.

Voyantic UHF RFID Measurement Unit System

This RFID system included a single circular antenna, antenna stand, transponder and transponder stand, a reader/measurement unit, and a laptop with Tagformance 3.5.1. Figure 5 shows an image of the Tagformance reader and components included in the kit.



Figure 5: The Voyantic Tagformance Kit Components

The Tagformance measurement unit has two main ports: an in-50 ohms and out-50 ohms (essentially transmit and receive ports). A 6 dB attenuator was attached to the received cable for appropriately calibrating the system with the cable loss and gain. The antenna used for this system was a Motorola model AN200. This antenna is circularly polarized and bi-static which allows transmitting and receiving signals in two planes through one connection point on the antenna.

The transponder type was an Alien Technologies Higgs-2 transponder. A single circularly-polarized antenna was used for all measurements. The antenna stand consisted of a wood base and a 3-foot long piece of polyvinyl chloride (PVC) pipe. A connector for attaching the antenna was at the top of the antenna stand. The transponder stand was made of an aluminum base, high density

polyethylene (HDPE) tubing, and a polystyrene transponder holder. The Tagformance software contains seven different features that were used to measure and analyze the performance of the transponder and antenna communication capabilities.

Impinj Speedway Reader

This system was set up using a single circularly-polarized antenna, antenna stand, coaxial cable, crossover Ethernet cable, a laptop and an Impinj Speedway UHF reader. This UHF RFID reader was used as the identifiable RF noise source that was introduced into each location to provide additional concentrated amounts of RF energy within the operating frequency of the Voyantic Measurement Unit in the form of noise.

Statistical Consulting Center's Data Analysis Model

The experimental model was designed by the Statistical Consulting Center (SCC), which is affiliated with the College of Agriculture and Natural Resources at Michigan State University. It was designed to analyze the feedback data and produce multiple outputs that are statistical valid. Scenarios, locations, and frequency were compared to show, statistically, the differences and similarities among them, focusing mainly on probability/significance values.

Environments/Locations

Location 1

The first location was an office area of the MSU AIRTC containing a wireless network, nearby cellular tower, and various metal cabinets (Figure 6). For the past few years, the AIRTC has been the location for numerous RFID related tests and experiments. The surrounding buildings contain a variety of companies and businesses including manufacturing and business office setups. In addition, two radio stations and a cell tower are within a half mile of the AIRTC. Although testing was conducted in an area where physical obstructions were not a direct factor, the large amount of external RF activity could be the source of measurement complications. The testing scenario layout for this location is displayed in Figure 37 in Appendix B.



Figure 6: Location 1 –The Michigan State University Auto-ID Research and Testing Center (MSU AIRTC)

Location 2

The School of Packaging is a standalone building on the MSU campus, compiled of multiple labs and offices. The machinery lab was chosen as Location 2 for testing within the Packaging building. This location has a large amount of space with metal objects in the environment (Figures 7 and 8). Testing took place in an open aisle close to the center of the room. This area was chosen to simulate a working environment for RFID in a manufacturing environment. The testing scenario layout for this location is displayed in Figure 38 in Appendix B.

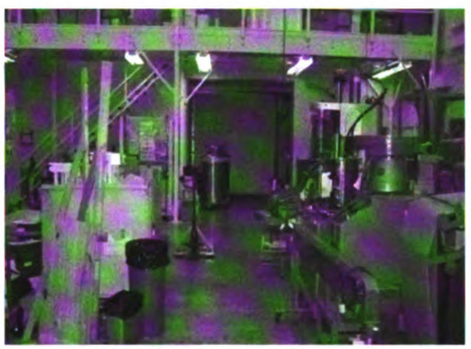

Figure 7: Location 2 – The Packaging Building Machine Lab, Front View

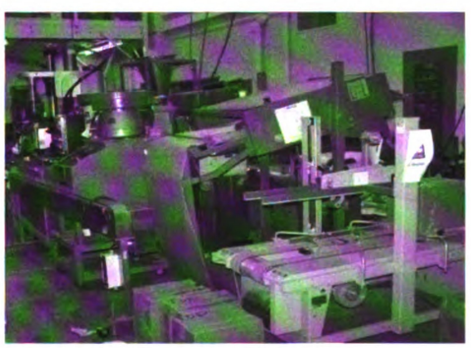

Figure 8: Location 2 – The Packaging Building Machine Lab, Right Side View

Location 3

Unlike the first two locations, Location 3 was in a basement of the MSU Engineering building that houses many labs and pieces of equipment. The testing area (Figures 9 and 10) was completely surrounded by cinderblock walls, conduit and piping in the ceiling, and various metal objects that are potential inhibitors of RF signals. This location was free of wireless signals from Internet routers and mobile phone service. This location displayed the cleanest RF environment compared to Locations 1 and 2. It, too, provided a potential simulation of an actual working environment for an RFID system. The testing scenario layout for this location is displayed in Figure 39 in Appendix B.



Figure 9: Location 3 – The Engineering Basement, Front/Left View



Figure 10: Location 3 – The Engineering Basement, Rear View

Testing Procedure

Set Up of Voyantic Measurement Unit

The Voyantic Measurement Unit was connected to the laptop and antenna using a 50-ohm convertor and 20-foot coaxial cable that was plugged into the transmitted port of the base unit. The opposite end of the coaxial cable was connected to the circular antenna. This antenna was attached to an antenna stand at a height of 3-feet above the floor. The transponder stand was placed 48-inches away from the front center position of the antenna. The transponder was placed in the center of the polystyrene transponder holder with the front side of the transponder facing the front center of the antenna. A single transponder and single bi-static, circular antenna were used throughout testing in the threshold and backscatter features. For both of these features, the transponder was placed in the center of the stand, parallel to the antenna's center.

Interference Feature

To ensure that the overall results from the measurements of the ambient RF noise in each location were an accurate account of the RF noises present in that location, the interference feature provided an initial look at the RF noise condition of the surrounding environment. Each testing session in each location began with a reading of the ambient RF noise present. The feature settings were:

- Measurement Mode :
    - Frequency Sweep
- Sweep Settings :

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- Start Frequency : 800 MHz
- Stop Frequency : 1000 MHz
- Frequency Step : 5 MHz

Threshold Feature

This feature was used to evaluate the communication abilities of the reader to the transponder. It looks at the efficiency and accuracy of the reader's ability to communicate. The frequency sweep ranged from 800 to 1,000 MHz. The measurements were displayed by comparing one of nine measurement options to the frequency band. The settings for this feature were:

- Command Mode :
  - ISO 18000-6C Query
- Sweep Settings :
  - Start Frequency : 800 MHz
  - Stop Frequency : 1000 MHz
  - Frequency Step : 5 MHz
  - Power Step : 1 dB

Backscatter Feature

The backscatter feature was used to evaluate the efficiency and accuracy of the reader's ability to communicate with the transponder by focusing on a specific frequency rather than conducting a frequency sweep. The measurements were displayed comparing one of three power-transmitting based measurement options (Transmitted Power, Electric Field Strength, and Power on

Tag Forward) to any of the other five remaining measurement options (Backscatter Power, Backscatter Signal Phase, Delta RCS, Power on Tag Reverse, and Theoretical Read Range Reverse). The feature settings were:

- Command Mode:
    - ISO 18000-6C Query
- Sweep Settings :
    - Start Power : 0 dBm
    - Stop Power : 30 dBm
    - Frequency : 915 MHz
    - Power Step : 1 dB

After the settings for each feature were set, the test trial began by pressing either the "Start" button or "Start Sweep" button to begin the measurement sequence for that specific option. Once the measurements were completed for a test trial, the software automatically stopped recording and ended the test trial, thus, there was no reason to press the "Stop" button at anytime. The succeeding test trials were started immediately after the conclusion of the previous one without any changes by simple pressing the "Start" button again. When 30 test trials were completed, all the data was saved as one file. After concluding the 30 test trials with the ambient RF noise only, the identifiable RF noise system was set up, put into place and activated. The settings for the all of the feature remained unchanged. Then, an additional 30 test trials were run using the same procedure for each measurement unit.

Set Up of Impinj Speedway UHF Reader (Identifiable RF noise source)

Areas at which this system could be set up were limited due to available space and access for Internet connection points and power outlets. The set up in Location 3 (Engineering building) varied from Locations 1 and 2 due to the distance from the nearest power outlet. However, this test was validated since the amounts of background noise produced in all locations were comparable.

Data Collection

Data was manually collected by using the Threshold feature of the Tagformance software. Within the operating frequency band of 900 to 930 MHz, data point were collected for the frequencies of 900, 902, 904, 906, 908, 910, 912, 914, 916, 918, 920, 922, 924, 926, 928, and 930 MHz. These data points were downloaded to a Microsoft Excel spreadsheet that was customized to calculate the mean, mode and standard deviation for 30 trials and all 16 frequencies. The data collecting process consisted of 9 measurement units, at three locations, with the two scenarios. These data sheets were ultimately combined into a sample file, which incorporated all data collected for analysis using the Statistical Analysis Software (SAS). Table 2 shows an example of the formatting that was necessary for processing the data from the Tagformance software.

Table 2: Example of Excel data formatted to use in Statistical Analysis Software (SAS).

Scenario	Location	Frequency	Trial	Transpwer	Backpwer	Backsignal
1	1	900	1	14.3	-49.9	-41
1	1	902	1	14.3	-50.2	-10
1	1	904	1	14.3	-50.5	22

Data Analysis Procedure

The data was ready for analysis by SCC once it was appropriately formatted. The analysis calls the data file from the folder, loads it to memory, and creates the data set named Noise. After the data set is loaded, each response variable must be pulled and analyzed individually. Each of the ten measurement units were abbreviated as followed; Transpwer, Backpwer, Recpwer, Electfield, Delta RCS, Backsignal, POTF, POTR, TRRF, and TRRR.

After selecting a response variable, the data was plotted to identify if the shape of the data followed a normal distribution. Distribution is identified by looking at plotted data graphs. If necessary, the data was subjected to a transformation command to try and fit the data to a normal distribution. Transformations were necessary for all response variables that contained negative values. To correct this issue, the absolute value of the response variable was used to convert negatives to positive values. The affected response variables included Backpwer, Delta RCS, POTF, POTR, and Recpwer.

Deciding the appropriate variance-covariance structure was a vital part in calculating the correct probability/significance values. All of the data used one of two structures; autoregressive or autoregressive homogeneous.

The final model to analyze the data set in the appropriate manner was determined. It was derived to incorporate individual components from various testing into a lone command. It outputted results based on least-square-means (LSM). In addition, effect slices (a feature in the SAS program) were produced to identify the comparisons among the repeating structure, that which provided key significance. Results were produced by graphs and tables. The graphs and tables can display both a 2-way or 3-way comparisons between the variables in the repeated structure.

Chapter 4: Results

This chapter will discuss and display the result from the tested hypotheses. The discussion begins with the statistical analysis processing of the data. This continues on with defining a causal relationship between communication capabilities focusing on Sensitivity and Backscatter units. The results are displayed based on scenario. Each scenario displays figures for each Sensitivity and Backscatter units. Scenarios are summarized at the end of each section. Finally, the hypotheses are restated with a brief discuss.

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Statistical Analysis

The data set for this study consists of nine response variables and three fixed factors. The first factor was scenario with two levels, the 2nd factor was location with three levels and, the 3rd factor was frequency with 16 levels. Thus, a single response variable was measured in two scenarios each with three locations and 16 frequencies. A total of 30 test trials were run as replicates for the experiment. For each response variable, a total of 2,880 observations were measured and considered for analysis. The data analysis for this study contained six essential steps: 1. Define the statistical model; 2. Check statistical assumptions; 3. Select variance-covariance matrix for repeated measures term; 4. Performing F-test to identify significance in each term; 5. Use final model for comparisons; and 6. Plot the results.

Define the Statistical Model

The experimental design is a three-way factorial with frequency being repeated measures. Since each combination of location and scenario was measured 16 times, this is considered to be a potential source of correlation. This statistical analysis follows a general linear:

(Equation 1)

$$Y_{ijk} = \mu + sce_i + loc_j + (sce_i \times loc_j) + fre_k + (loc_i \times fre_k) + (sce_j \times fre_k) + (fre_k \times loc_i \times sce_i) + E_{ijk}$$

Whereas,

$Y_{ijk} = Response\ Variable,$
$\mu = Great\ mean,$
$sce_i = Scenario,$
$loc_j = Location,$
$fre_k = Frequency,$
$E_{ijk} = Error(residual),$

Check Statistical Assumptions

After constructing an equation for the model, two main assumptions needed to be validated. The first assumption required a normal distribution in the residuals. Since the data sets were so large and had multiple replications, the results were more precise and accurate statistically. However, large data sets can also provide challenges if the distribution of the data does not follow a normal distribution.

A bell-shaped distribution was found for all of the data sets but with a higher peak around zero values. Figure 11 is a sample of the data distribution which shows a general bell-shaped curve however the center peak extends slightly higher than what is normally preferred.

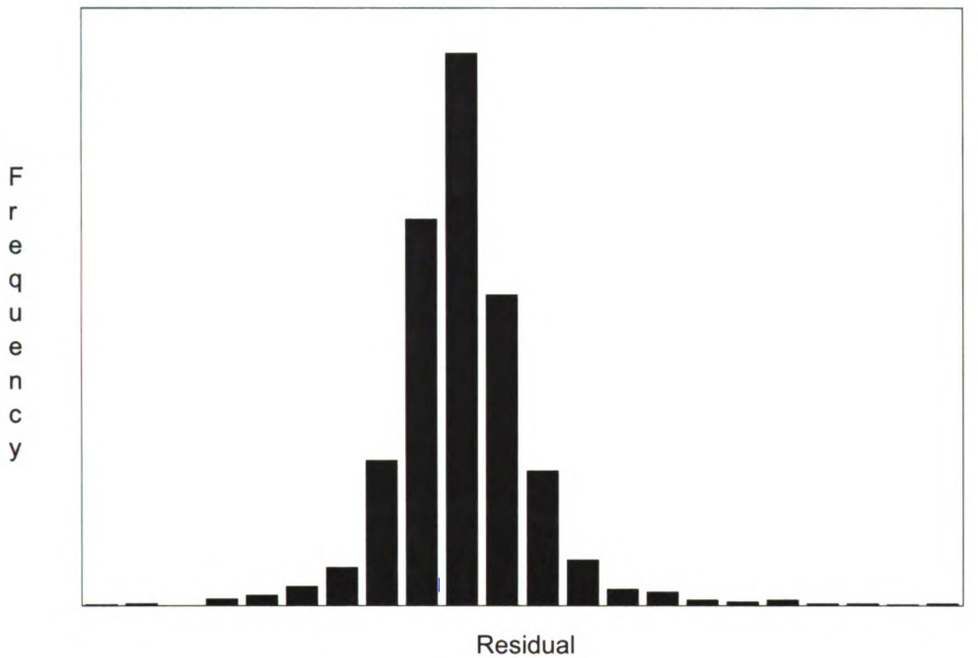


Figure 11: Example of Data Distribution.

This type of issue is normally resolved by using transformations. A number of transformations such as square root, cube root, logarithm base 10, and some angular transformations were used but had little to no effect on the distribution of the residuals. Therefore, these transformations were not used on the data set.

After further analyses, the distribution for all data sets was sufficient and did not have a significant impact on the final results. Conversely, all the data sets that contained negative values required a transformation to positive values.

The second assumption is to check the variances across treatment groups. With this assumption, the variance is checked by focusing on the residuals again. This was done by looking at box plots of residuals based on scenario, location, and frequency. As seen in Figure 12, the box plots show equal variance among the location because the box sections of the box plots are of

relatively equal size. In order to determine whether or not the variances are equal or not, Levene's test was used. This test concluded whether or not the populations were different. If determined that the variances are different, then each variable must use different variance (Ramachandran, & Tsokos, 2009).

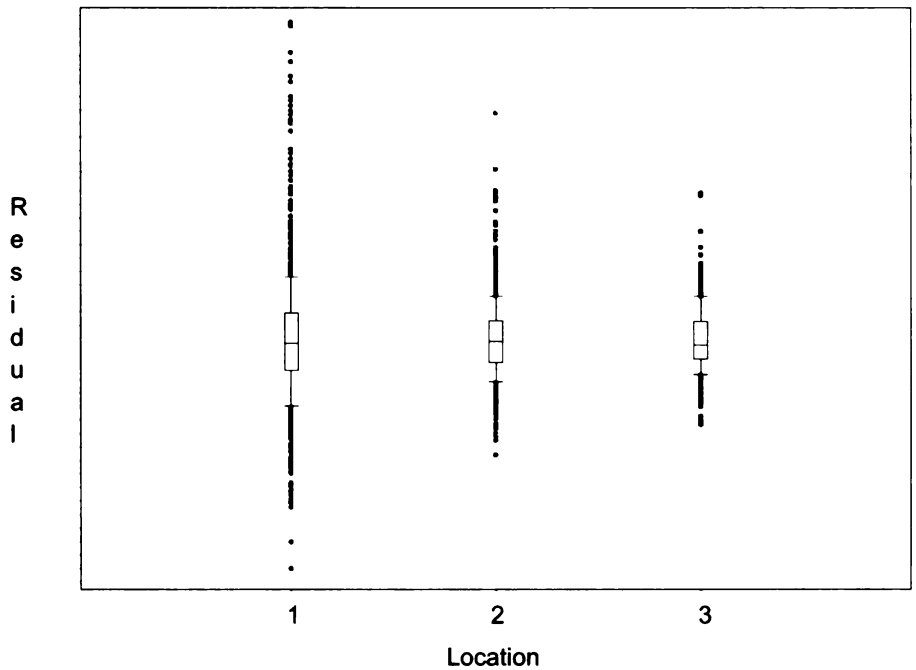


Figure 12: Example of Box Plots Comparing Locations

Select Variance-Covalence Matrix for Repeated Measures

Four types of matrices were used including 1st order autoregressive (AR), 1st order autoregressive heterogeneous (ARH), compound symmetry (CS), and compound symmetry heterogeneous (CSH). An example of the selection process for choosing the appropriate covalence matrix is displayed in Table 3. Indicated by a star next to it, the best choice for this example was ARH. This designation held true for all 9 of the response variables. Similar to AR, ARH has a similar

pattern of correlation, however, the variances can be different. Going through the process of choosing a variance-covalence matrix also acts as a means of correcting any errors with unequal variances across the repeated measures.

Table 3: Selecting the Most Appropriate Variance-Covalence Matrix

Type	AIC	BIC
AR(1)	1,153.3	1,159.7
*ARH(1)	762.7	817.0
CS	4,151.4	4,157.8
CSH	3,816.5	3,870.8

Performing F-Test for Significance

This test identified whether or not there were any significant differences within the levels of each statistical term. The individual fixed variables along with interactions with each other were tested. Table 4 demonstrates the output after performing the F-test. This data identified whether or not any significant differences existed throughout the entire data set based on scenarios, locations, and frequencies, and then based on significant interactions among the fixed variables.

Table 4: Example of F-Test Results

Fixed Variable Combinations	Num DF	Den DF	F Value	PR > F
Scenario	1	235	4.59	0.0332
Location	2	235	681.69	<.0001
Scenario*Location	2	235	38.86	<.0001
Frequency	15	1144	250.85	<.0001
Scenario*Frequency	15	1144	20.01	<.0001
Location*Frequency	30	1553	55.71	<.0001
Scenario*Location*Frequency	30	1553	13.57	<.0001

The F-Test provided away to avoided wasting time looking for significance difference in comparisons that were not relevant. Unfortunately, this was normally not the case due to the results showing that all comparisons presented significant differences. There were significant differences noticed through all comparisons within each of the nine response variables.

Table 4 further displays the different interaction combinations between the three fixed variables. These interactions are described as one-, two-, or three-way interactions. Based on the probability values displayed in Table 3, there were significant differences among all interaction combinations within this data set. Significance for all testing was based on an alpha value of .05. This means if the probability value is less than the alpha value, then the difference between an interaction and a comparison was significant. Since this table shows three-way interactions exist, any one- or two-way interactions used to form conclusive results would be inaccurate.

Fit Final Model

The initial probability (probt) results were very liberal. These probabilities were formed by comparisons involving locations and scenarios. The comparisons were based on All-Pair Wise comparisons used in T-testing. Using this method generated estimation values using least-square-means (LSM) and least-square-difference (LSD). Therefore, a more strict and conservative adjustment was implemented in order to identify true significance from comparisons.

This data contained multiple test and comparisons. The LSM and LSD methods were not recommended due to the amount of comparisons required. They require multiple T-tests for every possible combination. Not only were multiple tests necessary, but this would also increase the significance level dramatically. One way to approach this was to use a common technique for multiple comparisons called Tukey-Kramer method (Ramachandran, & Tsokos, 2009). The Tukey tested all possible differences of means to determine if one or both of the differences are significantly different from zero.

Both methods assume confidence intervals of 95% (0.05) throughout adjustments, however, with the robust size of the data set, probt produced using LSD were not accurate. The LSD criteria for determining significance did not account for the number of comparisons involved, thus overcompensating the criteria for finding significance and producing false significance. Tukey is similar to LSD but takes a conservative approach in adjustment criteria for measuring significance. This adjustment accounted for the number of comparisons involved, and thus adjusted the criteria for measuring significance between comparisons appropriately (Ramachandran, & Tsokos, 2009).

Plot Results

After all of the processing was completed the results were displayed in a simple and effective way that made forming conclusions simpler. The data had multiple ways to be presented, but forming conclusions that were supported by the data as well as relevant to RFID communication was complicated. The two-way interactions between scenarios and locations were easy to show and

analyze. However, based on the findings in Table 4, there was significance within the three-way interaction of scenarios, locations, and frequencies. A total of five graphs for each response variable were created based on results from Scenario 1, Scenario 2, Location 1, Location 2, and Location 3.

Theoretical and Actual Connection Between Communication Capabilities

Transforming data into an overall performance of the transponder's communication capabilities under each scenario and location was complex. This theorized relationship was only meant to increase understanding of these results, thus may not always be borne out in testing. It was based on an understanding of desired values to indicate "good" or "bad" performances in terms of communcation capabilities between the reader and transponder. The formula was applied within specific frequency ranges where significant differences among all locations or scenarios existed for either Sensitivity or Backscatter units.The following causal relationships were formed for Sensitivity and Backscatter units:

(Equation 2)

$$Sensitivity\ units\text{: } if\ TP_{Low}\ and\ EFS_{Low}\ and\ POTF_{Low}, then\ TRRF_{High}$$

- **Transmit Power (TP in dBm)** : Favors low estimation values
- **Electric Field Strength (EFS in V/m)** : Favors low values
- **Power on Tag Forward (POTF in dBm)** : Favors low values
- **Theoretical Read Range Forward (TRRF in m)** : Favors high values

(Equation 3)

$$Backscatter\ units: if\ BP_{High} and\ Delta\ RCS_{High} and\ POTR_{High}, then\ TRRR_{High}$$

- **Backscatter/Received Power (BP/RP in dBm)** : Favors estimation high values
- **Differential Radar Cross-Section (Delta RCS in dBsqm)** : Favors high values
- **Power on Tag Reverse (POTR in dBm)** : Favors high values
- **Theoretical Read Range Reverse (TRRR in m)** : Favors high values

The sensitivity unit deals with the transponder's ability to receive the transmitted signal from the interrogation zone generated by the reader. These units include Transmit Power, Electric field strength, Power on Tag Forward, and Theoretical Read Range Forward. Power on Tag Forward is the only measurement recorded using negative dBm, therefore, all of the data in this section for this response variable were displayed using the absolute value.

The backscatter measurement units relate to the transponder's response signal after activation from the reader. These units include Backscatter Power, Received Power, Delta RCS, Power on Tag Reverse, and Theoretical Read Range Reverse. All of these measurements (excluding Theoretical Read Range Reverse) were recorded using negative dBm values; therefore the absolute values were used and are represented in these results. The Received Power represents the ambient and identifiable RF noise measurements from the Interference feature. This value was considered independent of the other

measurement units because the other measurement units are dependent on Received Power.

A highlighted section on each figure represents the frequency range (s) that contain significant differences among all three locations. Figure 13 (pg. 63) is a visual representation of the Transmit Power data from Tables 5 and 6 (pg. 64-67) respectively.

To demonstrate the analysis by example, Table 6 breaks down location comparisons for each frequency. If the adjusted probability (AdjP) areas were less than .05, then these values were shaded for visual representation . It can be seen that only 924 MHz has a three-way significance among locations, hence the box on Figure 13. The shaded areas in Table 6 show that there are other frequencies with significant difference, however these are two-way interactions instead of three-way interactions.

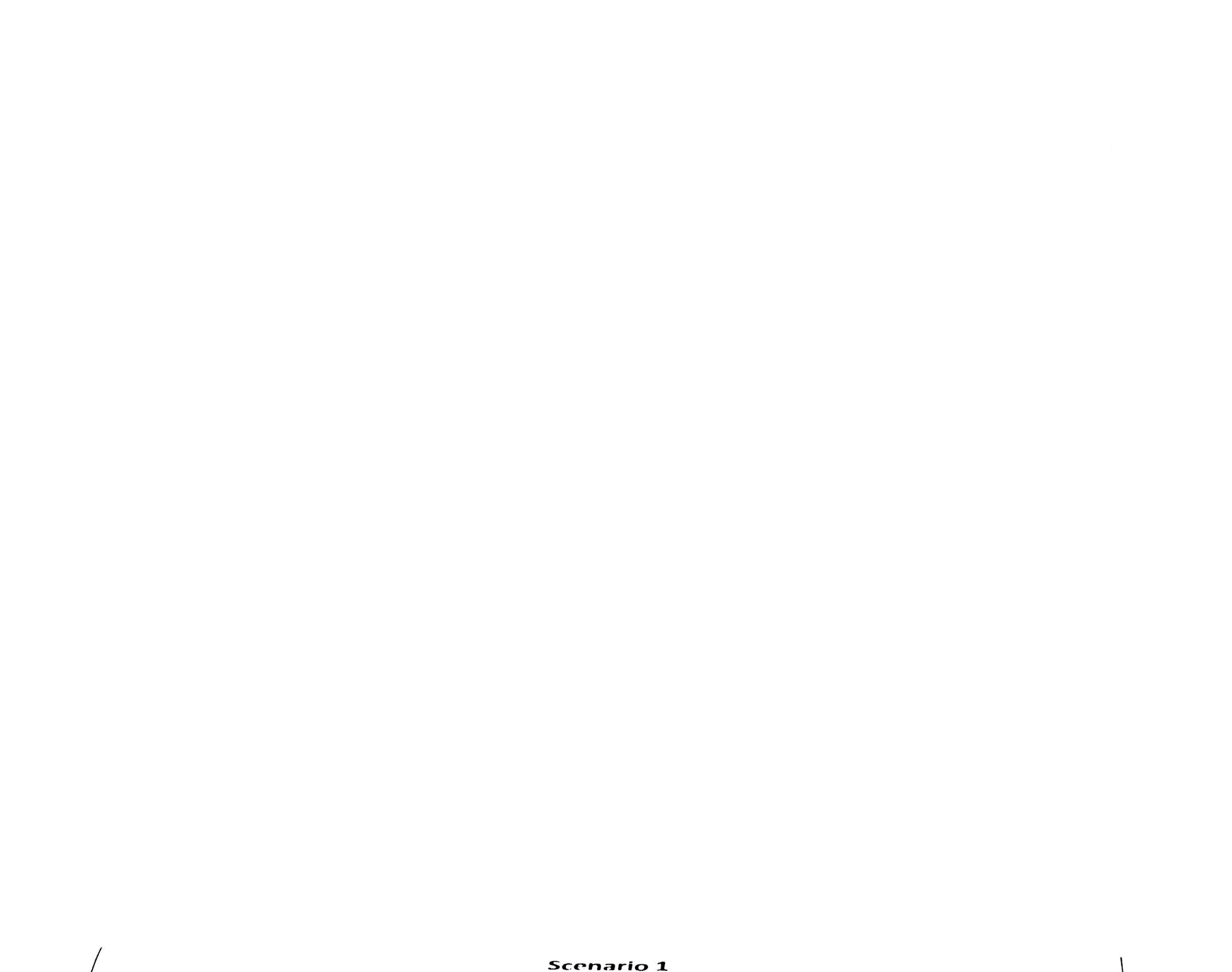
All measurenment units for each scenario have two similar tables that display all the information found in the respective Figure. These tables can be found in Appendix D. In some cases, the figures may not have any sections highlighted. This does not mean that there was no significance found, but can mean one of three things:

1. **All frequencies showed significant differences among all locations and frequencies**. This is only relevant for Figures 47, 56, and 65 where data for the Absolute Recevied Power is compared among scenarios at each location. These figures are found in Appendix F-H . The data

contained in these figure has been incorporated in the the figures in this chapter, however, when combined with other variables, no figures demonstrated this result.

2. **There are significant differences, but not among all three locations at one given frequency**. However,differences could exist among two of the three locations as seen in Figure 27.
3. **No significant differences exist**. This is only relevant for Figures 60-68 , which are found in Appendix H . The data contained in these figures has been incorporated in the the figures in this chapter, however, when combined with other variables, no figures demonstrated this result.

Scenario 1 – The Measurement of Ambient RF Noise


Scenario 1

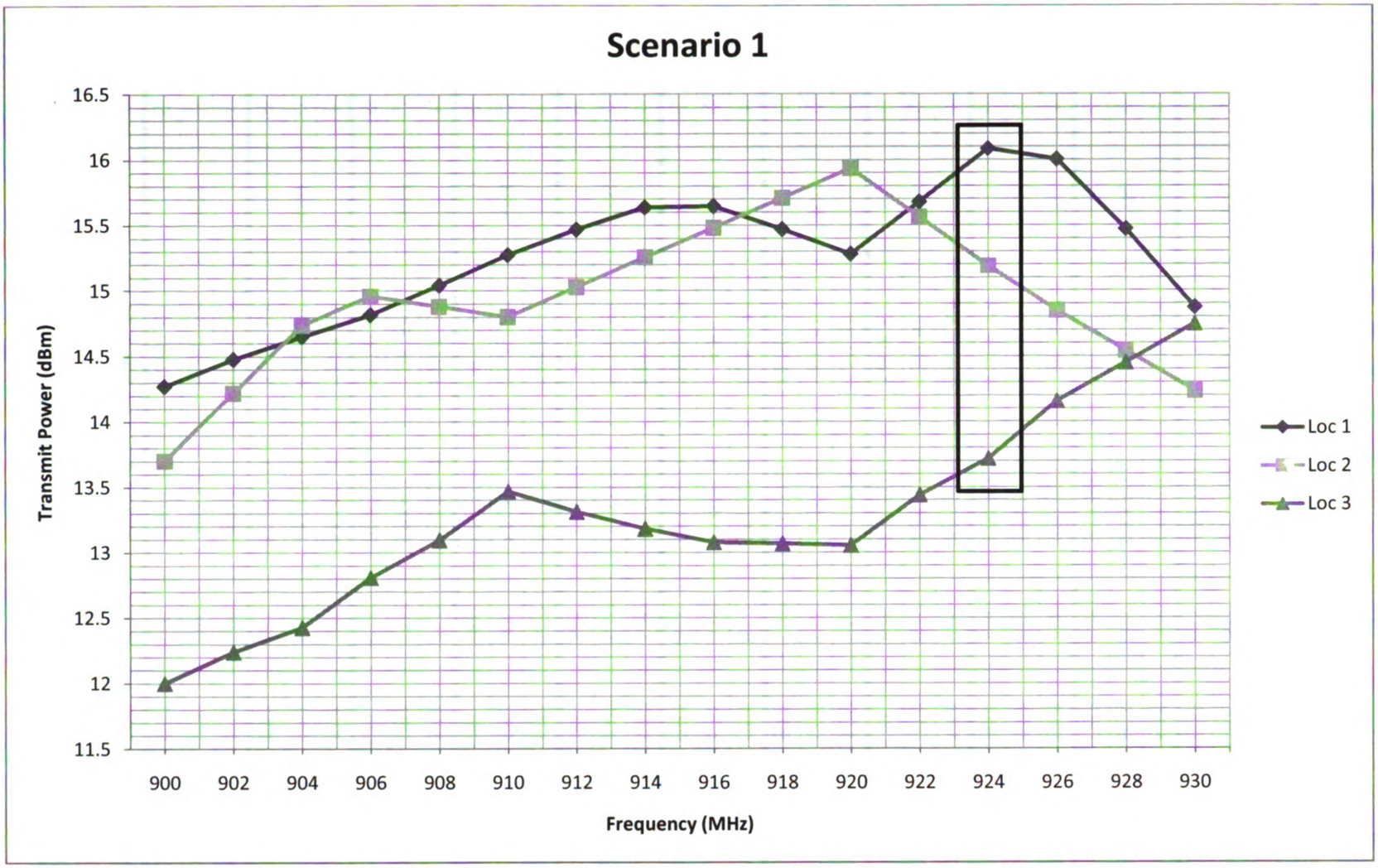


Figure 13: Scenario 1 - Transmit Power (dBm) vs. Frequency (MHz)

Table 5: Transmit Power (dBm) Scenario 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	14.27	0.07243	215	197.02	<.0001
1	2		13.7033	0.07243	215	189.2	<.0001
1	3		12	0.07243	215	165.68	<.0001
1	1	902	14.4767	0.06779	249	213.56	<.0001
1	2		14.22	0.06779	249	209.77	<.0001
1	3		12.24	0.06779	249	180.56	<.0001
1	1	904	14.65	0.08463	261	173.11	<.0001
1	2		14.7367	0.08463	261	174.14	<.0001
1	3		12.4267	0.08463	261	146.84	<.0001
1	1	906	14.8167	0.08354	258	177.36	<.0001
1	2		14.96	0.08354	258	179.08	<.0001
1	3		12.8067	0.08354	258	153.3	<.0001
1	1	908	15.04	0.0734	247	204.91	<.0001
1	2		14.88	0.0734	247	202.73	<.0001
1	3		13.0933	0.0734	247	178.38	<.0001
1	1	910	15.2733	0.08972	246	170.23	<.0001
1	2		14.8	0.08972	246	164.96	<.0001
1	3		13.4667	0.08972	246	150.09	<.0001
1	1	912	15.4683	0.0711	254	217.55	<.0001
1	2		15.0267	0.0711	254	211.34	<.0001
1	3		13.31	0.0711	254	187.2	<.0001
1	1	914	15.6367	0.08047	266	194.33	<.0001
1	2		15.2533	0.08047	266	189.56	<.0001
1	3		13.18	0.08047	266	163.8	<.0001
1	1	916	15.6433	0.08486	273	184.34	<.0001
1	2		15.48	0.08486	273	182.42	<.0001
1	3		13.0767	0.08486	273	154.1	<.0001
1	1	918	15.4667	0.09041	284	171.08	<.0001
1	2		15.7067	0.09041	284	173.73	<.0001
1	3		13.0667	0.09041	284	144.53	<.0001
1	1	920	15.2767	0.1165	295	131.17	<.0001
1	2		15.9333	0.1165	295	136.8	<.0001
1	3		13.0533	0.1165	295	112.08	<.0001
1	1	922	15.6767	0.09568	299	163.85	<.0001
1	2		15.56	0.09568	299	162.63	<.0001
1	3		13.4367	0.09568	299	140.44	<.0001

Table 5: Continued

1	1	924	16.0833	0.09556	295	168.31	<.0001
1	2		15.1867	0.09556	295	158.93	<.0001
1	3		13.7167	0.09556	295	143.54	<.0001
1	1	926	16	0.09565	285	167.28	<.0001
1	2		14.8467	0.09565	285	155.22	<.0001
1	3		14.1567	0.09565	285	148	<.0001
1	1	928	15.47	0.103	278	150.15	<.0001
1	2		14.54	0.103	278	141.12	<.0001
1	3		14.45	0.103	278	140.25	<.0001
1	1	930	14.87	0.1393	252	106.77	<.0001
1	2		14.2333	0.1393	252	102.19	<.0001
1	3		14.7467	0.1393	252	105.88	<.0001

Table 6: Transmit Power (dBm) Scenario 1 Comparisons

loc	Fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.5667	0.1024	215	5.53	<.0001	Tukey-Kramer	0.0002
1		3	2.27	0.1024	215	22.16	<.0001	Tukey-Kramer	<.0001
2		3	1.7033	0.1024	215	16.63	<.0001	Tukey-Kramer	<.0001
1	902	2	0.2567	0.09587	249	2.68	0.0079	Tukey-Kramer	0.9883
1		3	2.2367	0.09587	249	23.33	<.0001	Tukey-Kramer	<.0001
2		3	1.98	0.09587	249	20.65	<.0001	Tukey-Kramer	<.0001
1	904	2	-0.08667	0.1197	261	-0.72	0.4696	Tukey-Kramer	1
1		3	2.2233	0.1197	261	18.58	<.0001	Tukey-Kramer	<.0001
2		3	2.31	0.1197	261	19.3	<.0001	Tukey-Kramer	<.0001
1	906	2	-0.1433	0.1181	258	-1.21	0.2262	Tukey-Kramer	1
1		3	2.01	0.1181	258	17.01	<.0001	Tukey-Kramer	<.0001
2		3	2.1533	0.1181	258	18.23	<.0001	Tukey-Kramer	<.0001
1	908	2	0.16	0.1038	247	1.54	0.1245	Tukey-Kramer	1
1		3	1.9467	0.1038	247	18.75	<.0001	Tukey-Kramer	<.0001
2		3	1.7867	0.1038	247	17.21	<.0001	Tukey-Kramer	<.0001
1	910	2	0.4733	0.1269	246	3.73	0.0002	Tukey-Kramer	0.2972
1		3	1.8067	0.1269	246	14.24	<.0001	Tukey-Kramer	<.0001
2		3	1.3333	0.1269	246	10.51	<.0001	Tukey-Kramer	<.0001
1	912	2	0.4417	0.1006	254	4.39	<.0001	Tukey-Kramer	0.0345
1		3	2.1583	0.1006	254	21.46	<.0001	Tukey-Kramer	<.0001
2		3	1.7167	0.1006	254	17.07	<.0001	Tukey-Kramer	<.0001
1	914	2	0.3833	0.1138	266	3.37	0.0009	Tukey-Kramer	0.618
1		3	2.4567	0.1138	266	21.59	<.0001	Tukey-Kramer	<.0001
2		3	2.0733	0.1138	266	18.22	<.0001	Tukey-Kramer	<.0001
1	916	2	0.1633	0.12	273	1.36	0.1746	Tukey-Kramer	1
1		3	2.5667	0.12	273	21.39	<.0001	Tukey-Kramer	<.0001
2		3	2.4033	0.12	273	20.03	<.0001	Tukey-Kramer	<.0001
1	918	2	-0.24	0.1279	284	-1.88	0.0615	Tukey-Kramer	1
1		3	2.4	0.1279	284	18.77	<.0001	Tukey-Kramer	<.0001
2		3	2.64	0.1279	284	20.65	<.0001	Tukey-Kramer	<.0001
1	920	2	-0.6567	0.1647	295	-3.99	<.0001	Tukey-Kramer	0.1442
1		3	2.2233	0.1647	295	13.5	<.0001	Tukey-Kramer	<.0001
2		3	2.88	0.1647	295	17.49	<.0001	Tukey-Kramer	<.0001
1	922	2	0.1167	0.1353	299	0.86	0.3892	Tukey-Kramer	1
1		3	2.24	0.1353	299	16.55	<.0001	Tukey-Kramer	<.0001
2		3	2.1233	0.1353	299	15.69	<.0001	Tukey-Kramer	<.0001

Table 6: Continued

1	924	2	0.8967	0.1351	295	6.64	<.0001	Tukey-Kramer	<.0001
1		3	2.3667	0.1351	295	17.51	<.0001	Tukey-Kramer	<.0001
2		3	1.47	0.1351	295	10.88	<.0001	Tukey-Kramer	<.0001
1	926	2	1.1533	0.1353	285	8.53	<.0001	Tukey-Kramer	<.0001
1		3	1.8433	0.1353	285	13.63	<.0001	Tukey-Kramer	<.0001
2		3	0.69	0.1353	285	5.1	<.0001	Tukey-Kramer	0.0015
1	928	2	0.93	0.1457	278	6.38	<.0001	Tukey-Kramer	<.0001
1		3	1.02	0.1457	278	7	<.0001	Tukey-Kramer	<.0001
2		3	0.09	0.1457	278	0.62	0.5373	Tukey-Kramer	1
1	930	2	0.6367	0.197	252	3.23	0.0014	Tukey-Kramer	0.7405
1		3	0.1233	0.197	252	0.63	0.5318	Tukey-Kramer	1
2		3	-0.5133	0.197	252	-2.61	0.0097	Tukey-Kramer	0.9939

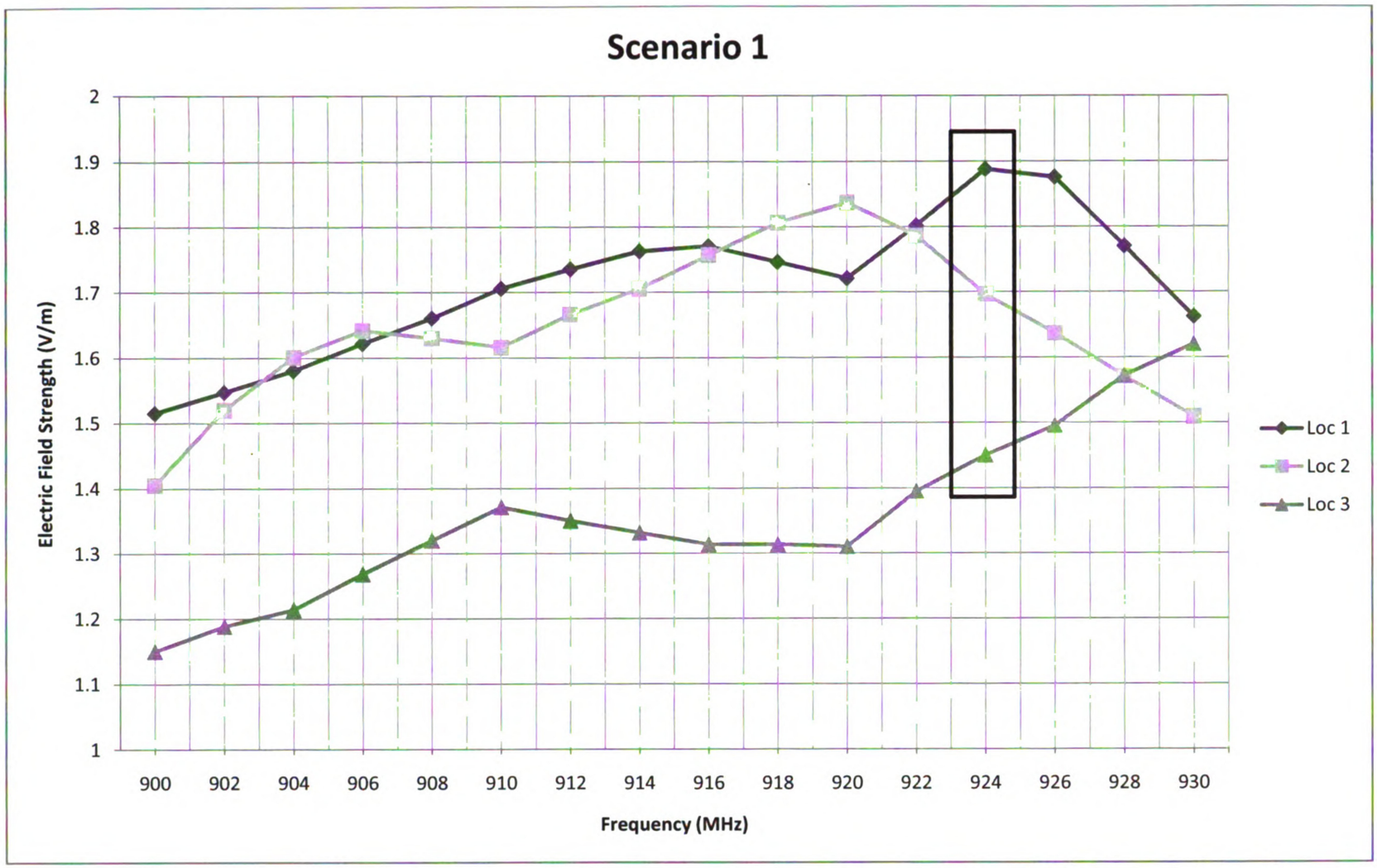


Figure 14: Scenario 1 - Electric Field Strength (V/m) vs. Frequency (MHz)

Scenario 1

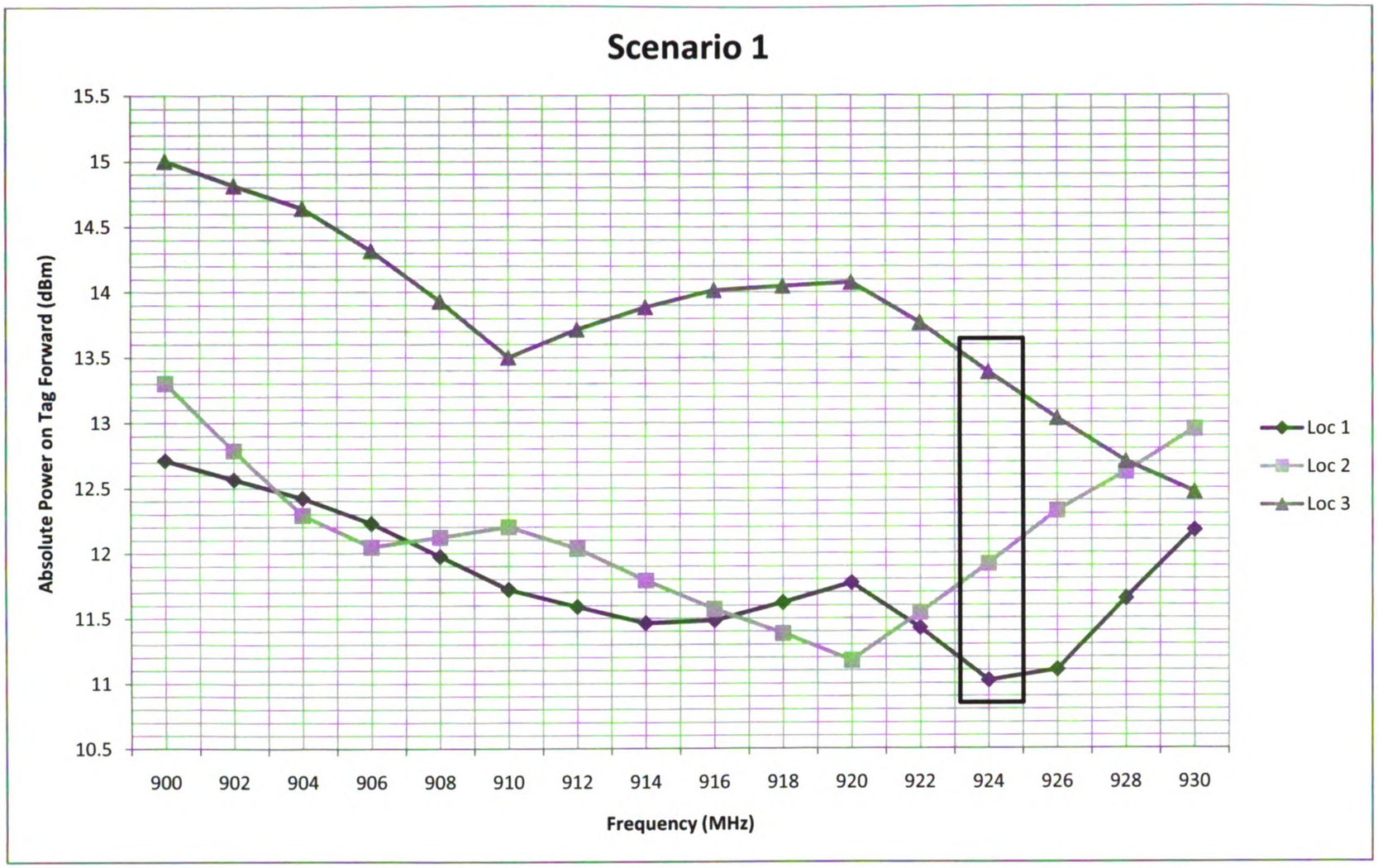
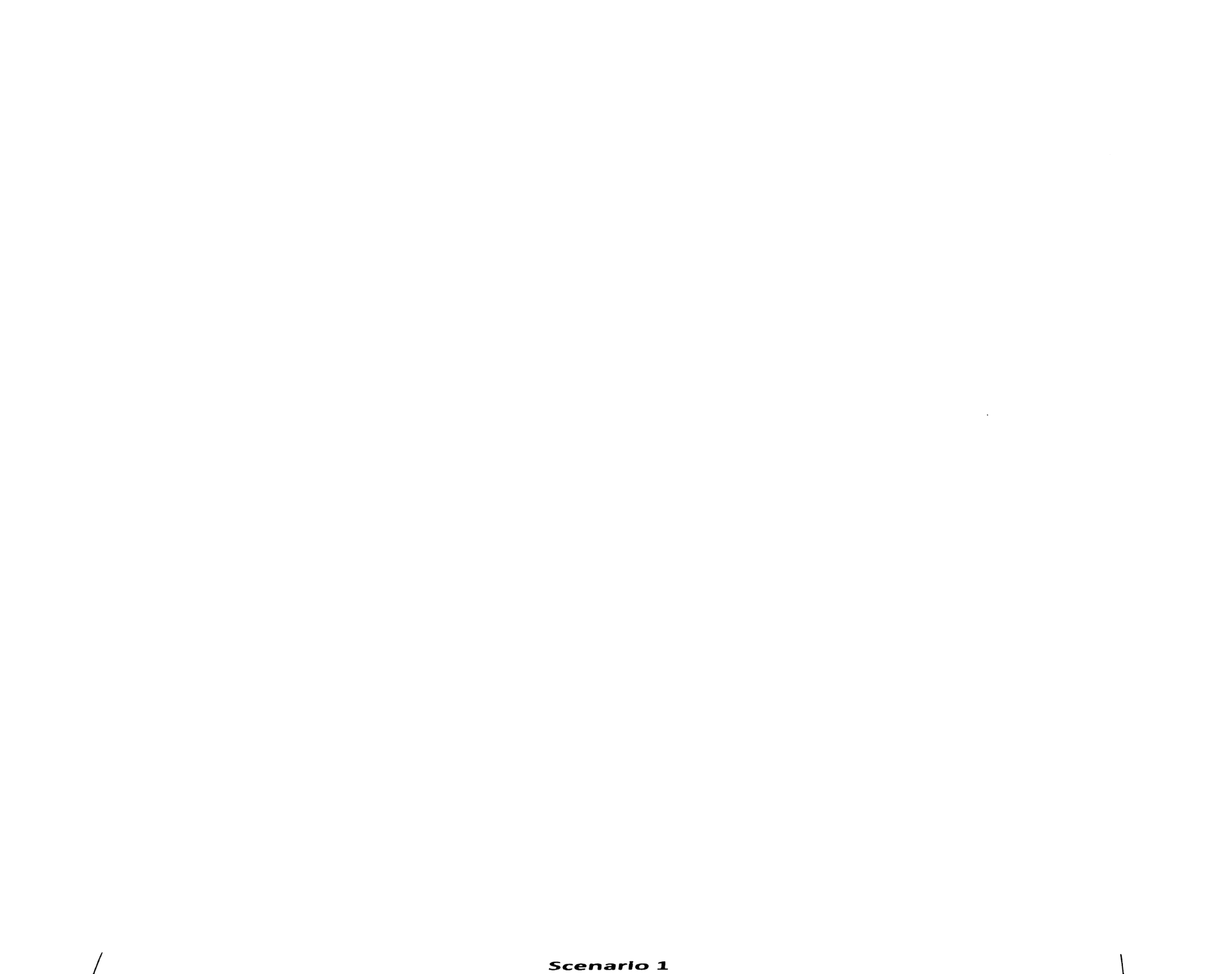


Figure 15: Scenario 1 - Absolute Power on Tag Forward (dBm) vs. Frequency (MHz)


Scenario 1

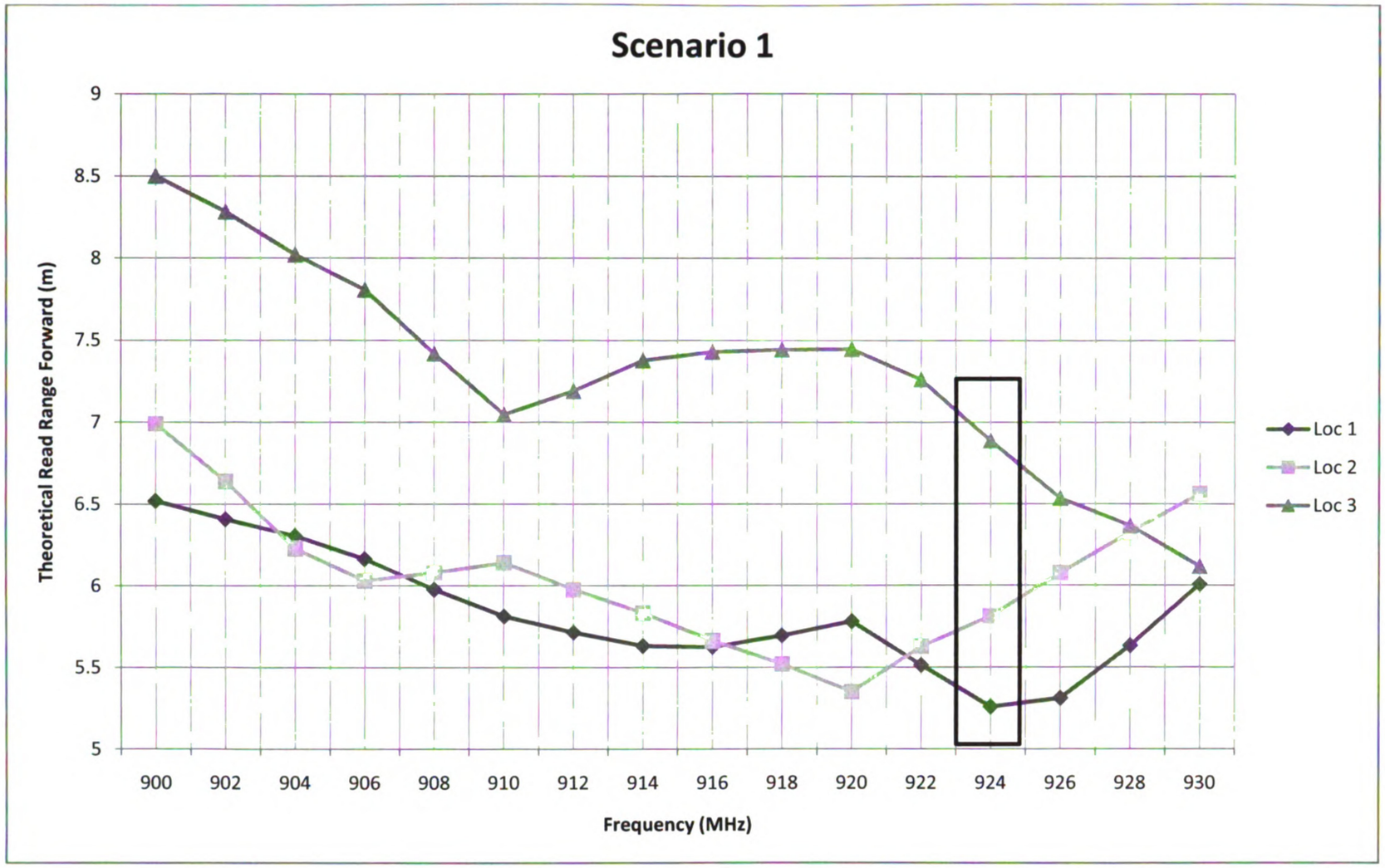


Figure 16: Theoretical Read Range Forward (m) vs. Frequency (MHz)

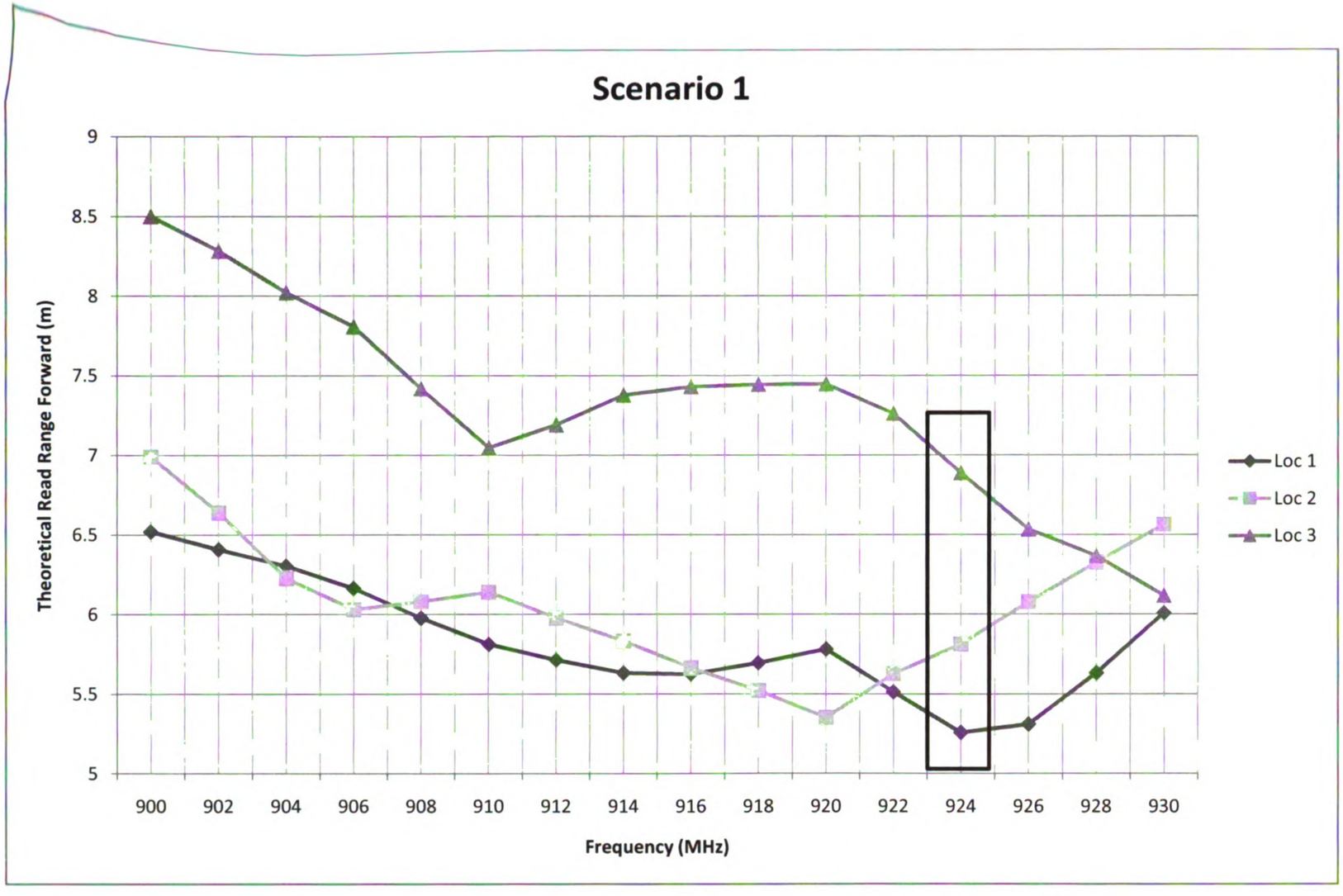


Figure 16: Theoretical Read Range Forward (m) vs. Frequency (MHz)

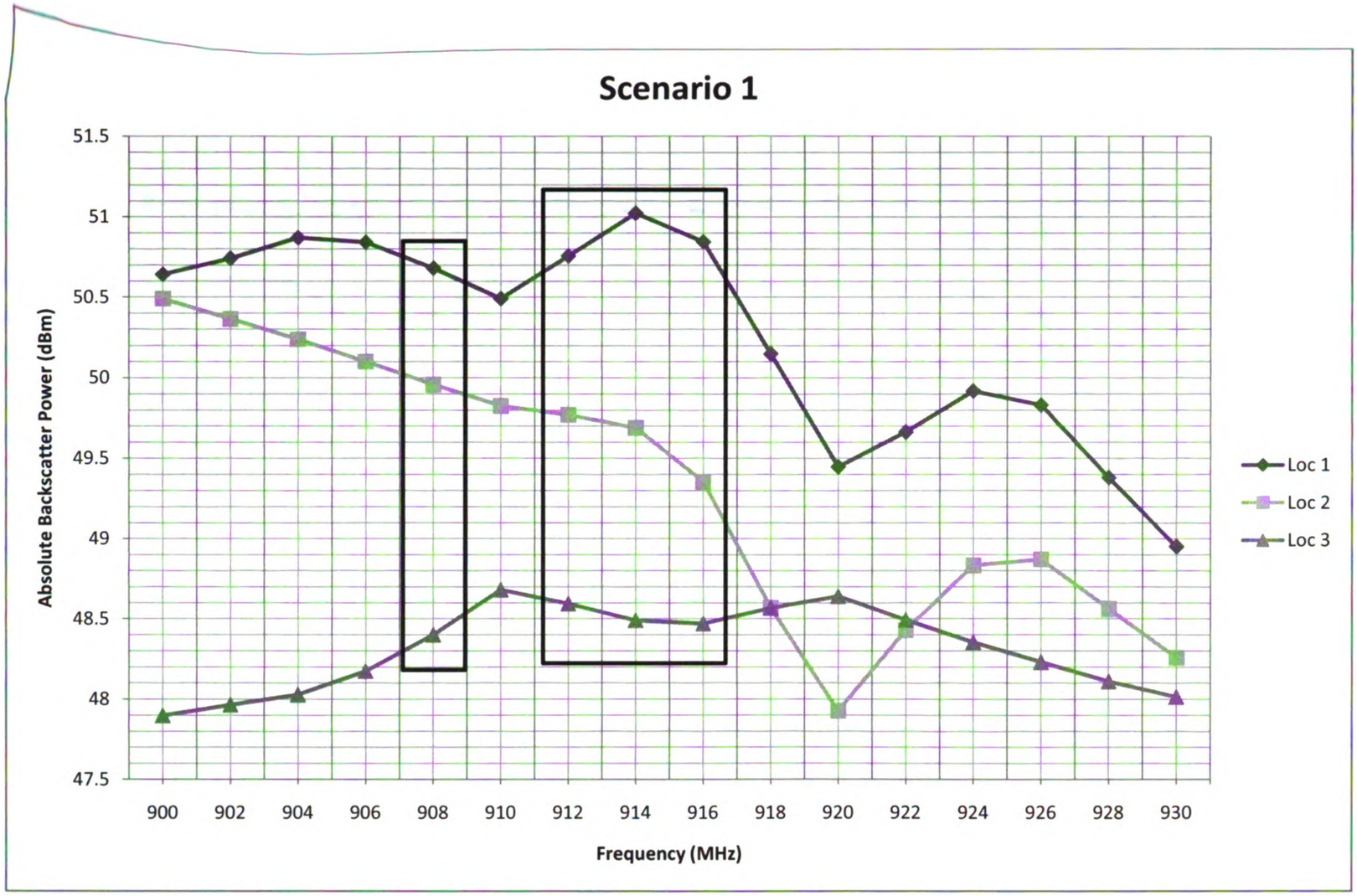


Figure 17: Scenario 1 - Absolute Backscatter Power (dBm) vs. Frequency (MHz)

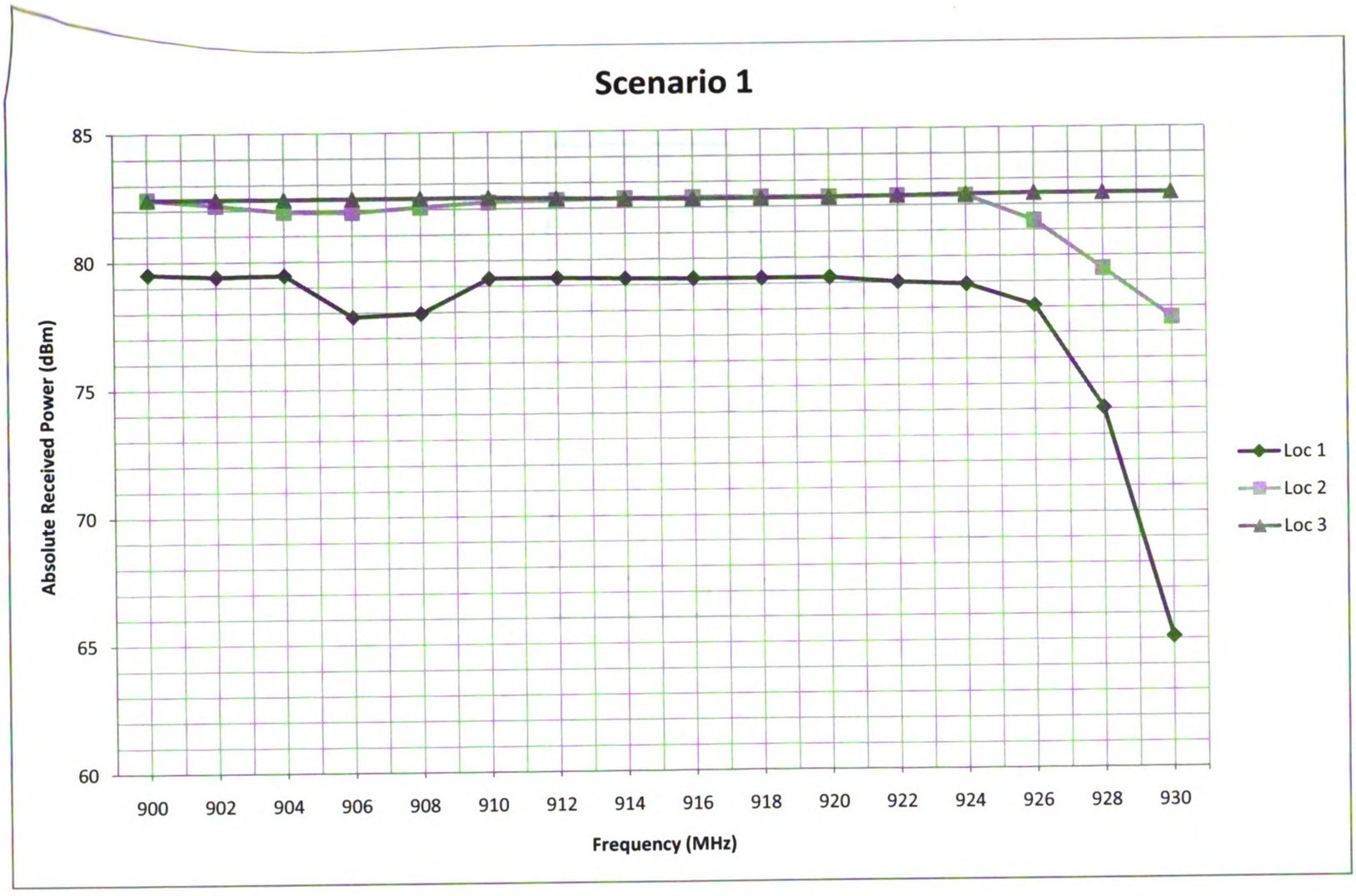


Figure 18: Scenario 1 - Absolute Received Power (dBm) vs. Frequency (MHz)

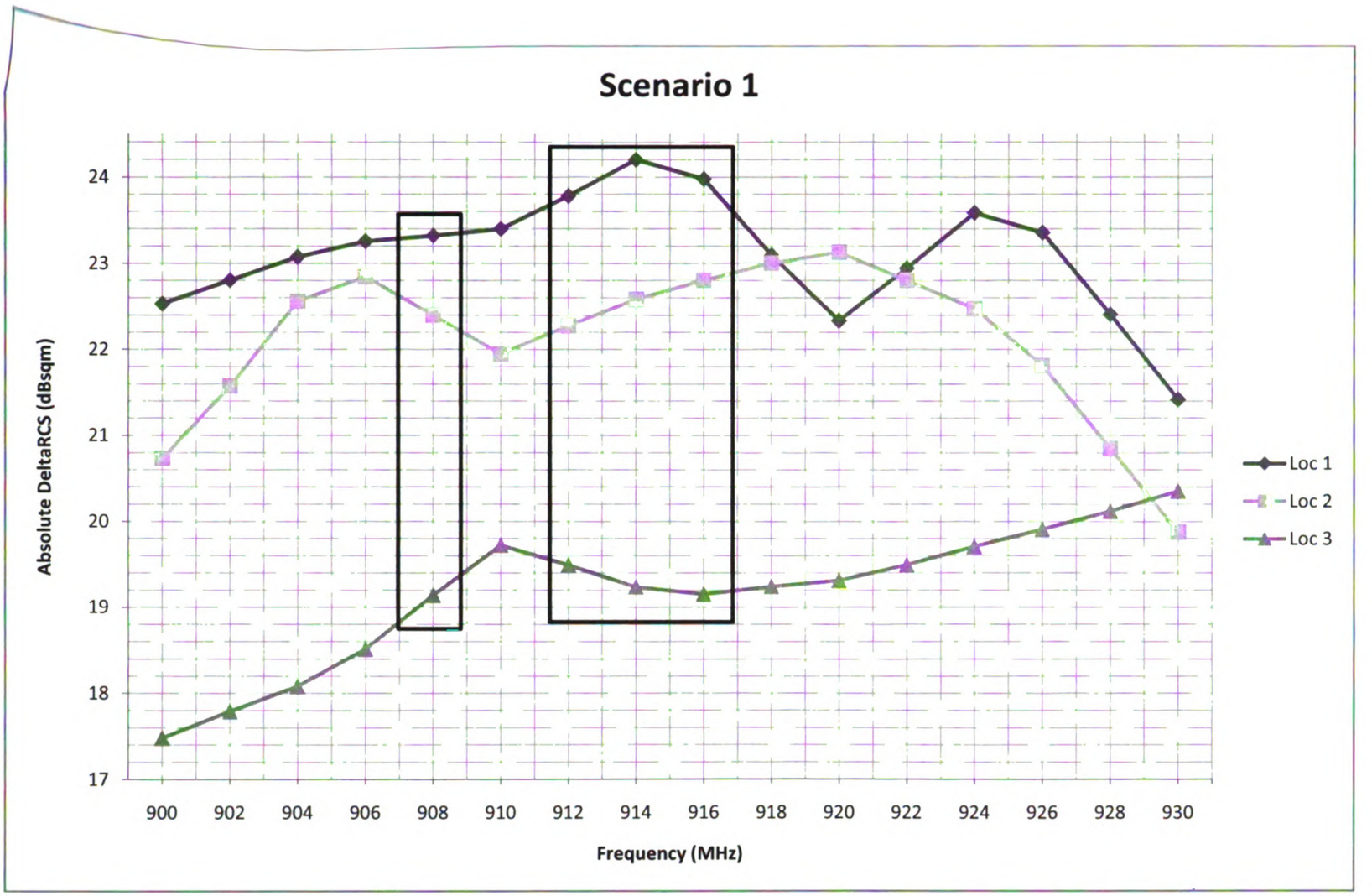


Figure 19: Scenario 1 - Absolute Delta RCS (dBsqm) vs. Frequency (MHz)

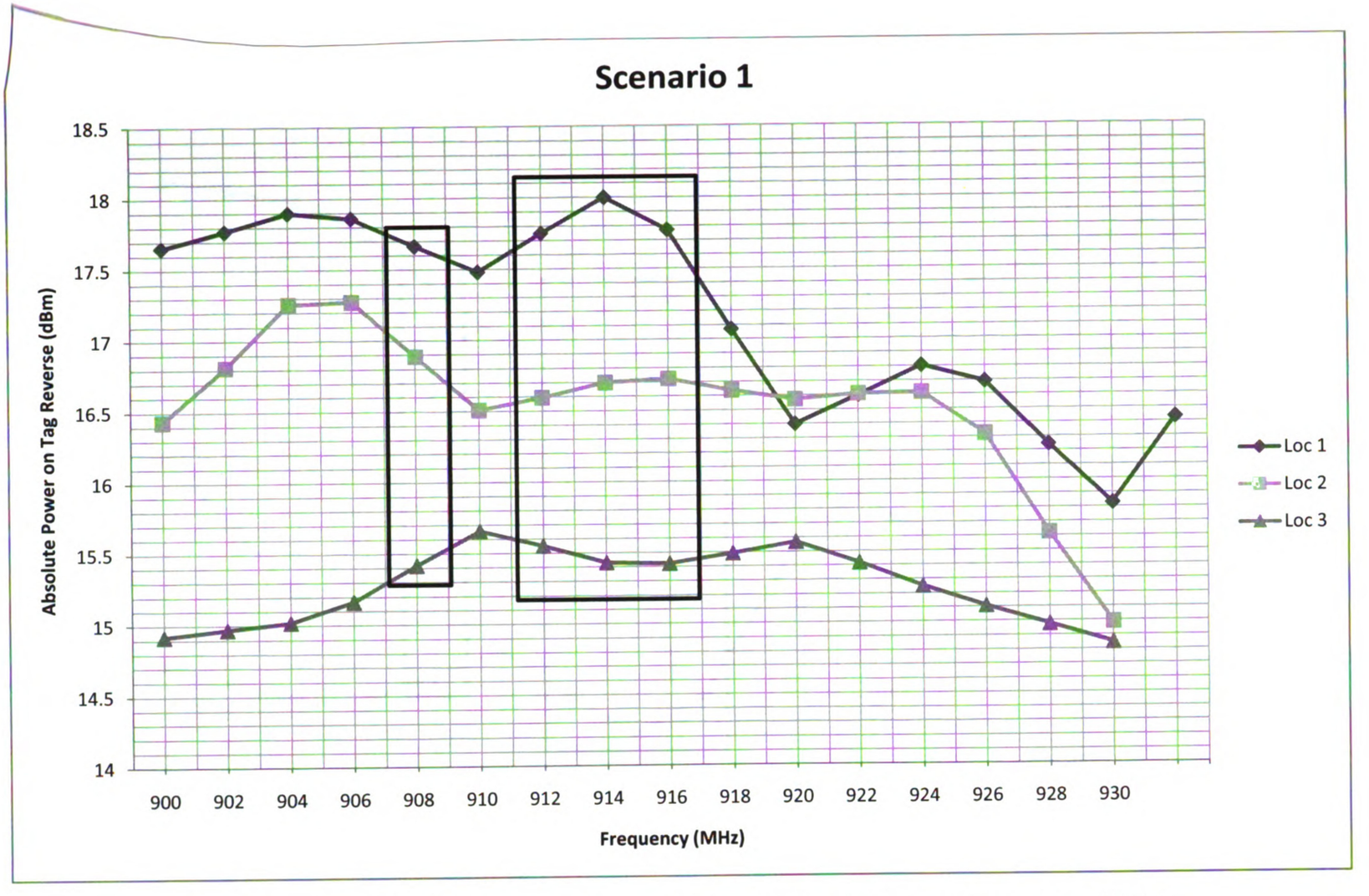


Figure 20: Scenario 1 - Absolute Power on Tag Reverse (dBm) vs. Frequency (MHz)

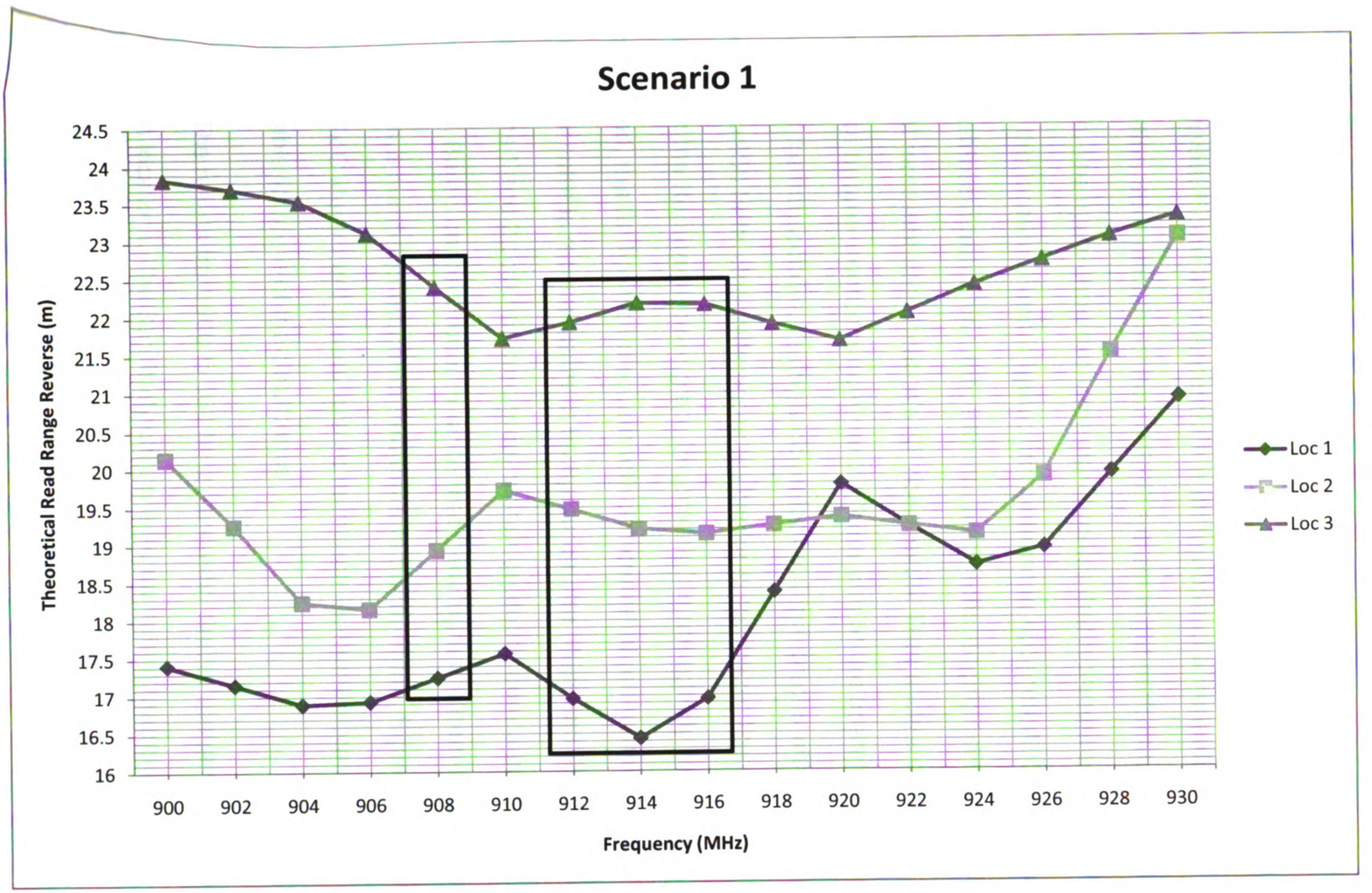


Figure 21: Scenario 1 - Theoretical Read Range Reverse (m) vs. Frequency (MHz)

Scenario 1

The received power measurements showed like differences according to data analysis. Figure 31 in Appendix A is an example of a misleading visualization representation of how a RFID system might perform under this condition. The figure show two large signal spikes that represent ambient RF noise at this location. Similar figures can be found in Appendix A. Constructed by Voyantic Measurement Unit, these figures are graphs ranging from 800 to 1,000 MHz that represent each location's RF noise levels. They show a distinct difference between locations however the focus was on the operating frequency range of the transponder. Taking a closer look at these graphs within the range of 900 to 930 MHz, clear differences are harder to recognize. The seemingly flat line from the Received Power graph in Location 3 is not actually flat. Instead, if magnified, this flat line would appear with demonstrated peaks and valleys. This low-level noise is representative of background noise (Weisman, 2002). Locations 1 and 2 both had continuous signals produced from unconfirmed sources. Based on the frequency range that these signals appeared, and the locations, a number of educated assessments can be made. Figures 40-41 in Appendix C identify cell towers located near each location that could be responsible for some of the disturbance.

The results from 900 to 930 MHz bandwidth directly compared differences between locations. The Sensitivity units shared multiple frequencies where significant differences were identified. However, there was a limited range of

frequencies where all three locations showed differences. At these frequencies, conclusions about the scenarios and locations can be made valid.

The Backscatter units also have a similar frequency range that allows for similar valid comparisons as well. In some cases, a specific frequency or range of frequencies contain significant differences and was common among all measurement units. This allowed for direct comparisons among both sensitivity and Backscatter units. However, this was not the case with these particular results.

The Sensitivity units displayed a common frequency at 924 MHz (Tables 5-6 & 19-24 and Figures 13-16), while Backscatter units shared the frequencies of 908 and 912 to 916 MHz (Tables 25-34 and Figures 17-21). 924 MHz was the only frequency that appeared with significant differences among all locations for Sensitivity units.

Tables 7 and 8, displays the performance evaluation of the measurement units in Scenario 1 within specific frequency ranges. Based on the causal relationship recreated in Tables 9 -10, communication should be at a peak when the Transmit Power, Electric Field Strength and Power on Tag Forward estimations are ranked "low". If these conditions are met, then a "high" estimation value should appear from the theoretical read range forward. The rankings given in Tables 7 and 8 represent the best estimation value (1st) to the worst (3rd). Location 3 matches the ideal conditions for all sensitivity and backscatter

estimations by receiving the 1st place ranking with all measurement units.

Locations 1 and 2 were ranked 3rd and 2nd respectfully.

Table 7: Scenario 1 - Sensitivity Unit Performance Summary at 924 MHz

	TP	EFS	POTF	TRRF
Values	Low	Low	Low	High
Rank: 1st	Location 3	Location 3	Location 3	Location 3
Values	Medium	Medium	Medium	Medium
Rank: 2nd	Location 2	Location 2	Location 2	Location 2
Values	High	High	High	Low
Rank: 3rd	Location 1	Location 1	Location 1	Location 1

Table 8: Scenario 1 - Backscatter Unit Performance Summary at 908, 912, 914, and 916 MHz

	BP	Delta RCS	POTR	TRRR	RP
Values	High	High	High	High	Low
Rank: 1st Status: Good	Location 3	Location 3	Location 3	Location 3	Location 3
Values	Medium	Medium	Medium	Medium	Low
Rank: 2nd Status: Good	Location 2	Location 2	Location 2	Location 2	Location 2
Values	Low	Low	Low	Low	Low
Rank: 3rd Status: Good	Location 1	Location 1	Location 1	Location 1	Location 1

Table 9: Ideal Outcome Based on Causal Relationship for Sensitivity Units at 924 MHz

924 MHz	If	TP	and	EFS	and	POTF	Then,	TRRF
Values		Low		Low		Low		High

Table 10: Ideal Outcome Based on Causal Relationship for Backscatter Units at 908, 912, 914, and 916 MHz

908, 912 to 916 MHz	If	BP	and	Delta RCS	and	POTR	Then,	TRRR
Values		High		High		High		High

It is important to note that the initial rankings from Tables 7 and 8 are not always representative of all the frequency within the transponder's operating frequency range. Looking at the overall performance and the number of better quality estimation values through the operating frequency of 900 to 930 MHz, Tables 7 and 8 demonstrates Location 3 received an overall 1st place ranking while Locations 1 and 2 received the rankings of 3rd and 2nd respectively.

Table 11 presents the number of differences and similarities among all 16 operating frequencies. The differences column represents significant differences one location had between the other two locations. Similarities represent having at least one other location at that frequency that does not display a significant difference in estimation value. In theory, the higher number of differences showed less equivalent comparisons among other locations, thus displaying the purity of the initial rankings shown in the Tables 7 and 8. For example, looking at the Transmit Power in Location 2 at 924 MHz from Tables 7, the estimation value

ranked 2nd best out of the three locations. However, the number of differences and similarities illustrates 12 out of 16 frequencies had no significant differences between Location 1 or 3. This showed that the 2nd place ranking at 924 MHz does not actually represent the overall result throughout the 900 to 930 MHz bandwidth.

Table 11: Scenario 1 - Number of Differences and Similarities for Operating Frequency Range

	Location 1		Location 2		Location 3	
	# Differences	# Similarities	# Differences	# Similarities	# Differences	# Similarities
TP	5	11	4	12	14	2
EFS	4	12	2	14	13	3
POTF	4	12	3	13	2	14
TRRF	5	11	5	11	14	2
BP	10	6	6	10	10	6
Delta RCS	14	2	13	3	15	1
POTR	10	6	9	7	15	1
TRRR	7	9	7	9	13	3

Scenario 2 – Combination of Ambient and Identified RF Noise

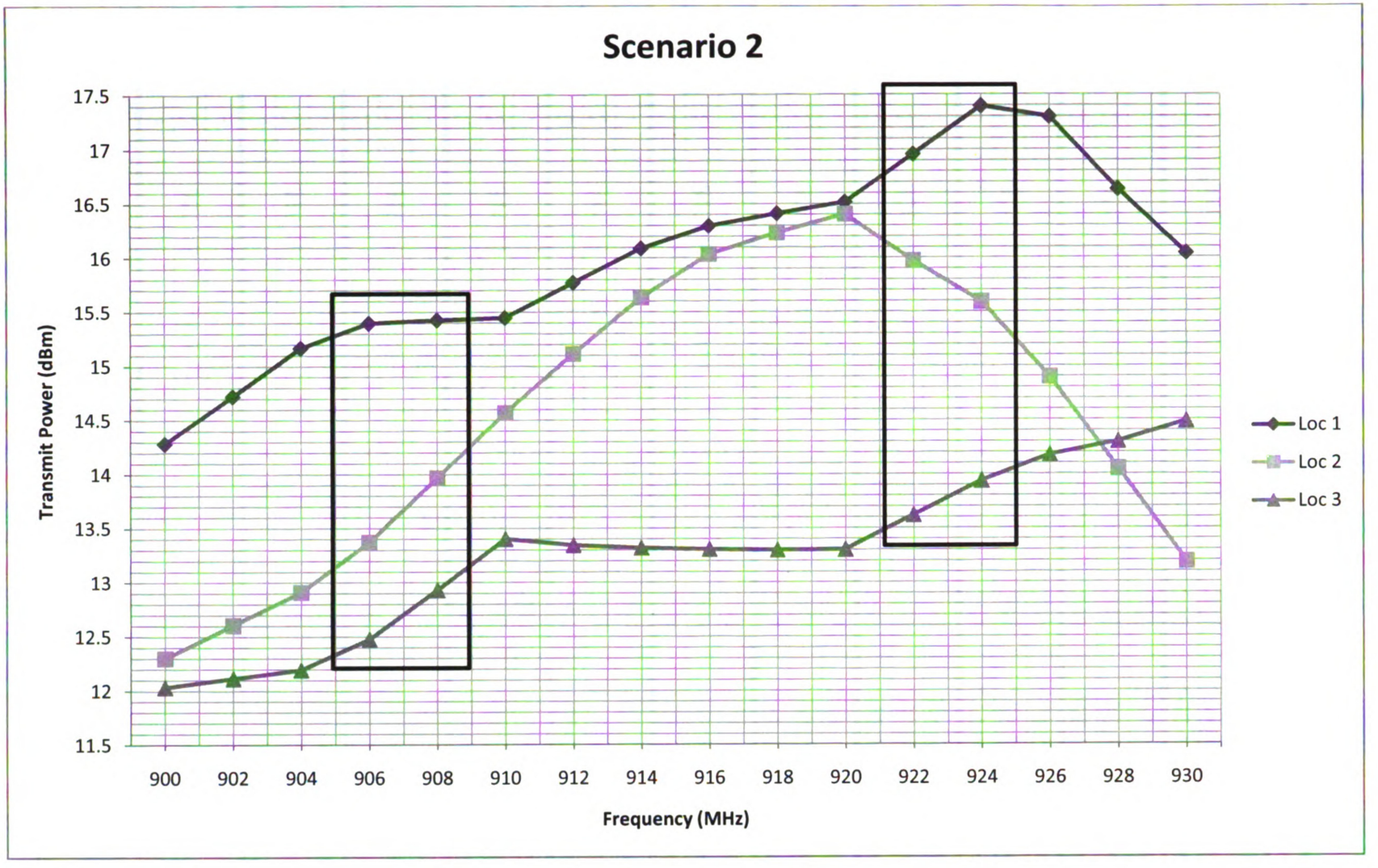


Figure 22: Scenario 2 - Transmit Power (dBm) vs. Frequency (MHz)

Table 12: Transmit Power (dBm) Scenario 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
2	1	900	14.2833	0.07243	215	197.2	<.0001
2	2		12.3	0.07243	215	169.82	<.0001
2	3		12.0333	0.07243	215	166.14	<.0001
2	1	902	14.72	0.06779	249	217.15	<.0001
2	2		12.6067	0.06779	249	185.97	<.0001
2	3		12.1133	0.06779	249	178.7	<.0001
2	1	904	15.1667	0.08463	261	179.22	<.0001
2	2		12.91	0.08463	261	152.55	<.0001
2	3		12.1933	0.08463	261	144.08	<.0001
2	1	906	15.3967	0.08354	258	184.3	<.0001
2	2		13.37	0.08354	258	160.04	<.0001
2	3		12.4767	0.08354	258	149.35	<.0001
2	1	908	15.425	0.0734	247	210.15	<.0001
2	2		13.9667	0.0734	247	190.28	<.0001
2	3		12.93	0.0734	247	176.16	<.0001
2	1	910	15.4467	0.08972	246	172.16	<.0001
2	2		14.5667	0.08972	246	162.35	<.0001
2	3		13.4	0.08972	246	149.35	<.0001
2	1	912	15.77	0.0711	254	221.79	<.0001
2	2		15.1117	0.0711	254	212.53	<.0001
2	3		13.3433	0.0711	254	187.66	<.0001
2	1	914	16.0867	0.08047	266	199.92	<.0001
2	2		15.6333	0.08047	266	194.28	<.0001
2	3		13.3167	0.08047	266	165.49	<.0001
2	1	916	16.2933	0.08486	273	192	<.0001
2	2		16.0333	0.08486	273	188.94	<.0001
2	3		13.3033	0.08486	273	156.77	<.0001
2	1	918	16.4067	0.09041	284	181.48	<.0001
2	2		16.23	0.09041	284	179.52	<.0001
2	3		13.2967	0.09041	284	147.08	<.0001
2	1	920	16.5133	0.1165	295	141.78	<.0001
2	2		16.4	0.1165	295	140.81	<.0001
2	3		13.3	0.1165	295	114.19	<.0001
2	1	922	16.9533	0.09568	299	177.19	<.0001
2	2		15.97	0.09568	299	166.92	<.0001
2	3		13.6167	0.09568	299	142.32	<.0001

Table 12: Continued

2	1	924	17.3917	0.09556	295	182	<.0001
2	2		15.59	0.09556	295	163.15	<.0001
2	3		13.9333	0.09556	295	145.81	<.0001
2	1	926	17.295	0.09565	285	180.81	<.0001
2	2		14.8933	0.09565	285	155.71	<.0001
2	3		14.1733	0.09565	285	148.18	<.0001
2	1	928	16.6283	0.103	278	161.39	<.0001
2	2		14.045	0.103	278	136.32	<.0001
2	3		14.2967	0.103	278	138.76	<.0001
2	1	930	16.035	0.1393	252	115.13	<.0001
2	2		13.1867	0.1393	252	94.68	<.0001
2	3		14.4833	0.1393	252	103.99	<.0001

Table 13: Transmit Power (dBm) Scenario 2 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	1.9833	0.1024	215	19.36	<.0001	Tukey-Kramer	<.0001
1		3	2.25	0.1024	215	21.97	<.0001	Tukey-Kramer	<.0001
2		3	0.2667	0.1024	215	2.6	0.0099	Tukey-Kramer	0.994
1	902	2	2.1133	0.09587	249	22.04	<.0001	Tukey-Kramer	<.0001
1		3	2.6067	0.09587	249	27.19	<.0001	Tukey-Kramer	<.0001
2		3	0.4933	0.09587	249	5.15	<.0001	Tukey-Kramer	0.0012
1	904	2	2.2567	0.1197	261	18.86	<.0001	Tukey-Kramer	<.0001
1		3	2.9733	0.1197	261	24.84	<.0001	Tukey-Kramer	<.0001
2		3	0.7167	0.1197	261	5.99	<.0001	Tukey-Kramer	<.0001
1	906	2	2.0267	0.1181	258	17.15	<.0001	Tukey-Kramer	<.0001
1		3	2.92	0.1181	258	24.72	<.0001	Tukey-Kramer	<.0001
2		3	0.8933	0.1181	258	7.56	<.0001	Tukey-Kramer	<.0001
1	908	2	1.4583	0.1038	247	14.05	<.0001	Tukey-Kramer	<.0001
1		3	2.495	0.1038	247	24.04	<.0001	Tukey-Kramer	<.0001
2		3	1.0367	0.1038	247	9.99	<.0001	Tukey-Kramer	<.0001
1	910	2	0.88	0.1269	246	6.94	<.0001	Tukey-Kramer	<.0001
1		3	2.0467	0.1269	246	16.13	<.0001	Tukey-Kramer	<.0001
2		3	1.1667	0.1269	246	9.19	<.0001	Tukey-Kramer	<.0001
1	912	2	0.6583	0.1006	254	6.55	<.0001	Tukey-Kramer	<.0001
1		3	2.4267	0.1006	254	24.13	<.0001	Tukey-Kramer	<.0001
2		3	1.7683	0.1006	254	17.59	<.0001	Tukey-Kramer	<.0001
1	914	2	0.4533	0.1138	266	3.98	<.0001	Tukey-Kramer	0.1456
1		3	2.77	0.1138	266	24.34	<.0001	Tukey-Kramer	<.0001
2		3	2.3167	0.1138	266	20.36	<.0001	Tukey-Kramer	<.0001
1	916	2	0.26	0.12	273	2.17	0.0311	Tukey-Kramer	1
1		3	2.99	0.12	273	24.91	<.0001	Tukey-Kramer	<.0001
2		3	2.73	0.12	273	22.75	<.0001	Tukey-Kramer	<.0001
1	918	2	0.1767	0.1279	284	1.38	0.1681	Tukey-Kramer	1
1		3	3.11	0.1279	284	24.32	<.0001	Tukey-Kramer	<.0001
2		3	2.9333	0.1279	284	22.94	<.0001	Tukey-Kramer	<.0001
1	920	2	0.1133	0.1647	295	0.69	0.4919	Tukey-Kramer	1
1		3	3.2133	0.1647	295	19.51	<.0001	Tukey-Kramer	<.0001
2		3	3.1	0.1647	295	18.82	<.0001	Tukey-Kramer	<.0001
1	922	2	0.9833	0.1353	299	7.27	<.0001	Tukey-Kramer	<.0001
1		3	3.3367	0.1353	299	24.66	<.0001	Tukey-Kramer	<.0001
2		3	2.3533	0.1353	299	17.39	<.0001	Tukey-Kramer	<.0001

Table 13: Continued

1	924	2	1.8017	0.1351	295	13.33	<.0001	Tukey-Kramer	<.0001
1		3	3.4583	0.1351	295	25.59	<.0001	Tukey-Kramer	<.0001
2		3	1.6567	0.1351	295	12.26	<.0001	Tukey-Kramer	<.0001
1	926	2	2.4017	0.1353	285	17.75	<.0001	Tukey-Kramer	<.0001
1		3	3.1217	0.1353	285	23.08	<.0001	Tukey-Kramer	<.0001
2		3	0.72	0.1353	285	5.32	<.0001	Tukey-Kramer	0.0005
1	928	2	2.5833	0.1457	278	17.73	<.0001	Tukey-Kramer	<.0001
1		3	2.3317	0.1457	278	16	<.0001	Tukey-Kramer	<.0001
2		3	-0.2517	0.1457	278	-1.73	0.0852	Tukey-Kramer	1
1	930	2	2.8483	0.197	252	14.46	<.0001	Tukey-Kramer	<.0001
1		3	1.5517	0.197	252	7.88	<.0001	Tukey-Kramer	<.0001
2		3	-1.2967	0.197	252	-6.58	<.0001	Tukey-Kramer	<.0001

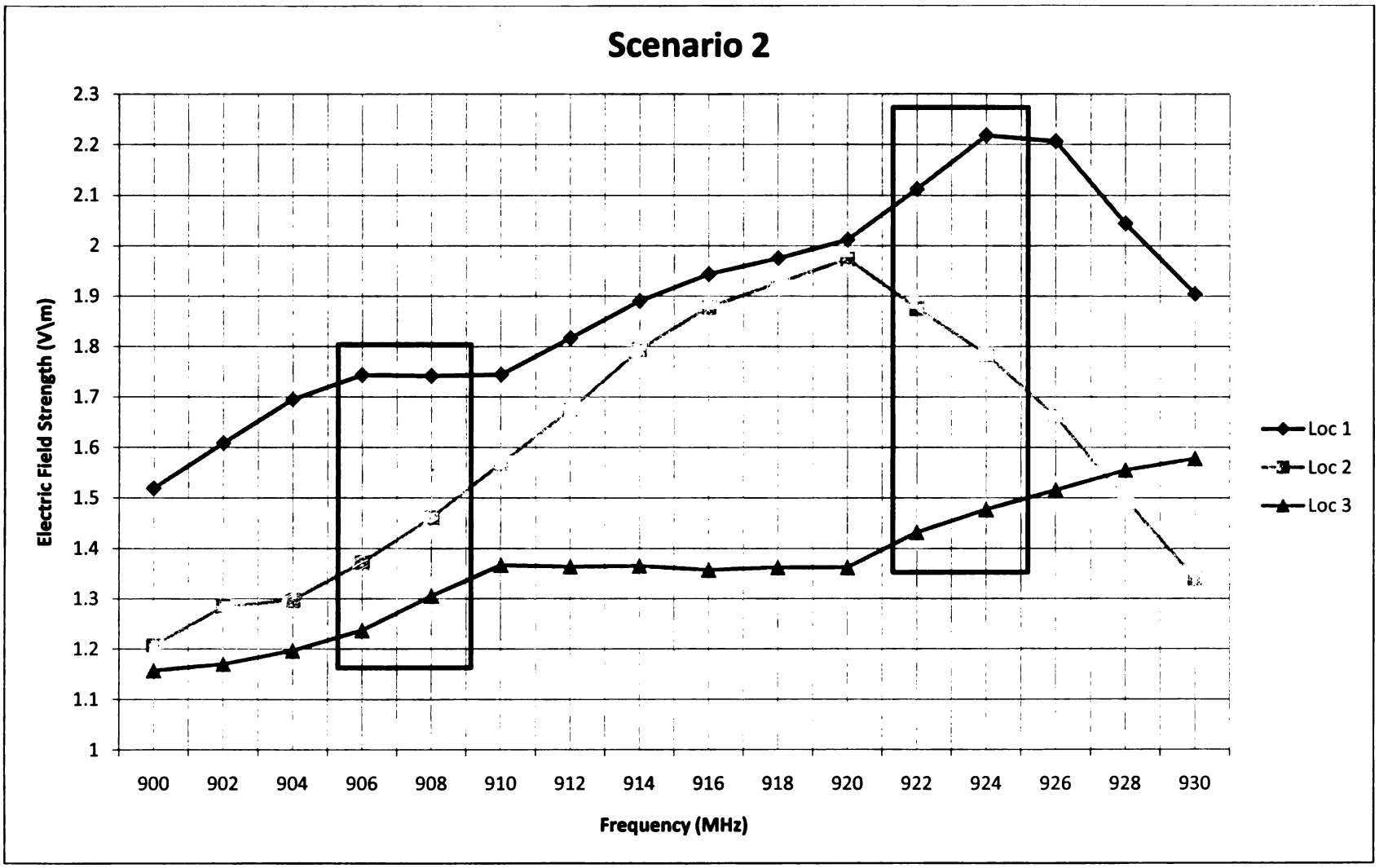


Figure 23: Scenario 2 - Electric Field Strength (V/m) vs. Frequency (MHz)

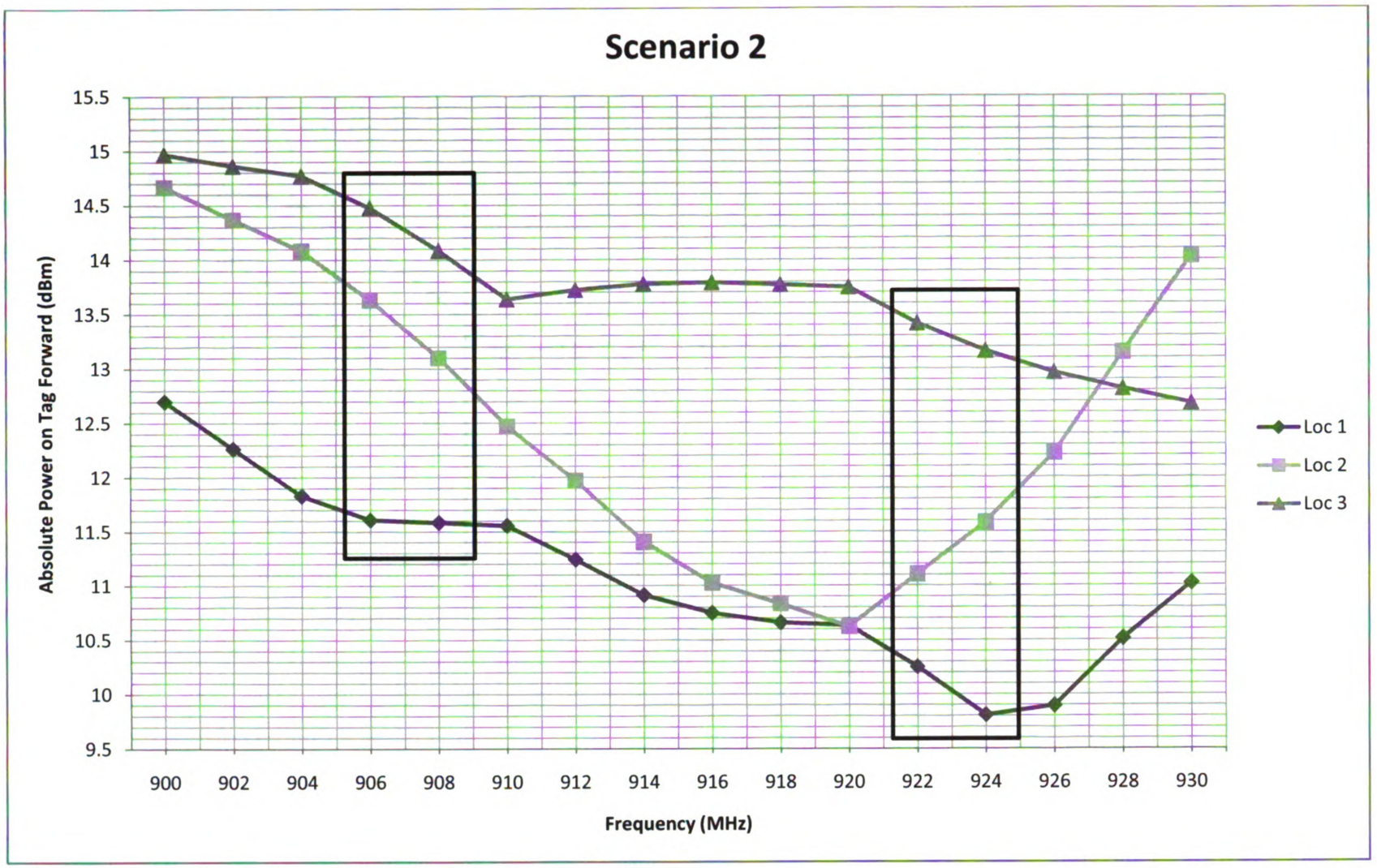


Figure 24: Scenario 2 - Absolute Power on Tag Forward (dBm) vs. Frequency (MHz)

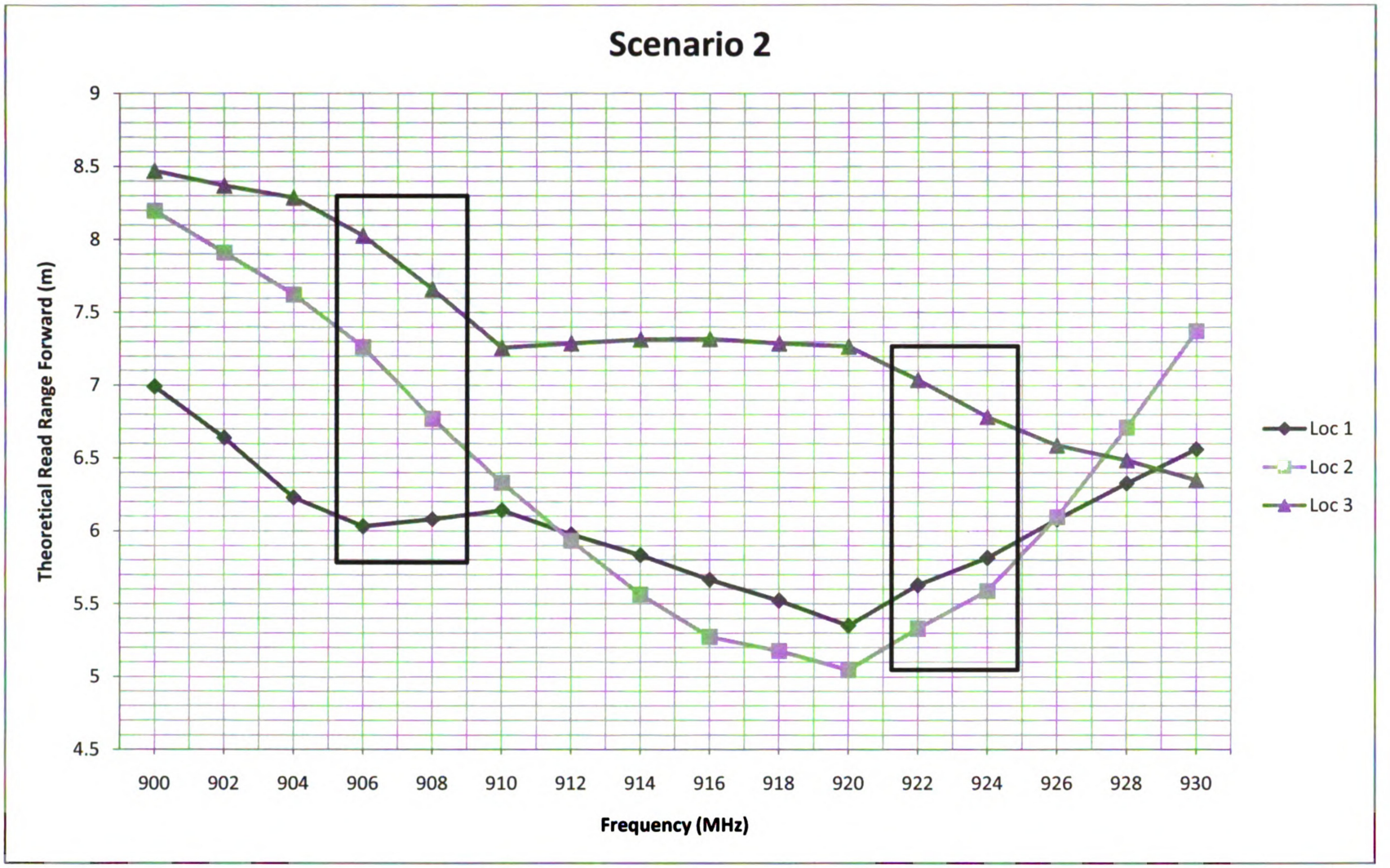


Figure 25: Scenario 2 - Theoretical Read Range Forward (m) vs. Frequency (MHz)

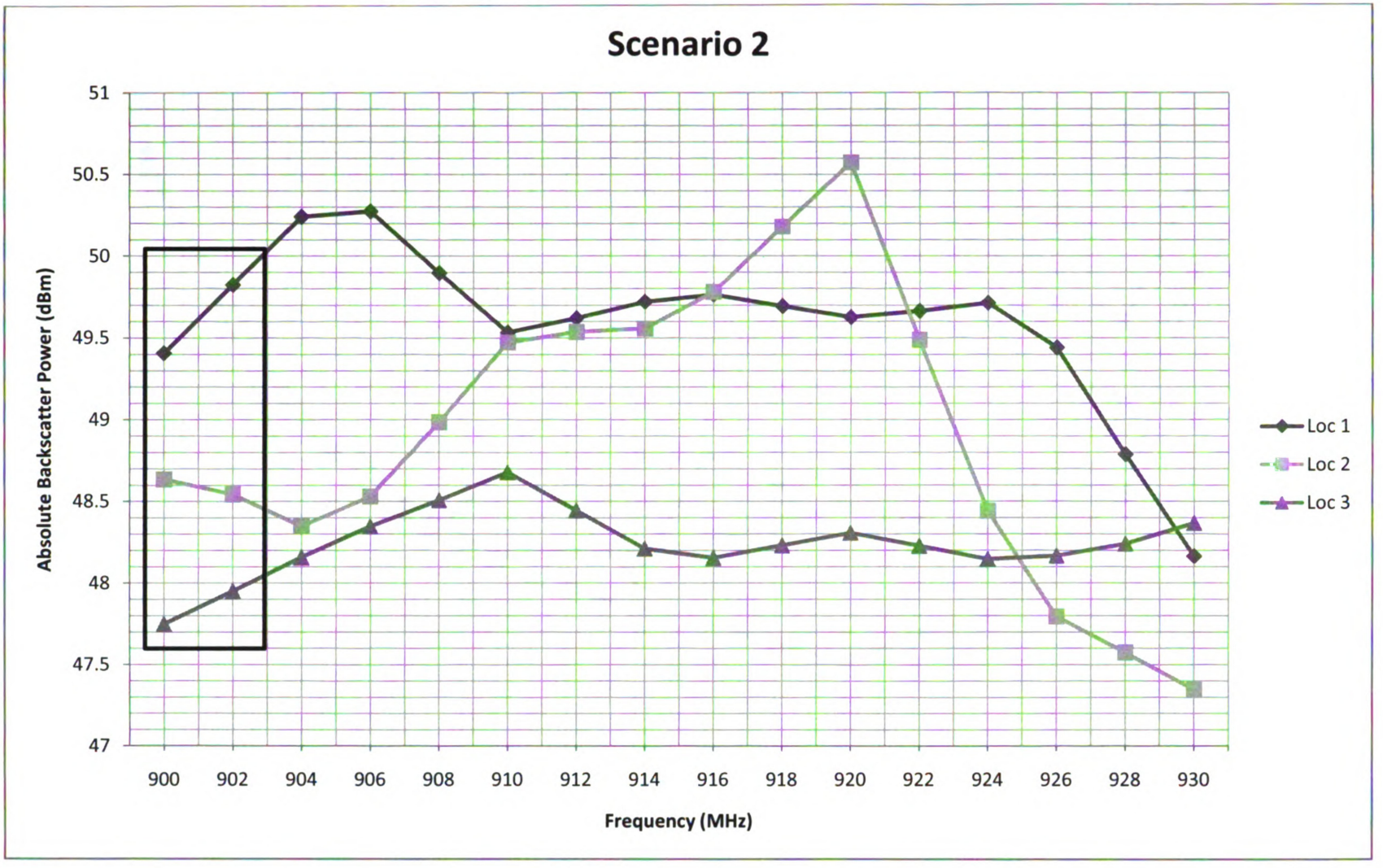


Figure 26: Scenario 2 - Absolute Backscatter Power (dBm) vs. Frequency (MHz)

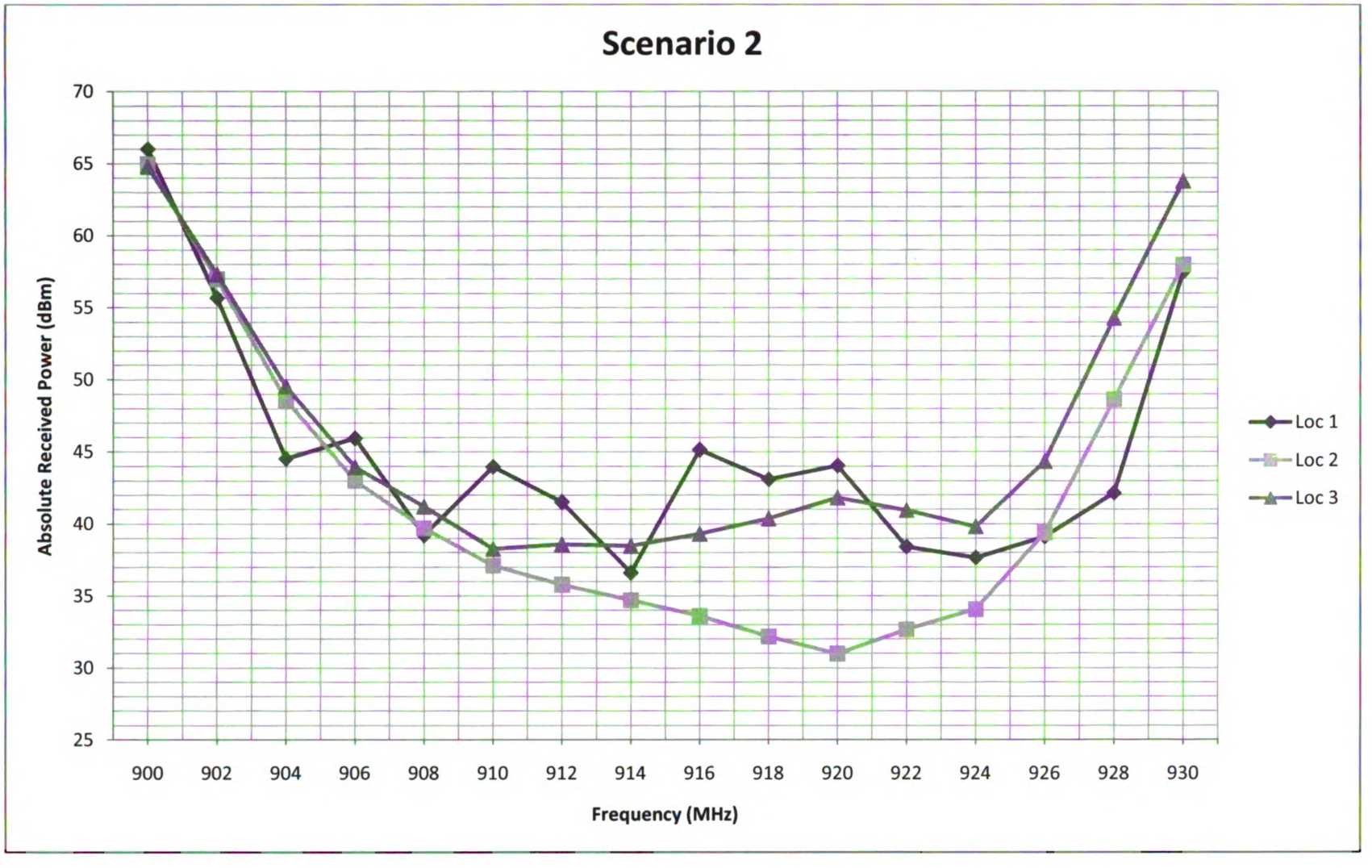


Figure 5: Scenario 2 - Absolute Received Power (dBm) vs. Frequency (MHz)

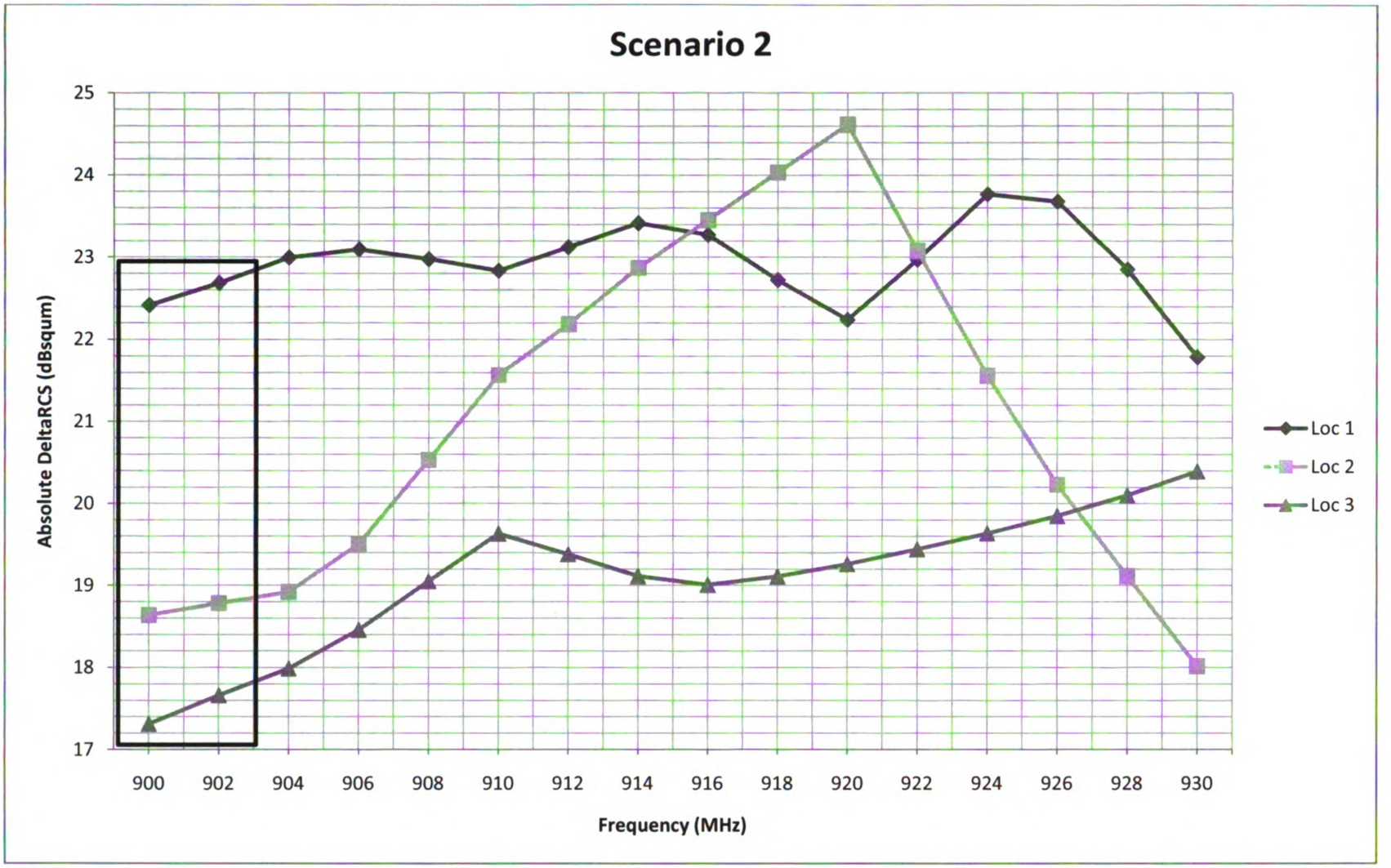


Figure 28: Scenario 2 - Absolute Delta RCS (dBsqm) vs. Frequency (MHz)

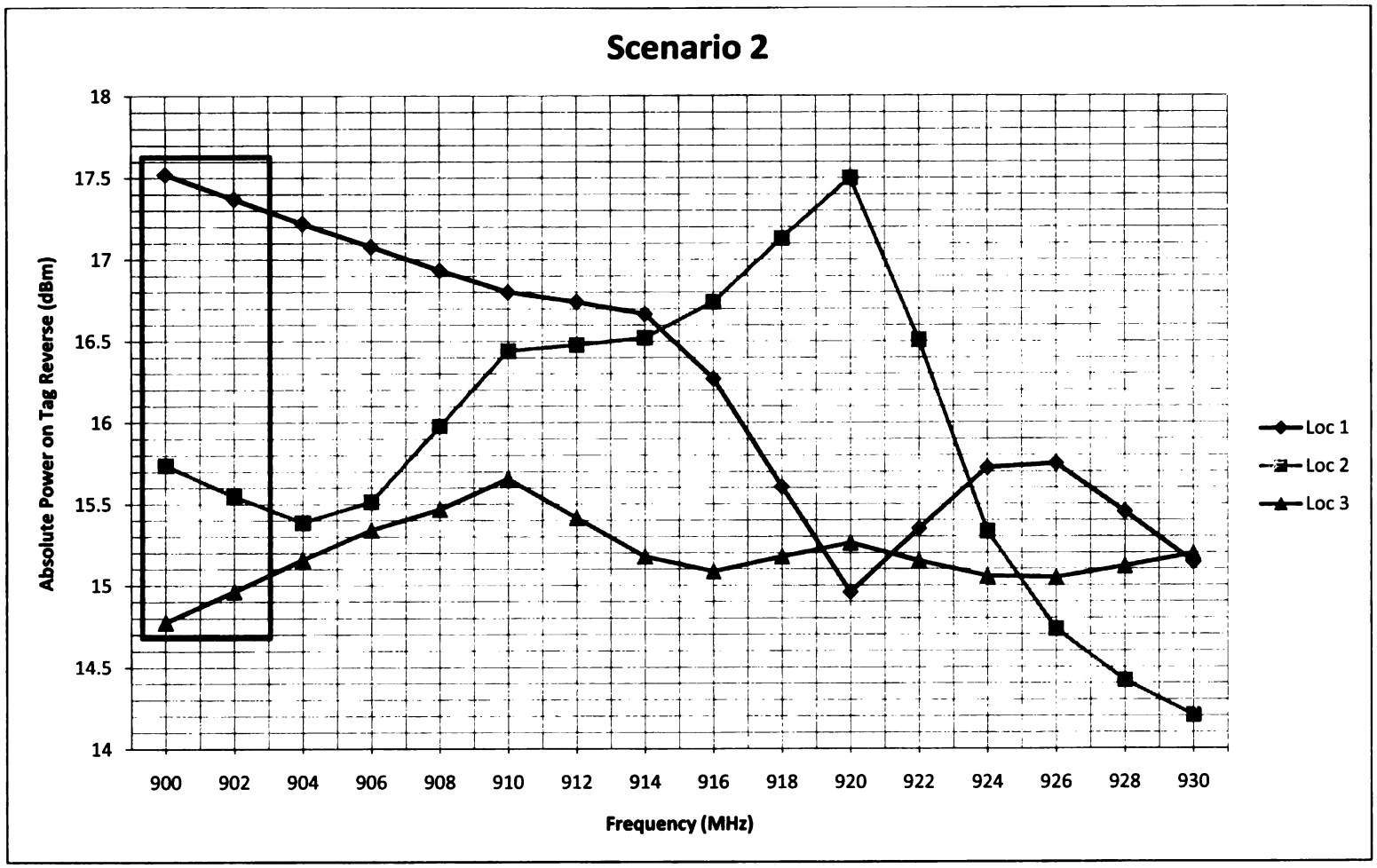


Figure 29: Absolute Power on Tag Reverse (dBm) vs. Frequency (MHz)

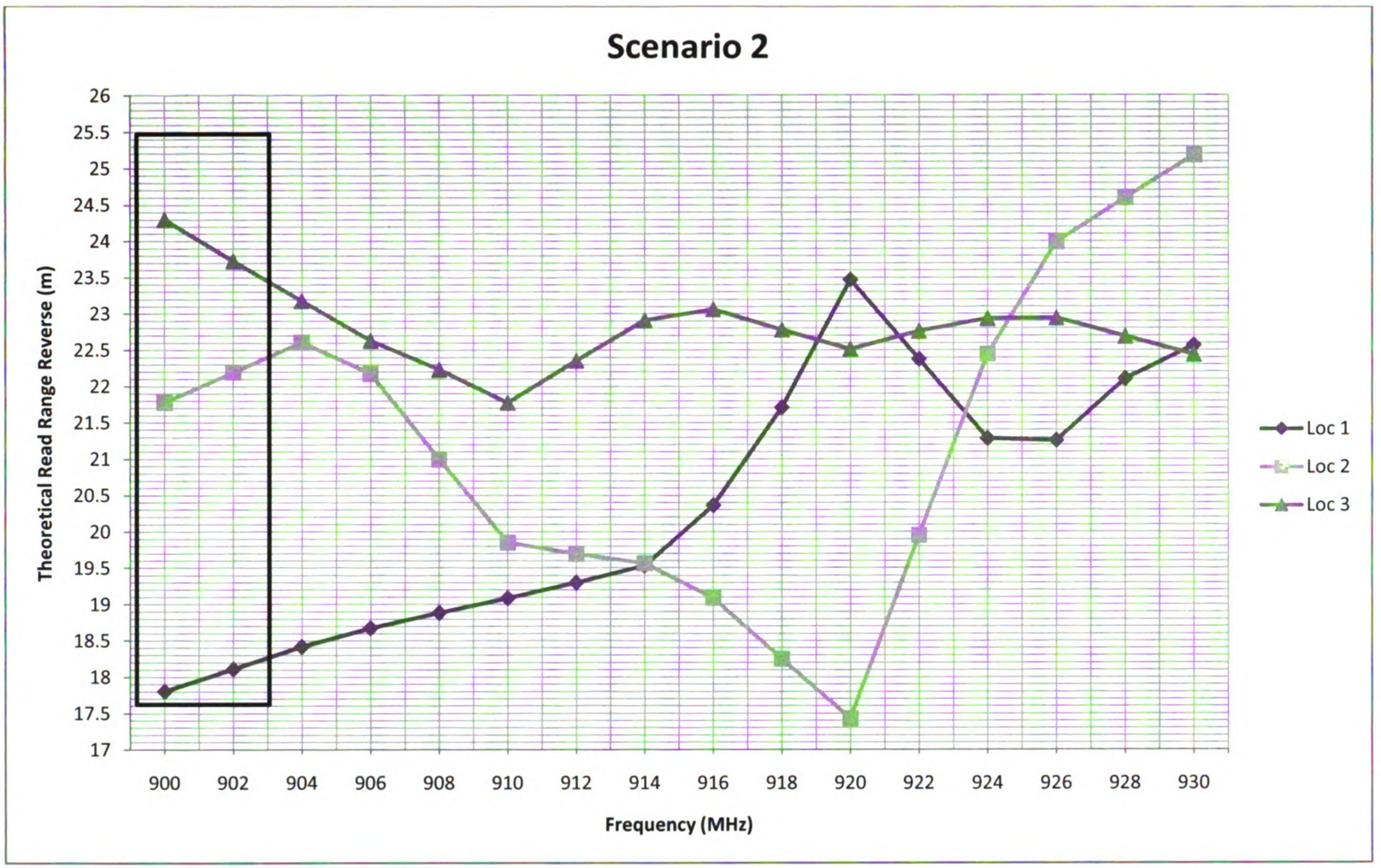


Figure 30: Scenario 2 - Theoretical Read Range Reverse (m) vs. Frequency (MHz)

Scenario 2

There were no significant differences in the Received Power that were shared among all locations. This means that no one frequency showed significant differences in all locations. This further means that, statistically, there should be no difference between the Locations as far as the level of RF noise in the environment. Furthermore, this brings up the possibility that the environment has a stronger influence on the results than does RF noise.

Scenario 2 followed a similar pattern to that of Scenario 1. Both sensitivity and Backscatter units have similar frequency ranges that displayed significant differences among all locations. The Sensitivity units shared the ranges of 906 to 908 MHz and 922 to 924 MHz (Tables 14-15 & 35-40 and Figures 22-25) while the Backscatter units share the range of 900 to 902 MHz (Tables 41-50 and Figures 26-30). The 924 MHz frequency within the Sensitivity units was a commonly shared frequency with significant differences among all locations for both scenarios which means that comparisons and conclusions about the best and worst performing locations can be made among all of these units. Comparisons within this particular frequency will be further discussed in the sections for each location.

The overall results shown in Tables 14 and 15 showed that Location 3 once again had the best overall results despite the presence of additional RF noise from an Identified Source. This became more evident because this location consistently had the best estimation values among all measurement units at a

majority of the frequencies. According to the same table, Locations 1 and 2 showed the same overall rankings of 3rd and 2nd best. Since these results do not show the entire picture for the transponder's operating frequency range, a closer look at the amount of differences and similarities between locations and frequencies is displayed in Table 16. Similar to Table 11 in the Scenario 1 results, differences and similarities help to determine how closely related the estimation values were for each measurement unit.

Table 14: Scenario 2 - Sensitivity Unit Performance Summary within 906, 908, 922, and 924 MHz

	TP	EFS	POTF	TRRF
Values	Low	Low	Low	High
Rank: 1st	Location 3	Location 3	Location 3	Location 3
Values	Medium	Medium	Medium	Medium
Rank: 2nd	Location 2	Location 2	Location 2	Location 2
Values	High	High	High	Low
Rank: 3rd	Location 1	Location 1	Location 1	Location 1

Table 15: Scenario 2 - Backscatter Unit Performance Summary within 900 to 930 MHz

	BP	Delta RCS	POTR	TRRR	RP
Values	High	High	High	High	High
Rank: 1st Status: Bad	Location 3	Location 3	Location 3	Location 3	Location 3
Values	Medium	Medium	Medium	Medium	High
Rank: 2nd Status: Bad	Location 2	Location 2	Location 2	Location 2	Location 2
Values	Low	Low	Low	Low	High
Rank: 3rd Status: Bad	Location 1	Location 1	Location 1	Location 1	Location 1

Table 16: Scenario 2 - Number of Differences and Similarities for Operating Frequency Range

	Location 1		Location 2		Location 3	
	# Differences	# Similarities	# Differences	# Similarities	# Differences	# Similarities
TP	12	4	10	6	14	2
EFS	13	3	9	7	12	4
POTF	13	3	11	5	14	2
TRRF	11	5	11	5	13	3
BP	8	8	5	11	9	7
Delta RCS	14	2	14	2	16	0
POTR	7	9	7	9	6	10
TRRR	7	9	7	9	8	8

Looking at Equations 2 and 3 introduced at the beginning of the Results chapter, Location 3 followed this ideal situation once again (Tables 17 and 18). Unlike Locations 1 and 2 in Scenario 1, these locations provided a more difficult challenge because the number of estimation values within each measurement unit appeared to show less similarities and more variance in actual estimation values. In Scenario 1, these locations had more similarities among each other and consistently were higher (or lower) than Location 3, which made the gap between Location 3 estimation values and the other locations clear cut. However in Scenario 2, this trend vanished. In Scenario 2, the Locations appeared to bounce back and forth between stronger and weaker estimation values.

Table 17: Ideal Outcome Based on Causal Relationship for Sensitivity Units at 906, 908, 922, and 924 MHz

906 to 908, 922 to 924 MHz	If	TP	and	EFS	and	POTF	Then,	TRRF
Values		Low		Low		Low		High

Table 18: Ideal Outcome Based on Causal Relationship for Backscatter Units at 900 and 902 MHz

900 to 902 MHz	If	BP	and	Delta RCS	and	POTR	Then,	TRRR
Values		High		High		High		High

Null Hypotheses Findings

Null Hypothesis 1: The presence of ambient radio frequency noise within the operating frequency range of an ultra-high frequency radio frequency identification system will NOT have an effect on the communication capability of a passive transponder.

This null hypothesis was supported by the data. The ambient RF power measurements from each location varied, however the power measurements within the operating frequency range of the transponder was determined to be not significantly different. Using a more conservative significant value method, it was determined that all three locations were virtually the same in terms of ambient RF noise levels. Therefore, the presence of ambient RF noise alone had no significant effect on the communication capabilities of the transponder. This conclusion stated above does not include ambient RF noise and the possible effects of the environment together.

Null Hypothesis 2: Introducing additional radio frequency noise from an identified source, within the focused operating frequency range of 902 to 928 MHz, for a given location will NOT have an effect on the communication capabilities of a passive transponder.

This null hypothesis was supported and not supported by the data. Introducing additional RF noise from an identified source affected the sensitivity and backscatter measurements in comparisons to the result with only ambient RF noise present. Locations 1 and 2 showed the most significant differences

between Scenarios 1 and 2. These held true for both sensitivity and backscatter measurements. This shows an affected the communication capabilities of the passive transponder. This data not supports the null hypothesis.

Location 3 showed minimal effects based on the sensitivity and backscatter measurements. This means that the data showed little to no significant differences between Scenarios 1 and 2. Thus, it did not show an overall effect on the communication capabilities of the passive transponder in this location and, therefore, did support the null hypothesis.

In closer examination of this mixed finding, a question arose with respect to Location 3, Scenario 2. Was the lack of significant differences between Scenarios 1 and 2 due to this location acting as an anechoic chamber, or was there a system configuration difference between locations? Location 3 provided limitations on available power outlets to construct the additional RF noise source, and as a result, the positioning of the additional RF noise source varied from that of Locations 1 and 2. Although the distance from antenna to antenna stayed consistent, the angle varied at which the antenna from the identified RF noise source was placed in comparison to the Location 1 and Location 2 systems. It has yet to be determined whether or not the difference in identified RF noise configuration had an effect on the overall results. Further discussion on this topic, which includes additional suggestions on verification measures, can be found in the Future Work chapter.

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Null Hypothesis 3: The surrounding environment in which a radio frequency identification system is implemented will NOT have an effect on the communication capabilities of a passive transponder.

This null hypothesis was not supported by the data. Based on the measurements from both scenarios, the surrounding physical environment had an effect on the overall communication capabilities of the passive transponder. The possible effects shown in the differences in sensitivity and backscatter measurement units by the combination of the physical environment and the addition of identified RF noise were the cause for both constructive and destructive effects on the communication capabilities for each location. These effects were displayed especially in data concerning Location 2. This environment displayed possible signs of both constructive and destructive interference based on the extreme peaks and valleys in data patterns when comparing results from both scenarios in more than one response variable.

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Chapter 5: Conclusion

This chapter discusses and summarizes overall results and conclusions. Each location displayed different results based on the two scenarios. The conclusions formed were based on the three hypotheses and the results displayed in this study. The causes and reasoning for observations from the results are discussed.

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This research supports the following conclusions:

- There are 3-way interactions show a dependence relationship existing among all combinations of Scenarios, Locations, and Frequencies.
    - 2-way interactions exist, but due to the existence of 3-way interactions, statistical conclusions must be made based on 3-way interactions.
- Minimal significant differences between all locations were observed with ambient RF noise measurements existing within the transponder's operating frequency range.
- Minimal significant differences between all locations were observed with the combination of ambient and identified RF noise measurements existing within the transponder's operating frequency range.
- Introducing additional RF noise increases the likelihood of both constructive and destructive interference effects.
- Introducing additional RF noise into locations with numerous reflective surfaces can cause inconsistency in sensitivity and backscatter measurements.
- Location 3 (MSU Engineering Building Basement) showed no significant differences between Scenarios 1 and 2.

Location 1

Location 1 showed comparisons among the two scenarios. An easier look at the differences and similarities are displayed in Tables 51-68 and Figures 42-

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50. The Sensitivity units for this location showed significant differences within the frequency range of 924 to 930 MHz. Among Transmit Power, Electric Field Strength, and Power on Tag Forward measurements, Scenario 1 provided a more desired estimation value than that of Scenario 2. In the case of Theoretical Read Range Forward, Scenario 2 provided the better estimation values. This did not follow the causal relationship (Equations 2 and 3) proposed.

The Backscatter units for Location 1 share the frequency range of 912 to 916 MHz, which displayed significant differences among both scenarios. Remember that these given ranges were not the only significant differences found for each measurement unit, but represented significant differences among all Backscatter or Sensitivity units. Among all Backscatter units within 912 to 916 MHz, Scenario 2 provided better results than that of Scenario 1. In this case, the causal relationship (Equations 2 and 3) does hold true.

After looking at the initial analysis, Location 1 seemed like it would be the worst location to conduct RFID testing based on the ambient RF noise measurements from the Interference feature (Figure 31). However, initial thoughts did not show the complete picture of how an RFID system would operate there. Although this location consistently performed the worse in terms of activations power needed, strength of signal, and readable distance, it was more consistent than Location 2. Sometimes consistency can be just as important as recording the best overall measurement. Consistency shows more reliable measurements and repeatability of similar results for future testing in the same environment. The additional RF noise in the environment along with the physical

interaction with materials in the environment had some effect which at times were positive and at other times negative. The additional RF noise in the environment somehow allowed for stronger/weaker overall backscatter signals to reach the reader respectively. This could be from the effects of constructive interference on the response signals from the transponder or destructive interference of other RF noise in the environment.

Location 2

This location shows the most variability between strong and weak estimation values, which resulted in values similar at times to both Locations 1 and 3. Tables 69-86 and Figures 51-59 show the comparisons between the two scenarios at this location. This provided a larger range of significant differences between scenarios. The Sensitivity units had a range of 900 to 906 MHz and the Backscatter units ranged from 900 to 908 and 926 to 928 MHz. Unlike Location 1, Scenario 2 provided more desired estimation values for all Sensitivity units. This location followed the causal relationship as well.

Since there were two different frequency ranges that provided significant difference among the scenarios for the Backscatter units, this could mean that the units at this location were affected by the change in scenario. Scenario 2 showed better estimation values than that of Scenario 1 for the Backscatter units within both frequency ranges. Once again, the causal relationship (Equations 2 and 3) holds true in this location.

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It is theorized that most of the different effects on the performance of the communication capabilities of the transponder in this location were due to a mixture of the physical environment and the addition of identified RF noise into the environment. This location had a larger amount of metal based objects compared to the other locations. This would provide many opportunities for RF waves to reflect, interact, and interfere with each other.

Location 3

This location showed the least amount of significant differences between the two tested scenarios. This point is further demonstrated by looking at Tables 87-104 and Figures 60-68. There were no significant differences at all displayed in these figures and tables. This shows that the two scenarios had no significant effect on the Sensitivity or Backscatter units at this location.

There were some instances where Scenario 1 performed worse than Scenario 2, but also, vice versa. However, overall, there were not enough significant differences to conclude one scenario outperformed the other. This means that no matter which scenario was being tested, the results would have mostly been the same. The crossing interactions between the data lines on the graph further shows the differences between scenarios were minimal and less significant.

Overall Conclusions

In general, it is inconclusive whether or not the presence of RF noise will instantly translate into RF interference issues for an RFID system's

communication capabilities with transponders operating in the UHF band 902 to 928 MHz. The results and conclusion on the overall effects of ambient RF noise and identifiable RF noise on reader and transponder communication capabilities were inconclusive based on this data because of the presence of a 3-way comparison between the two scenarios, three locations, and 16 frequency points. With significant differences found between these three variables, a two-way comparison between the scenarios and locations did not provided a honest and accurate depiction of these findings.

Each location showed different effects from both the ambient and identified RF noise, some more so than others. The consistency, accuracy and efficiency of an RFID system depend on the ability for the system's components to communicate with each other. The opportunity for complications from RF noise present in the environment is not guaranteed just because it is detected/present in a particular operating frequency band. Location 3 was the closest thing to an ideal location to set up an RFID system based on the lack of ambient RF noise present initially, the physical locations providing a barrier to external RF noise, and the lack of defined change in the communication capabilities of the transponder even with the presence of the identified RF noise. However, location 2 showed a clear disturbance in communication capabilities from the amount of RF noise and the amount of reflective surfaces present in the surrounding environment. This location is a prime example of a location that is not ideal for implementing an RFID system. Location 1 also showed similar disturbances as

well. Although the results from locations and scenarios varied, the transponder remained operational.

It is often understood that field strength of a system will vary based on the set up placement location. This difference is often caused by the interference patterns that are generated by combining energy from a direct source and reflected energy from an object. Since the phase of reflected signals can return in any other angle from that of a direct energy pattern, this can affect the signal by amplifying or diminishing the strength of the signal. Areas that contain multiple emitters operating at various frequencies the field strength patterns can become very complex (4.1.2 Interference Patterns, 2003).

Unless some effort is made to shield out and reduce RF noise from the system placement location, the mixture of RF noise and reflective surface in the physical environment could diminish the performance of the system. The results from these tests help to identify the need for users of RFID equipment to be aware of the surrounding environment in which they plan to implement an RFID system. There is always a chance that RF noise present in a given location will have an effect on the communication abilities of the system, however, one needs to be aware of the possible effects from the combination of physical surrounding and RF noise. The presence of RF noise and the environment that houses the RFID system can have an effect on transponder's functionality. Appropriate precautions such as performing a site audit, identifying RF noise emitters, and reducing the amount of reflective surface in the interrogation zone can help limit the amount of future complications in the functionality of an RFID system.

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Chapter 6: Future Work

This chapter discusses testing ideas beyond this study. These ideas are spun off from the original work for this study. Many of these ideas are minor adjustments to the procedures and ideals used in this study. The following ideas were not conducted as part of this study because resources were not available, or time was not available.

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Although this research was unable to definitively determine how much of an influence RF noise truly has on transponder and reader communication, further research and testing needs to be conducted for further understanding. Initial plans for testing Scenario 1 were to provide varying significant levels of ambient RF noise in different locations in order to better display effects from RF noise of this sort. Each location provided a different ambient RF noise measurement within the 800 to 1,000 MHz frequency range by the Tagformance system. However, after further analyzing the test results, it was determined the initial testing scenario was not fully tested because the levels of ambient RF noise within the transponder's operating frequency were determined to be insignificant between locations.

Further research and testing on the effects of RF noise in a highly noisy RF environment would be the next step in continuing this research. It is suggested that similar testing procedure to that used in this testing should be followed, with a few adjustments. Instead of using various locations to provide a difference in ambient noise measurements, a single location with the purest ambient noise measurements such as Location 3 should be used. Within this environment, the number of indentified RF noise sources such as the Impinj Speedway UHF Reader used in this testing should be increased. Increasing the number of readers used within the environment at the same time should provide a more straight forward way to test, research, and further understand the effects of RF noise particularly from reader-to-reader interference noise.

Similar to the previous suggestion, it is believed that further research should also include testing with multiple transponders. Similar testing procedures could be followed as the previous example, however, instead of using multiple readers as the source of interference, multiple transponders can be used within very close proximity. Instead of a single transponder, use multiple ones to provide a means of creating tag interference. Although this normally is not considered to be interference from RF noise, this could provide a better understanding of tag interference or the tag coupling effect.

Since this work was unable to conconfirm my 2nd null hypothesis definitively, continued testing in environments with ambient noise at various energy concentrations within transponder operating frequencies is recommended. This would include performing a complete site survey including temperature and humidity analysis, and identification of all RF noise sources using a spectrum analyzer with direction antenna.

After closer examination of this mixed finding, a question arose with respect to Location 3, Scenario 2 findings. The question surrounding these results were based on the positioning of the identified RF noise source in Location 3, in comparison to the positioning of this same system in the other two locations. The identified RF noise sources in Location 1 and 2 were positioned 20 feet away, at an angle of 90 degrees, to the right of the front center position of the antenna. In Location 3, the same identified RF noise source was 20 feet away, at an angle of 45 degrees, to the left of the front center position of the antenna. In addition, the identified RF noise source was partially visible from the

set up location of the Voyantic measurement unit due to blockage from a cinderblock wall. To verify whether or not this difference in set up configuration affected the finding of Location 3, Scenario 2, reconstructing the identified RF noise set up of Location 1 and 2 at Location 3 will provide answers this question.

Appendix A: Interference Graphs – Received Power (dBm) vs. Frequency Sweep (800 to 1,000 MHz) for All Locations from Tagformance

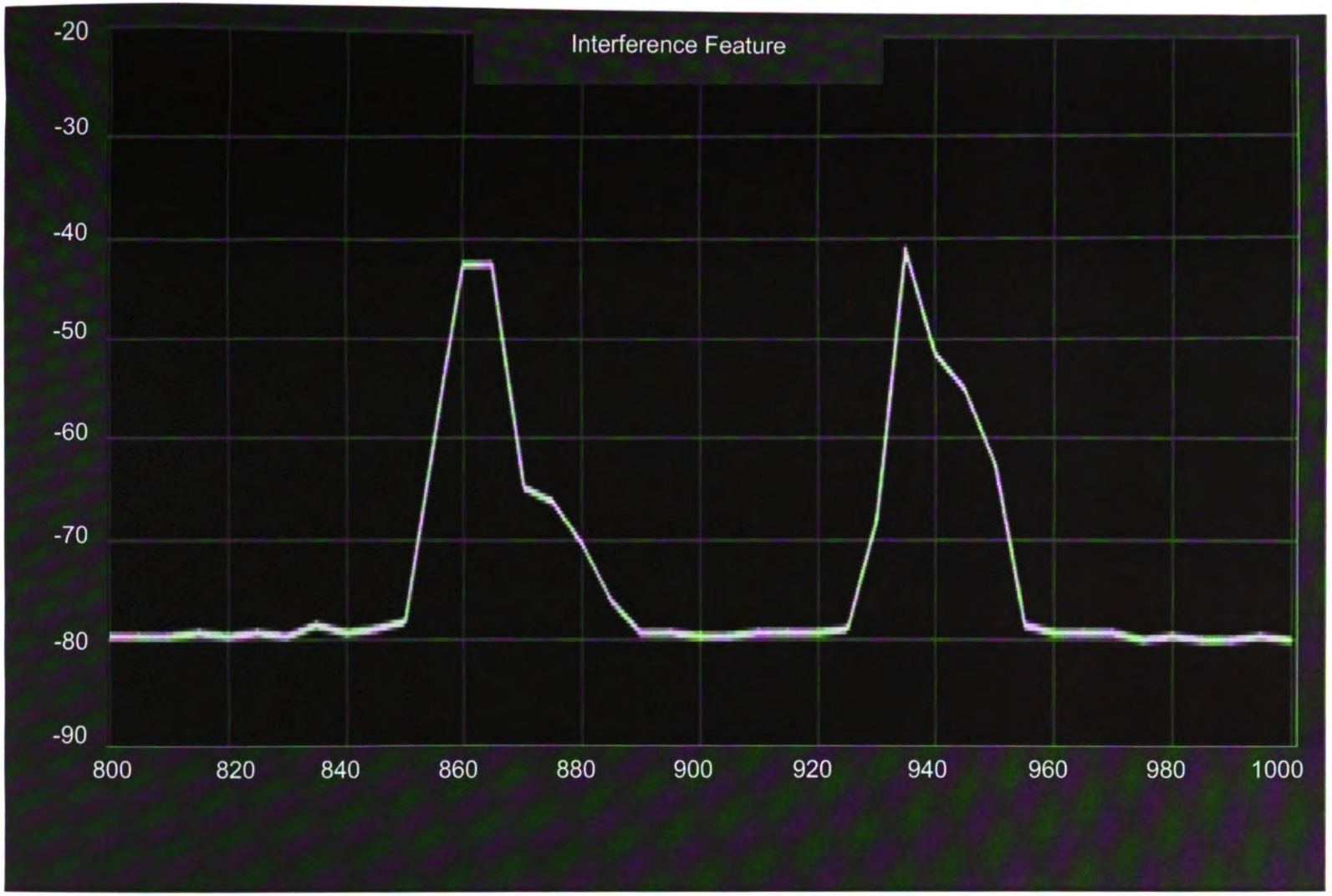

Figure 31: Scenario 1 - Location 1 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)

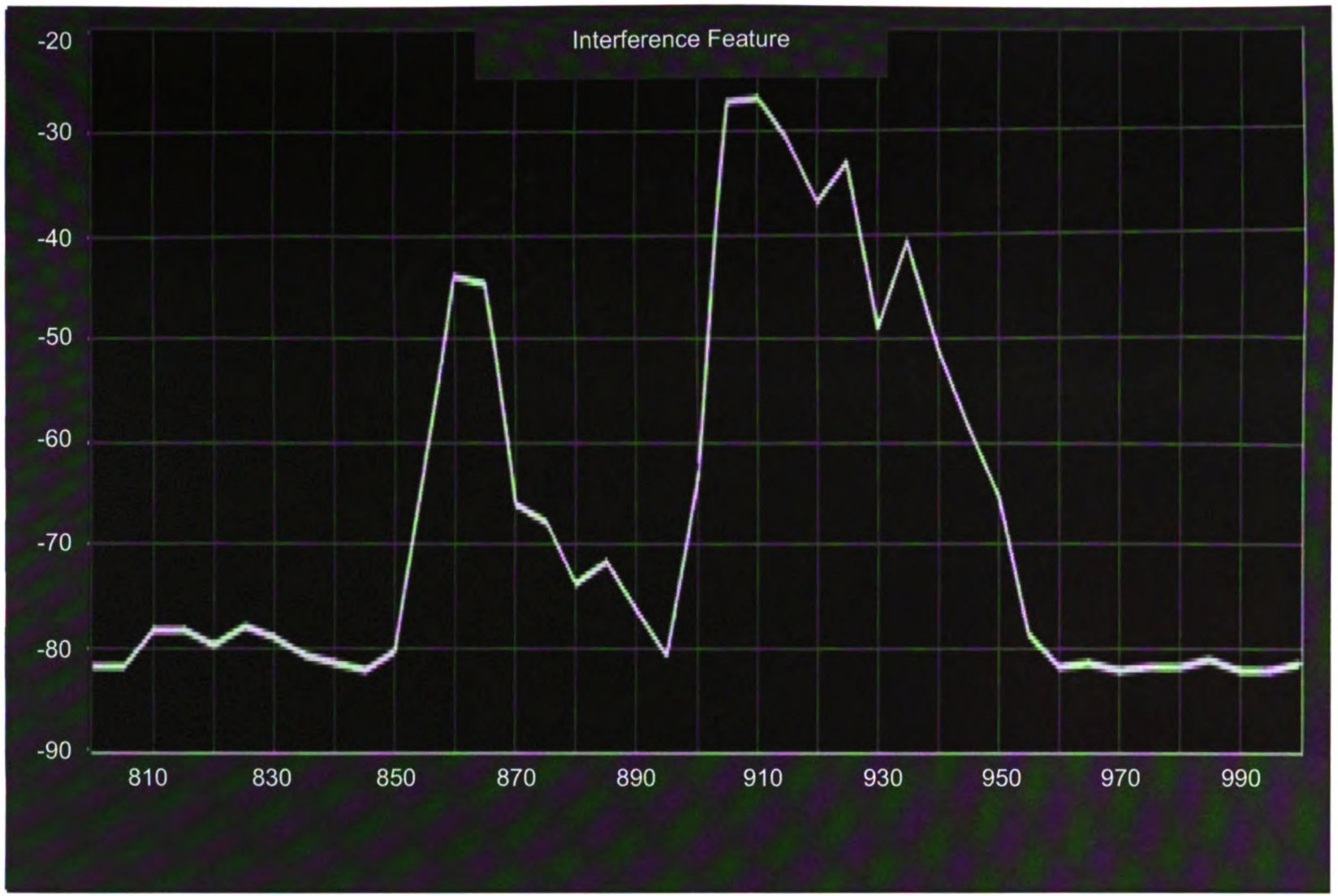

Figure 32: Scenario 2 - Location 1 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)

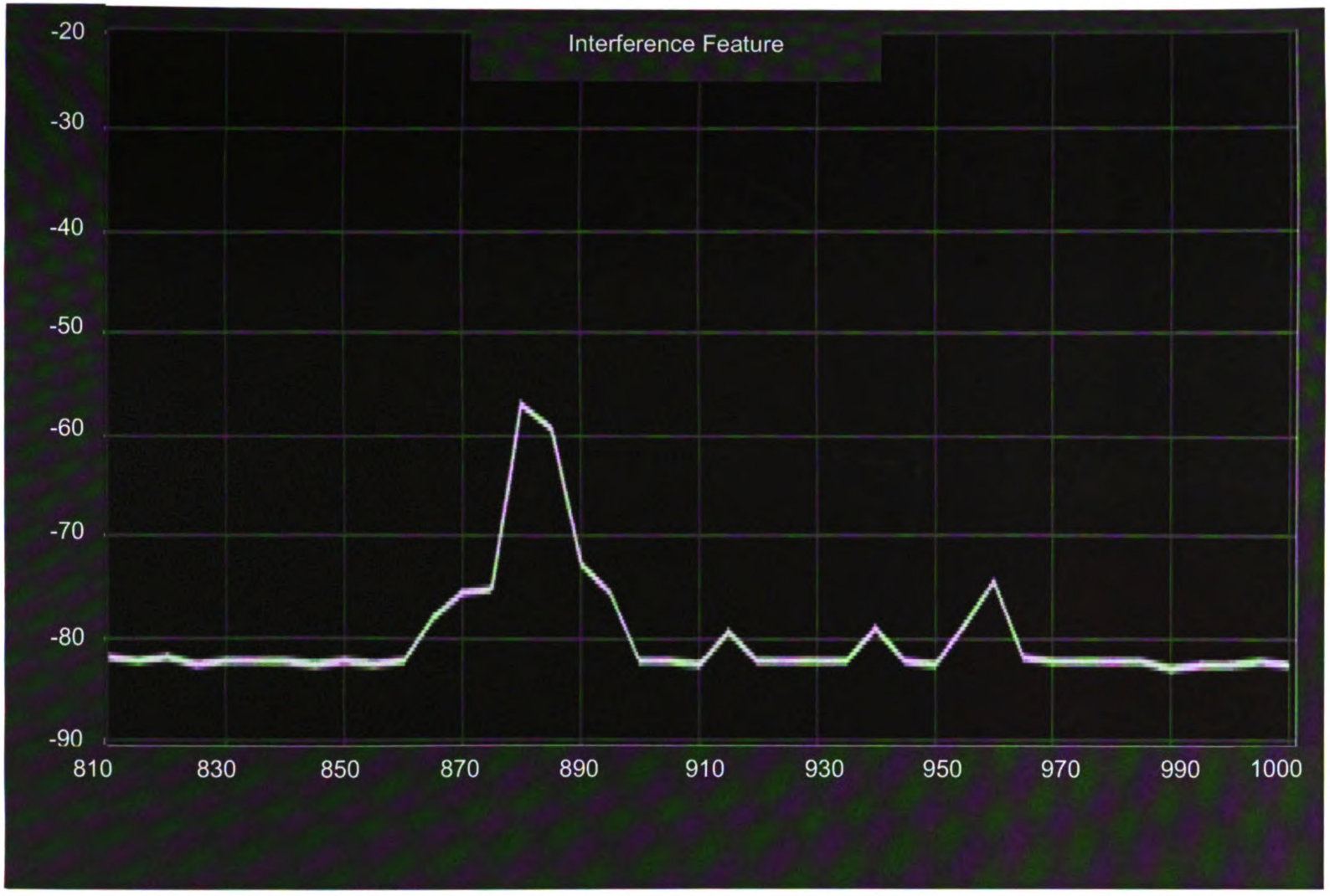

Figure 33: Scenario 1 - Location 2 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)

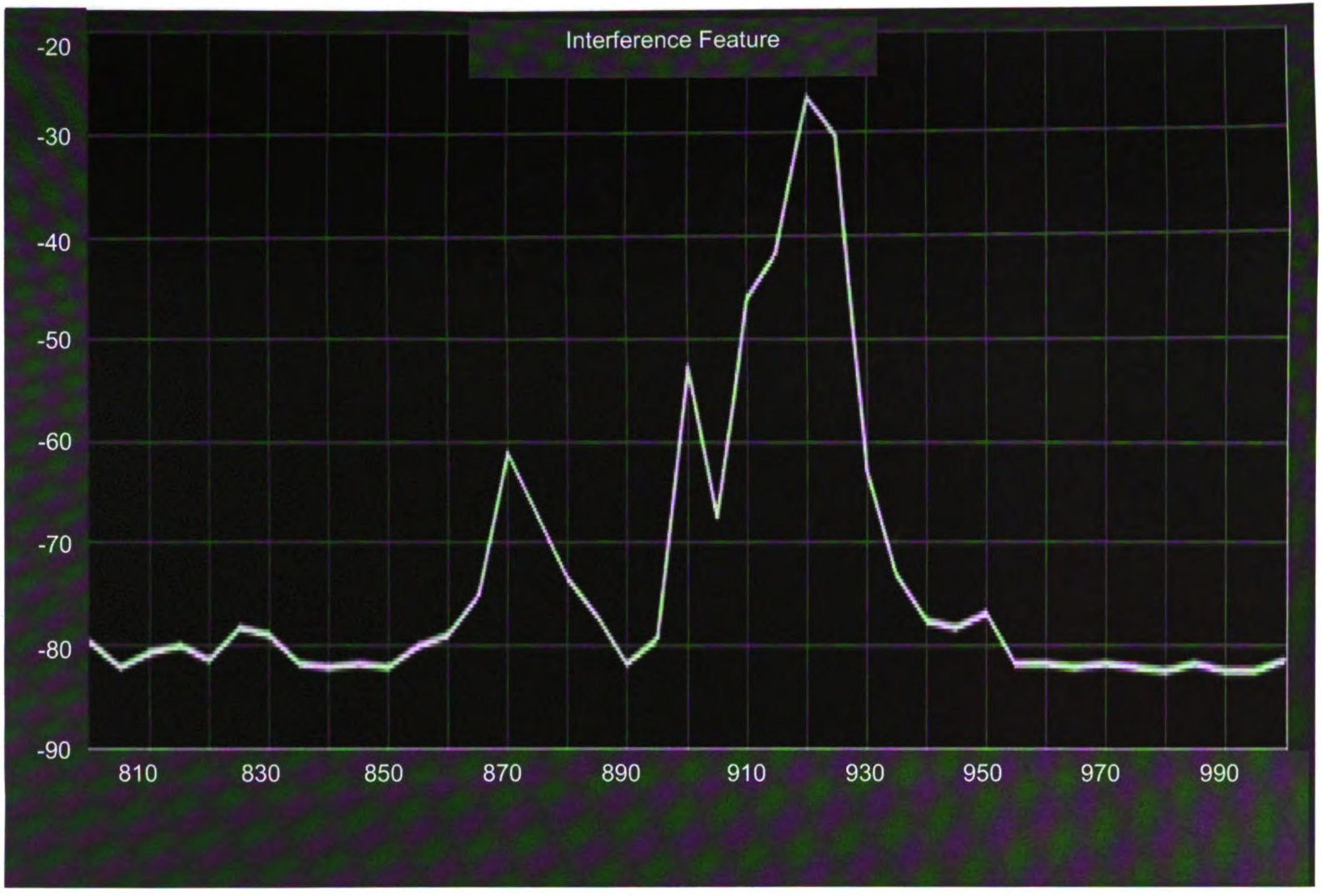

Figure 34: Scenario 2 - Location 2 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)

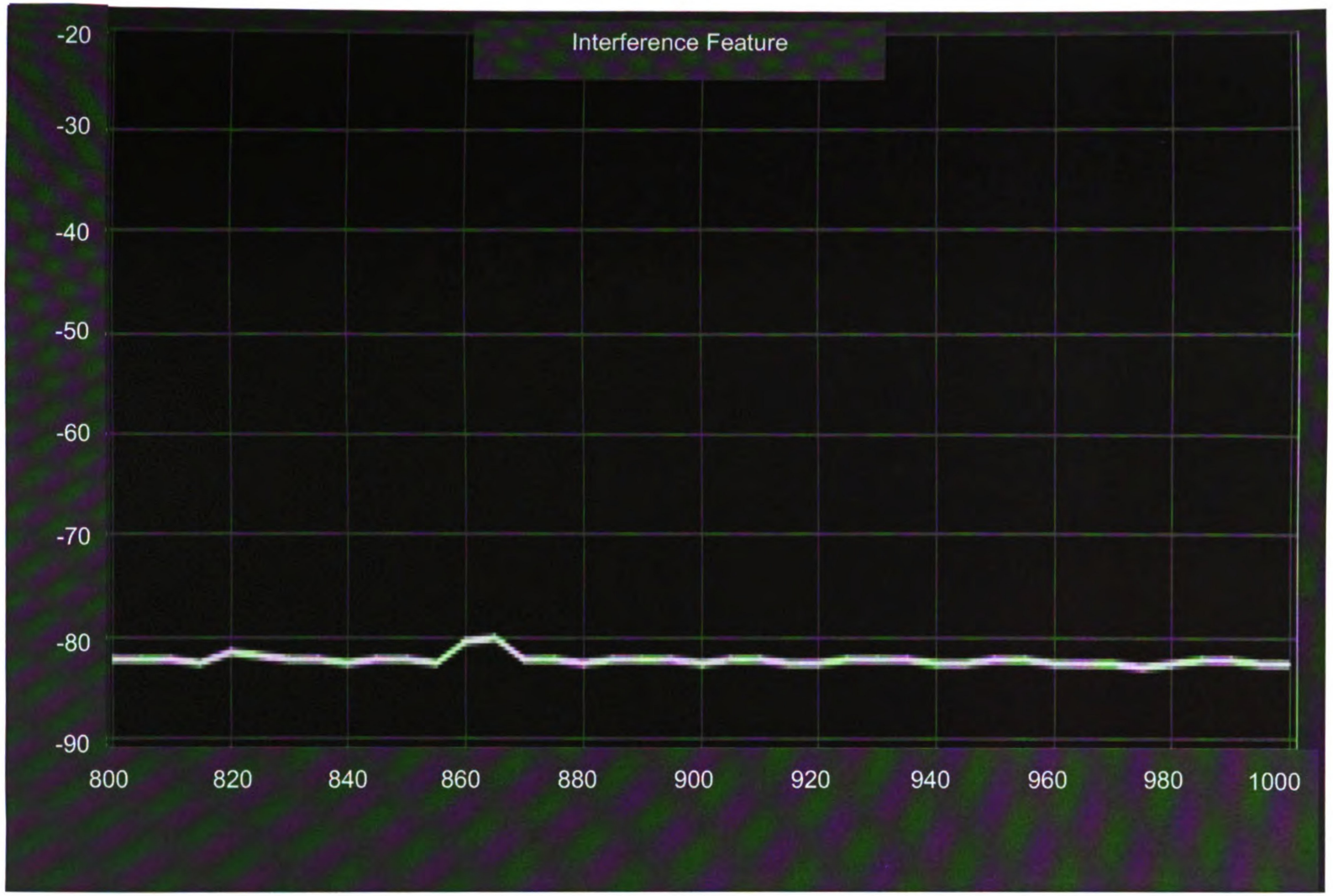

Figure 35: Scenario 1 - Location 3 Received Power (dBm) vs. Frequency Sweep (800 - 1,000 MHz)

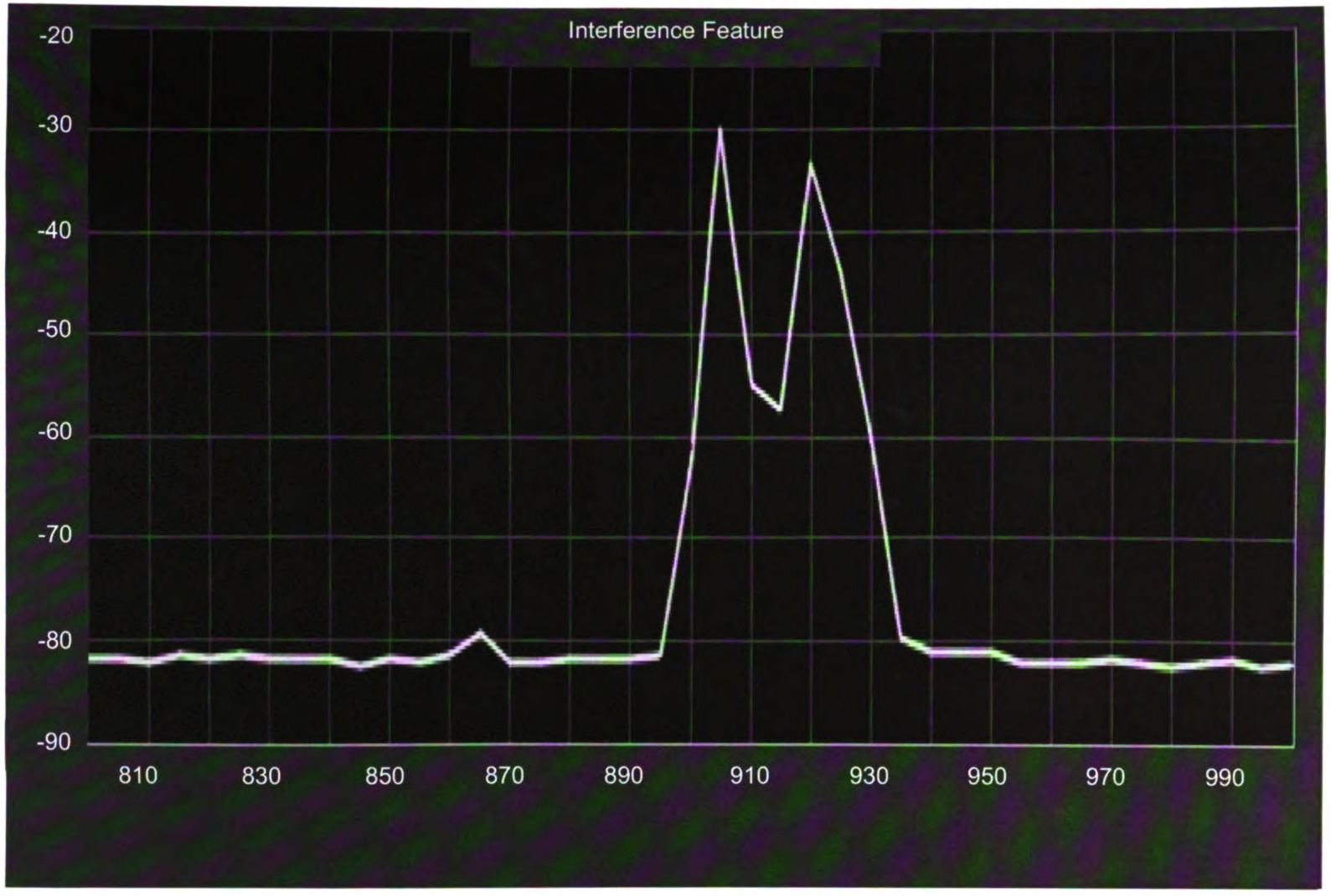

Figure 36: Scenario 2 - Location 3 Received Power (dBm) vs. Frequency Sweep (800 - 1,000) MHz

Appendix B: TESTING LAYOUTS AND SETUP

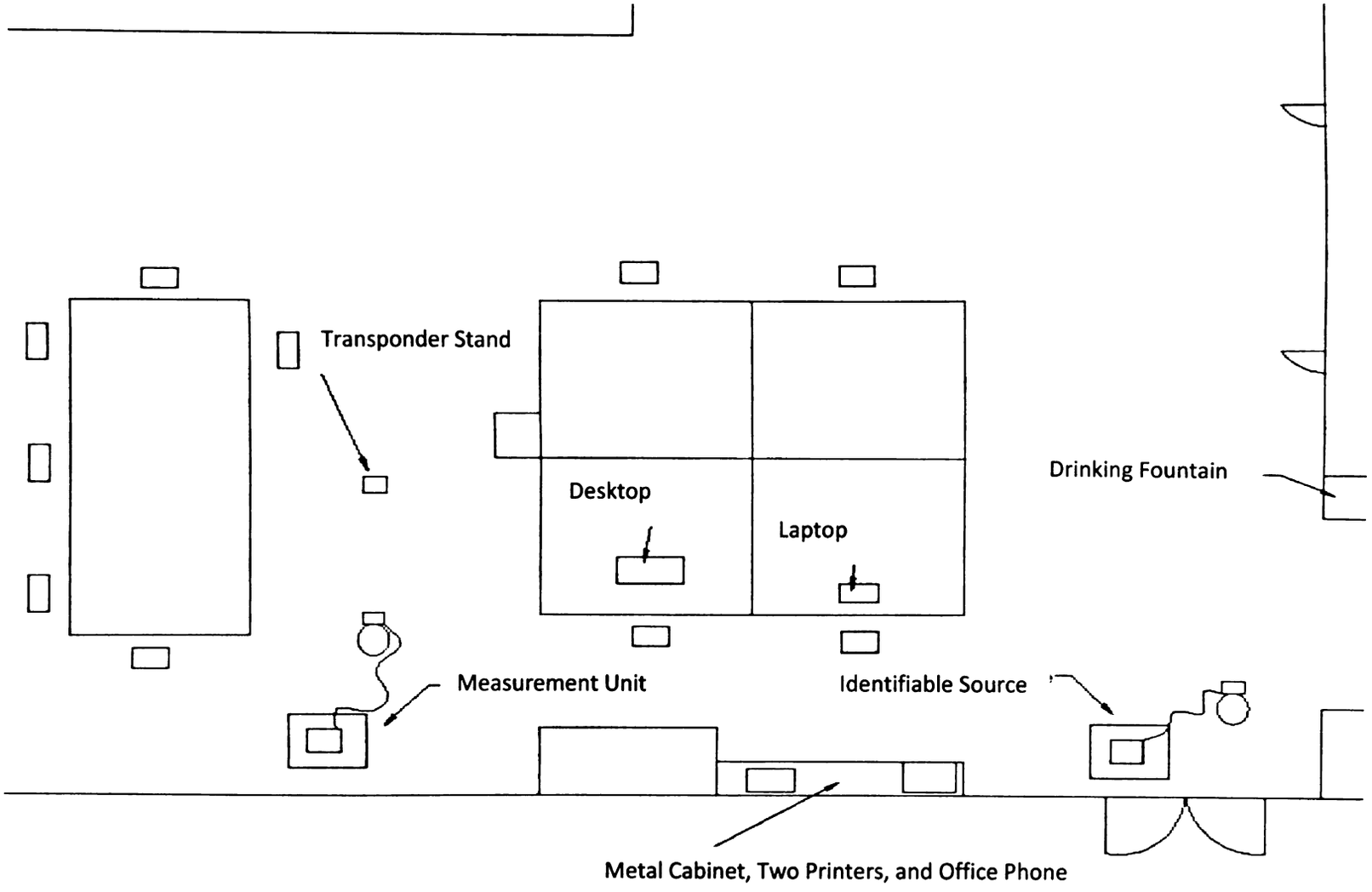

Figure 37: Location 1 - Michigan State University Auto-ID Research and Testing Center

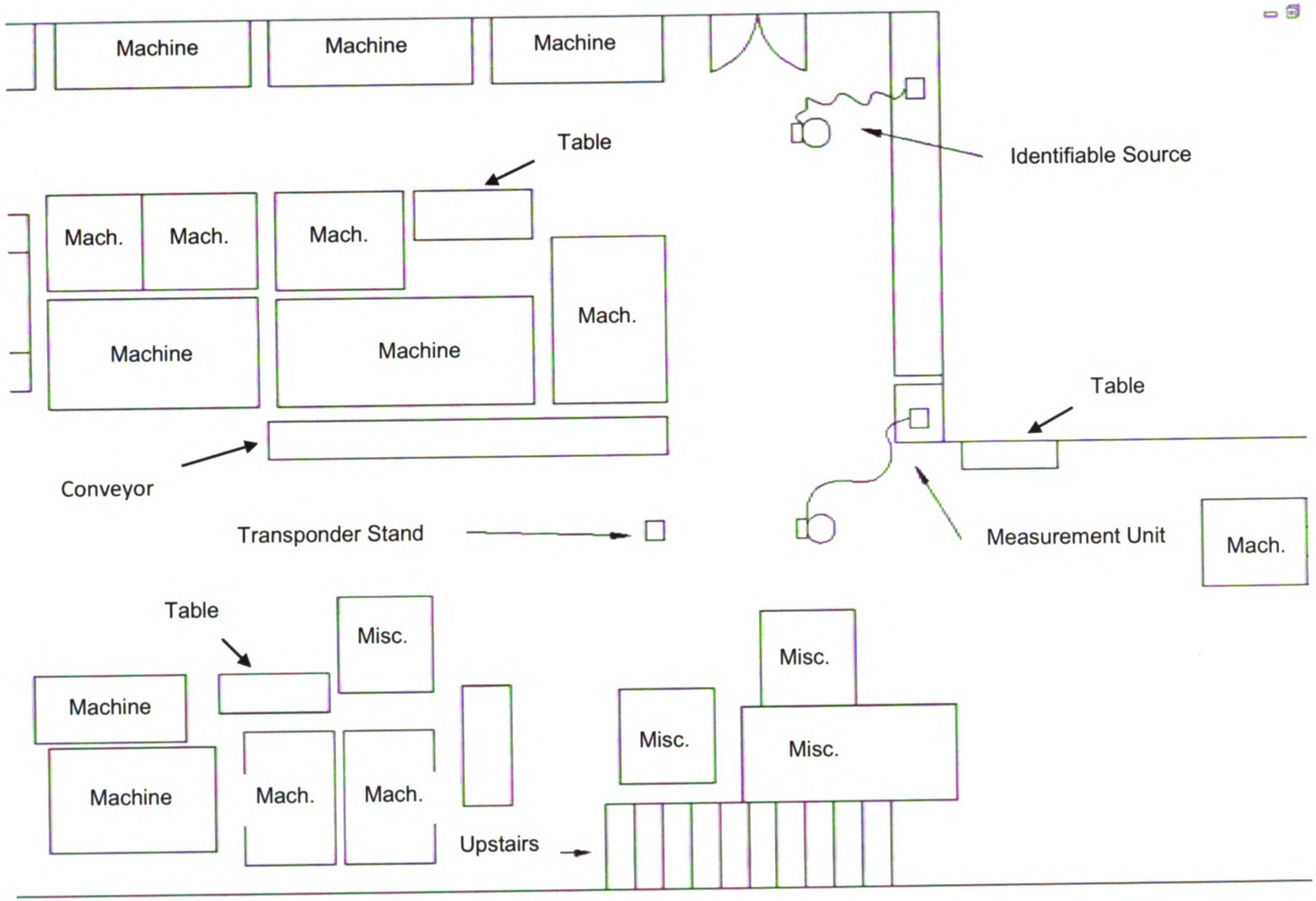

Figure 38: Location 2 - School of Packaging Machine Lab

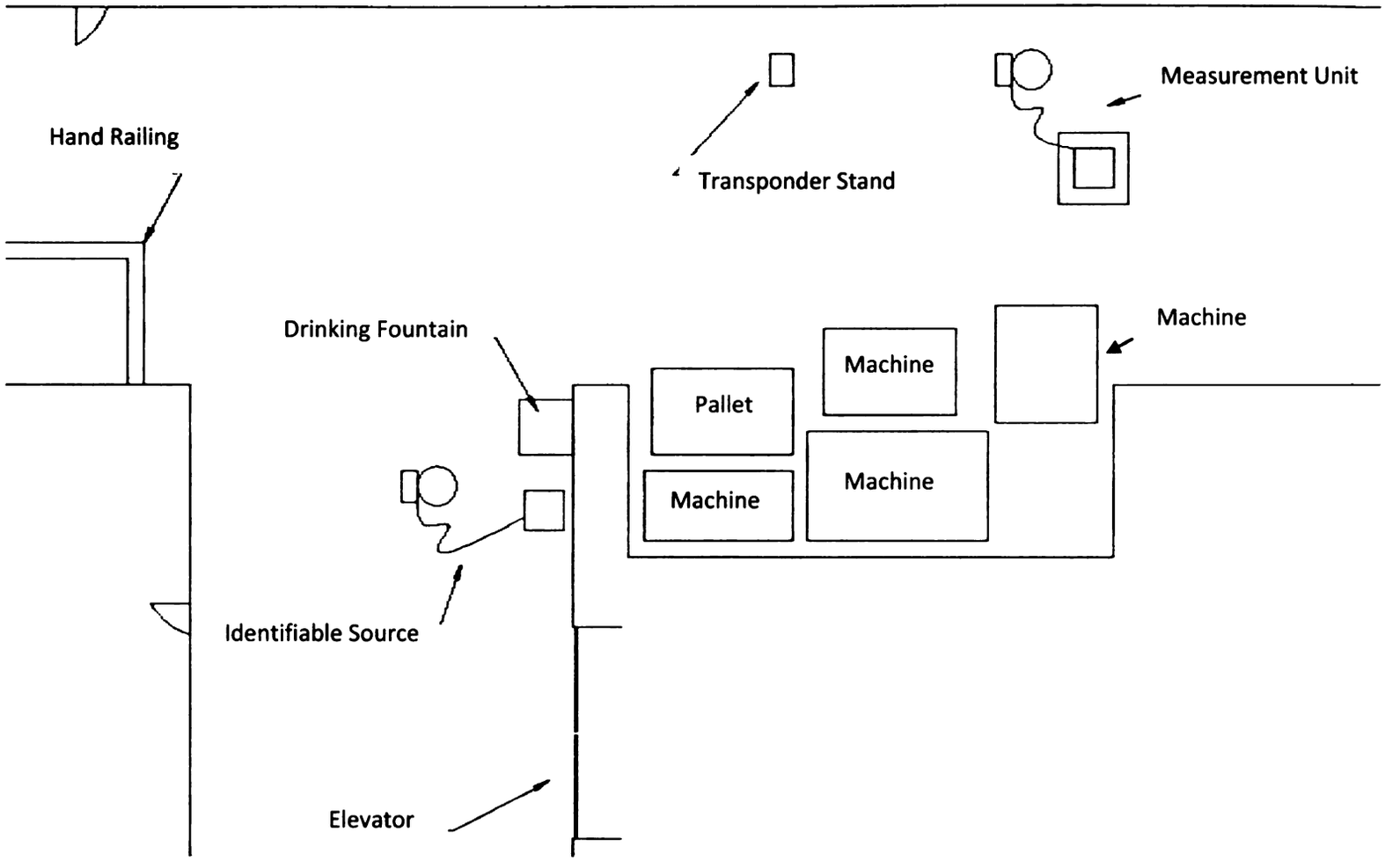

Figure 39: Location 3 - Engineering Building Basement

Appendix C: Mapped Locations of Nearby Cell Towers to Each Location

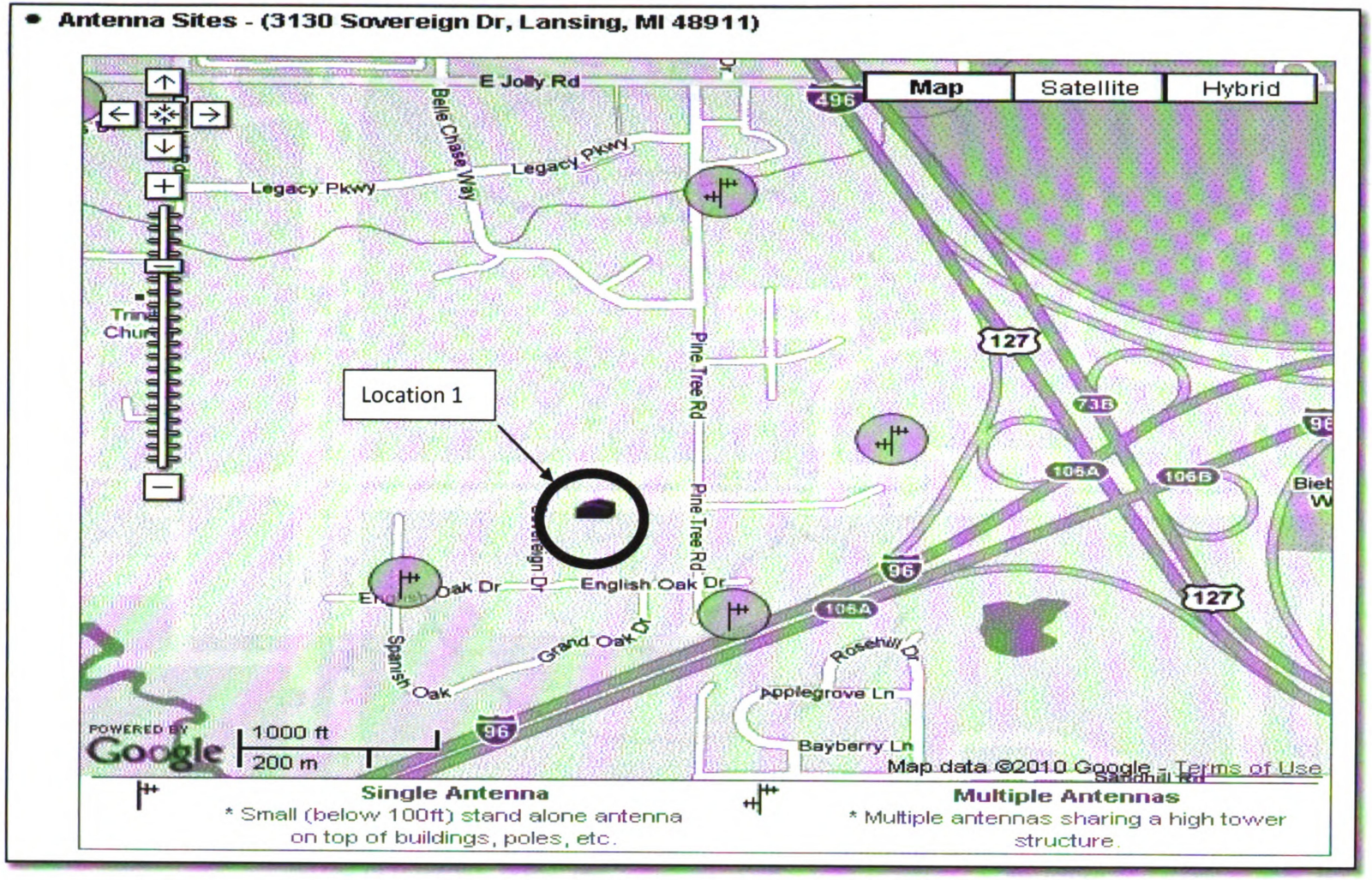

Figure 40: Location of Cell Towers around Location 1

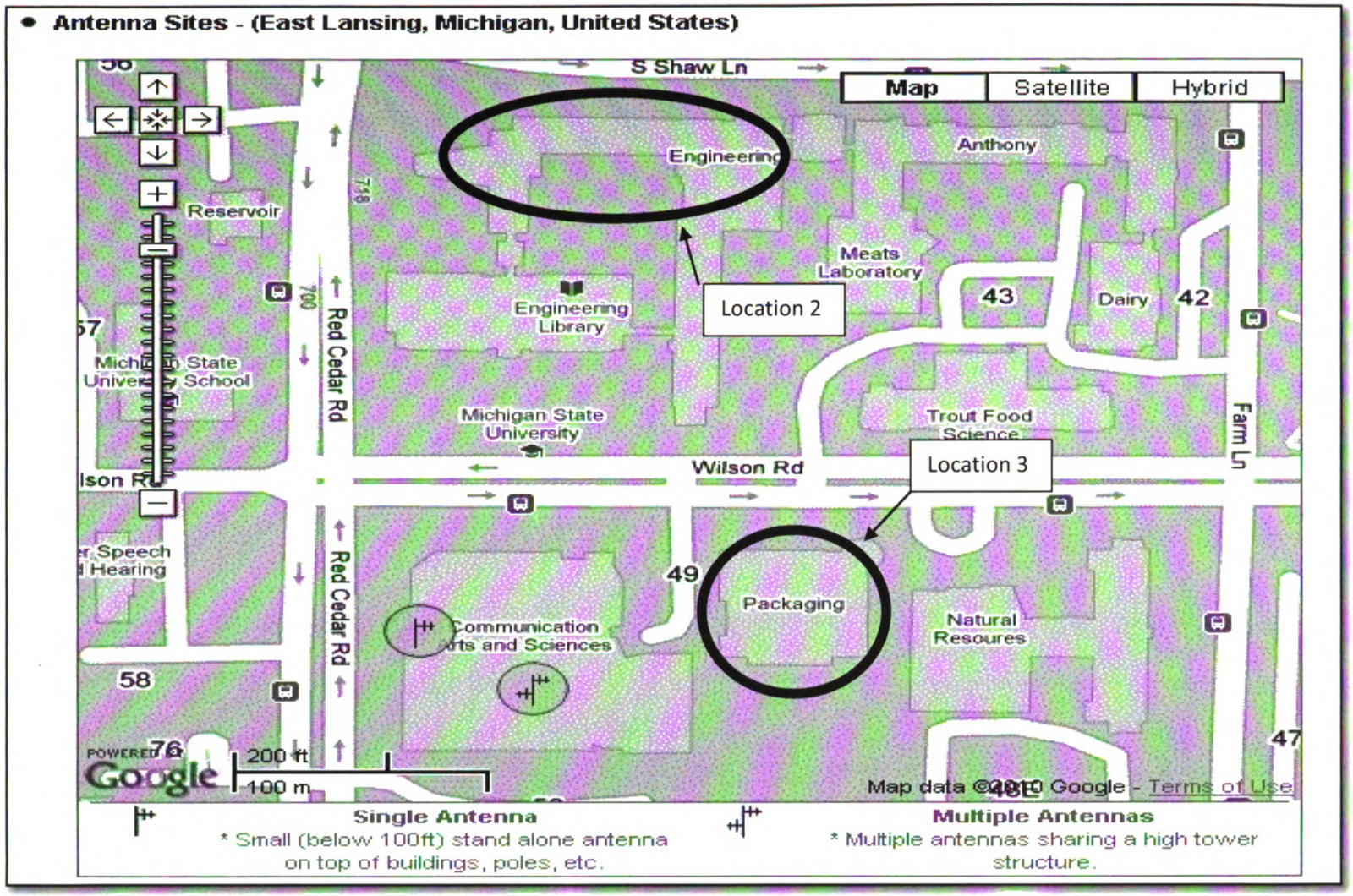

Figure 41: Location of Cell Towers around Locations 2 and 3

Appendix D: Scenario 1 Tables – Presence of Ambient Radio Frequency Noise

Table 5: Transmit Power (dBm) Scenario 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	14.27	0.07243	215	197.02	<.0001
1	2		13.7033	0.07243	215	189.2	<.0001
1	3		12	0.07243	215	165.68	<.0001
1	1	902	14.4767	0.06779	249	213.56	<.0001
1	2		14.22	0.06779	249	209.77	<.0001
1	3		12.24	0.06779	249	180.56	<.0001
1	1	904	14.65	0.08463	261	173.11	<.0001
1	2		14.7367	0.08463	261	174.14	<.0001
1	3		12.4267	0.08463	261	146.84	<.0001
1	1	906	14.8167	0.08354	258	177.36	<.0001
1	2		14.96	0.08354	258	179.08	<.0001
1	3		12.8067	0.08354	258	153.3	<.0001
1	1	908	15.04	0.0734	247	204.91	<.0001
1	2		14.88	0.0734	247	202.73	<.0001
1	3		13.0933	0.0734	247	178.38	<.0001
1	1	910	15.2733	0.08972	246	170.23	<.0001
1	2		14.8	0.08972	246	164.96	<.0001
1	3		13.4667	0.08972	246	150.09	<.0001
1	1	912	15.4683	0.0711	254	217.55	<.0001
1	2		15.0267	0.0711	254	211.34	<.0001
1	3		13.31	0.0711	254	187.2	<.0001
1	1	914	15.6367	0.08047	266	194.33	<.0001
1	2		15.2533	0.08047	266	189.56	<.0001
1	3		13.18	0.08047	266	163.8	<.0001
1	1	916	15.6433	0.08486	273	184.34	<.0001
1	2		15.48	0.08486	273	182.42	<.0001
1	3		13.0767	0.08486	273	154.1	<.0001
1	1	918	15.4667	0.09041	284	171.08	<.0001
1	2		15.7067	0.09041	284	173.73	<.0001
1	3		13.0667	0.09041	284	144.53	<.0001
1	1	920	15.2767	0.1165	295	131.17	<.0001
1	2		15.9333	0.1165	295	136.8	<.0001
1	3		13.0533	0.1165	295	112.08	<.0001
1	1	922	15.6767	0.09568	299	163.85	<.0001
1	2		15.56	0.09568	299	162.63	<.0001
1	3		13.4367	0.09568	299	140.44	<.0001

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Table 5: Continued

1	1	924	16.0833	0.09556	295	168.31	<.0001
1	2		15.1867	0.09556	295	158.93	<.0001
1	3		13.7167	0.09556	295	143.54	<.0001
1	1	926	16	0.09565	285	167.28	<.0001
1	2		14.8467	0.09565	285	155.22	<.0001
1	3		14.1567	0.09565	285	148	<.0001
1	1	928	15.47	0.103	278	150.15	<.0001
1	2		14.54	0.103	278	141.12	<.0001
1	3		14.45	0.103	278	140.25	<.0001
1	1	930	14.87	0.1393	252	106.77	<.0001
1	2		14.2333	0.1393	252	102.19	<.0001
1	3		14.7467	0.1393	252	105.88	<.0001

Table 6: Transmit Power (dBm) Scenario 1 Comparisons

loc	Fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.5667	0.1024	215	5.53	<.0001	Tukey-Kramer	0.0002
1		3	2.27	0.1024	215	22.16	<.0001	Tukey-Kramer	<.0001
2		3	1.7033	0.1024	215	16.63	<.0001	Tukey-Kramer	<.0001
1	902	2	0.2567	0.09587	249	2.68	0.0079	Tukey-Kramer	0.9883
1		3	2.2367	0.09587	249	23.33	<.0001	Tukey-Kramer	<.0001
2		3	1.98	0.09587	249	20.65	<.0001	Tukey-Kramer	<.0001
1	904	2	-0.08667	0.1197	261	-0.72	0.4696	Tukey-Kramer	1
1		3	2.2233	0.1197	261	18.58	<.0001	Tukey-Kramer	<.0001
2		3	2.31	0.1197	261	19.3	<.0001	Tukey-Kramer	<.0001
1	906	2	-0.1433	0.1181	258	-1.21	0.2262	Tukey-Kramer	1
1		3	2.01	0.1181	258	17.01	<.0001	Tukey-Kramer	<.0001
2		3	2.1533	0.1181	258	18.23	<.0001	Tukey-Kramer	<.0001
1	908	2	0.16	0.1038	247	1.54	0.1245	Tukey-Kramer	1
1		3	1.9467	0.1038	247	18.75	<.0001	Tukey-Kramer	<.0001
2		3	1.7867	0.1038	247	17.21	<.0001	Tukey-Kramer	<.0001
1	910	2	0.4733	0.1269	246	3.73	0.0002	Tukey-Kramer	0.2972
1		3	1.8067	0.1269	246	14.24	<.0001	Tukey-Kramer	<.0001
2		3	1.3333	0.1269	246	10.51	<.0001	Tukey-Kramer	<.0001
1	912	2	0.4417	0.1006	254	4.39	<.0001	Tukey-Kramer	0.0345
1		3	2.1583	0.1006	254	21.46	<.0001	Tukey-Kramer	<.0001
2		3	1.7167	0.1006	254	17.07	<.0001	Tukey-Kramer	<.0001
1	914	2	0.3833	0.1138	266	3.37	0.0009	Tukey-Kramer	0.618
1		3	2.4567	0.1138	266	21.59	<.0001	Tukey-Kramer	<.0001
2		3	2.0733	0.1138	266	18.22	<.0001	Tukey-Kramer	<.0001
1	916	2	0.1633	0.12	273	1.36	0.1746	Tukey-Kramer	1
1		3	2.5667	0.12	273	21.39	<.0001	Tukey-Kramer	<.0001
2		3	2.4033	0.12	273	20.03	<.0001	Tukey-Kramer	<.0001
1	918	2	-0.24	0.1279	284	-1.88	0.0615	Tukey-Kramer	1
1		3	2.4	0.1279	284	18.77	<.0001	Tukey-Kramer	<.0001
2		3	2.64	0.1279	284	20.65	<.0001	Tukey-Kramer	<.0001
1	920	2	-0.6567	0.1647	295	-3.99	<.0001	Tukey-Kramer	0.1442
1		3	2.2233	0.1647	295	13.5	<.0001	Tukey-Kramer	<.0001
2		3	2.88	0.1647	295	17.49	<.0001	Tukey-Kramer	<.0001
1	922	2	0.1167	0.1353	299	0.86	0.3892	Tukey-Kramer	1
1		3	2.24	0.1353	299	16.55	<.0001	Tukey-Kramer	<.0001
2		3	2.1233	0.1353	299	15.69	<.0001	Tukey-Kramer	<.0001

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Table 6: Continued

1	924	2	0.8967	0.1351	295	6.64	<.0001	Tukey-Kramer	<.0001
1		3	2.3667	0.1351	295	17.51	<.0001	Tukey-Kramer	<.0001
2		3	1.47	0.1351	295	10.88	<.0001	Tukey-Kramer	<.0001
1	926	2	1.1533	0.1353	285	8.53	<.0001	Tukey-Kramer	<.0001
1		3	1.8433	0.1353	285	13.63	<.0001	Tukey-Kramer	<.0001
2		3	0.69	0.1353	285	5.1	<.0001	Tukey-Kramer	0.0015
1	928	2	0.93	0.1457	278	6.38	<.0001	Tukey-Kramer	<.0001
1		3	1.02	0.1457	278	7	<.0001	Tukey-Kramer	<.0001
2		3	0.09	0.1457	278	0.62	0.5373	Tukey-Kramer	1
1	930	2	0.6367	0.197	252	3.23	0.0014	Tukey-Kramer	0.7405
1		3	0.1233	0.197	252	0.63	0.5318	Tukey-Kramer	1
2		3	-0.5133	0.197	252	-2.61	0.0097	Tukey-Kramer	0.9939

Table 19: Electric Field Strength (V/m) Scenario 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	1.515	0.01532	165	98.88	<.0001
1	2		1.405	0.01532	165	91.7	<.0001
1	3		1.15	0.01532	165	75.06	<.0001
1	1	902	1.5472	0.02764	184	55.98	<.0001
1	2		1.52	0.02764	184	55	<.0001
1	3		1.1883	0.02764	184	43	<.0001
1	1	904	1.58	0.01965	224	80.42	<.0001
1	2		1.6013	0.01965	224	81.51	<.0001
1	3		1.2137	0.01965	224	61.77	<.0001
1	1	906	1.6217	0.0163	247	99.47	<.0001
1	2		1.642	0.0163	247	100.71	<.0001
1	3		1.2683	0.0163	247	77.8	<.0001
1	1	908	1.6605	0.01309	249	126.87	<.0001
1	2		1.63	0.01309	249	124.54	<.0001
1	3		1.32	0.01309	249	100.85	<.0001
1	1	910	1.706	0.01521	256	112.15	<.0001
1	2		1.616	0.01521	256	106.23	<.0001
1	3		1.371	0.01521	256	90.13	<.0001
1	1	912	1.7352	0.01333	273	130.17	<.0001
1	2		1.6663	0.01333	273	125.01	<.0001
1	3		1.35	0.01333	273	101.28	<.0001
1	1	914	1.7628	0.01541	290	114.42	<.0001
1	2		1.7053	0.01541	290	110.69	<.0001
1	3		1.3317	0.01541	290	86.44	<.0001
1	1	916	1.7708	0.0168	301	105.43	<.0001
1	2		1.7567	0.0168	301	104.59	<.0001
1	3		1.3133	0.0168	301	78.19	<.0001
1	1	918	1.7463	0.01951	316	89.51	<.0001
1	2		1.806	0.01951	316	92.57	<.0001
1	3		1.3133	0.01951	316	67.32	<.0001
1	1	920	1.7208	0.02568	332	67.01	<.0001
1	2		1.8367	0.02568	332	71.53	<.0001
1	3		1.31	0.02568	332	51.02	<.0001
1	1	922	1.8017	0.02235	336	80.63	<.0001
1	2		1.7863	0.02235	336	79.94	<.0001
1	3		1.3947	0.02235	336	62.41	<.0001

Table 19: Continued

1	1	924	1.8878	0.02353	328	80.23	<.0001
1	2		1.6967	0.02353	328	72.11	<.0001
1	3		1.45	0.02353	328	61.62	<.0001
1	1	926	1.8753	0.02341	311	80.1	<.0001
1	2		1.637	0.02341	311	69.92	<.0001
1	3		1.4953	0.02341	311	63.87	<.0001
1	1	928	1.7702	0.02256	295	78.47	<.0001
1	2		1.571	0.02256	295	69.64	<.0001
1	3		1.572	0.02256	295	69.69	<.0001
1	1	930	1.6625	0.03025	258	54.96	<.0001
1	2		1.509	0.03025	258	49.89	<.0001
1	3		1.6203	0.03025	258	53.57	<.0001

Table 20: Electric Field Strength (V/m) Scenario 1 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.11	0.02167	165	5.08	<.0001	Tukey-Kramer	0.0017
1	900	3	0.365	0.02167	165	16.85	<.0001	Tukey-Kramer	<.0001
2	900	3	0.255	0.02167	165	11.77	<.0001	Tukey-Kramer	<.0001
1	902	2	0.02717	0.03909	184	0.7	0.4879	Tukey-Kramer	1
1	902	3	0.3588	0.03909	184	9.18	<.0001	Tukey-Kramer	<.0001
2	902	3	0.3317	0.03909	184	8.49	<.0001	Tukey-Kramer	<.0001
1	904	2	-0.02133	0.02779	224	-0.77	0.4434	Tukey-Kramer	1
1	904	3	0.3663	0.02779	224	13.18	<.0001	Tukey-Kramer	<.0001
2	904	3	0.3877	0.02779	224	13.95	<.0001	Tukey-Kramer	<.0001
1	906	2	-0.02033	0.02306	247	-0.88	0.3787	Tukey-Kramer	1
1	906	3	0.3533	0.02306	247	15.32	<.0001	Tukey-Kramer	<.0001
2	906	3	0.3737	0.02306	247	16.21	<.0001	Tukey-Kramer	<.0001
1	908	2	0.0305	0.01851	249	1.65	0.1007	Tukey-Kramer	1
1	908	3	0.3405	0.01851	249	18.4	<.0001	Tukey-Kramer	<.0001
2	908	3	0.31	0.01851	249	16.75	<.0001	Tukey-Kramer	<.0001
1	910	2	0.09	0.02151	256	4.18	<.0001	Tukey-Kramer	0.0751
1	910	3	0.335	0.02151	256	15.57	<.0001	Tukey-Kramer	<.0001
2	910	3	0.245	0.02151	256	11.39	<.0001	Tukey-Kramer	<.0001
1	912	2	0.06883	0.01885	273	3.65	0.0003	Tukey-Kramer	0.3595
1	912	3	0.3852	0.01885	273	20.43	<.0001	Tukey-Kramer	<.0001
2	912	3	0.3163	0.01885	273	16.78	<.0001	Tukey-Kramer	<.0001
1	914	2	0.0575	0.02179	290	2.64	0.0088	Tukey-Kramer	0.9916
1	914	3	0.4312	0.02179	290	19.79	<.0001	Tukey-Kramer	<.0001
2	914	3	0.3737	0.02179	290	17.15	<.0001	Tukey-Kramer	<.0001
1	916	2	0.01417	0.02375	301	0.6	0.5514	Tukey-Kramer	1
1	916	3	0.4575	0.02375	301	19.26	<.0001	Tukey-Kramer	<.0001
2	916	3	0.4433	0.02375	301	18.66	<.0001	Tukey-Kramer	<.0001
1	918	2	-0.05967	0.02759	316	-2.16	0.0313	Tukey-Kramer	1
1	918	3	0.433	0.02759	316	15.69	<.0001	Tukey-Kramer	<.0001
2	918	3	0.4927	0.02759	316	17.86	<.0001	Tukey-Kramer	<.0001
1	920	2	-0.1158	0.03631	332	-3.19	0.0016	Tukey-Kramer	0.7752
1	920	3	0.4108	0.03631	332	11.31	<.0001	Tukey-Kramer	<.0001
2	920	3	0.5267	0.03631	332	14.5	<.0001	Tukey-Kramer	<.0001
1	922	2	0.01533	0.0316	336	0.49	0.6278	Tukey-Kramer	1
1	922	3	0.407	0.0316	336	12.88	<.0001	Tukey-Kramer	<.0001
2	922	3	0.3917	0.0316	336	12.39	<.0001	Tukey-Kramer	<.0001

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Table 20: Continued

1	924	2	0.1912	0.03328	328	5.74	<.0001	Tukey-Kramer	<.0001
1	924	3	0.4378	0.03328	328	13.16	<.0001	Tukey-Kramer	<.0001
2	924	3	0.2467	0.03328	328	7.41	<.0001	Tukey-Kramer	<.0001
1	926	2	0.2383	0.03311	311	7.2	<.0001	Tukey-Kramer	<.0001
1	926	3	0.38	0.03311	311	11.48	<.0001	Tukey-Kramer	<.0001
2	926	3	0.1417	0.03311	311	4.28	<.0001	Tukey-Kramer	0.0532
1	928	2	0.1992	0.0319	295	6.24	<.0001	Tukey-Kramer	<.0001
1	928	3	0.1982	0.0319	295	6.21	<.0001	Tukey-Kramer	<.0001
2	928	3	-0.001	0.0319	295	-0.03	0.975	Tukey-Kramer	1
1	930	2	0.1535	0.04278	258	3.59	0.0004	Tukey-Kramer	0.4136
1	930	3	0.04217	0.04278	258	0.99	0.3252	Tukey-Kramer	1
2	930	3	-0.1113	0.04278	258	-2.6	0.0098	Tukey-Kramer	0.994

Table 21: Absolute Power on Tag Forward (dBm) Scenario 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	12.7133	0.07129	220	178.34	<.0001
1	2		13.3033	0.07129	220	186.62	<.0001
1	3		15	0.07129	220	210.42	<.0001
1	1	902	12.565	0.06457	254	194.6	<.0001
1	2		12.7867	0.06457	254	198.03	<.0001
1	3		14.8133	0.06457	254	229.42	<.0001
1	1	904	12.4217	0.08087	266	153.6	<.0001
1	2		12.29	0.08087	266	151.97	<.0001
1	3		14.64	0.08087	266	181.03	<.0001
1	1	906	12.2267	0.083	264	147.31	<.0001
1	2		12.0467	0.083	264	145.14	<.0001
1	3		14.3167	0.083	264	172.49	<.0001
1	1	908	11.9733	0.07273	252	164.62	<.0001
1	2		12.12	0.07273	252	166.63	<.0001
1	3		13.93	0.07273	252	191.52	<.0001
1	1	910	11.72	0.08883	247	131.93	<.0001
1	2		12.2	0.08883	247	137.34	<.0001
1	3		13.5	0.08883	247	151.97	<.0001
1	1	912	11.5883	0.07585	251	152.77	<.0001
1	2		12.0333	0.07585	251	158.64	<.0001
1	3		13.7133	0.07585	251	180.79	<.0001
1	1	914	11.4617	0.08056	262	142.28	<.0001
1	2		11.79	0.08056	262	146.35	<.0001
1	3		13.8833	0.08056	262	172.34	<.0001
1	1	916	11.4833	0.08209	270	139.89	<.0001
1	2		11.57	0.08209	270	140.95	<.0001
1	3		14.0133	0.08209	270	170.71	<.0001
1	1	918	11.62	0.08946	281	129.89	<.0001
1	2		11.3833	0.08946	281	127.25	<.0001
1	3		14.0467	0.08946	281	157.02	<.0001
1	1	920	11.77	0.1137	293	103.55	<.0001
1	2		11.1767	0.1137	293	98.33	<.0001
1	3		14.0767	0.1137	293	123.85	<.0001
1	1	922	11.4233	0.1001	297	114.18	<.0001
1	2		11.54	0.1001	297	115.34	<.0001
1	3		13.7667	0.1001	297	137.6	<.0001

Table 21: Continued

1	1	924	11.02	0.0994	294	110.86	<.0001
1	2		11.9133	0.0994	294	119.85	<.0001
1	3		13.3867	0.0994	294	134.67	<.0001
1	1	926	11.1	0.09691	284	114.54	<.0001
1	2		12.32	0.09691	284	127.13	<.0001
1	3		13.0333	0.09691	284	134.49	<.0001
1	1	928	11.645	0.1056	277	110.27	<.0001
1	2		12.62	0.1056	277	119.51	<.0001
1	3		12.7	0.1056	277	120.26	<.0001
1	1	930	12.1717	0.1403	249	86.78	<.0001
1	2		12.95	0.1403	249	92.33	<.0001
1	3		12.4667	0.1403	249	88.88	<.0001

Table 22: Absolute Power on Tag Forward (dBm) Scenario 1 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-0.59	0.1008	220	-5.85	<.0001	Tukey-Kramer	<.0001
1		3	-2.2867	0.1008	220	-22.68	<.0001	Tukey-Kramer	<.0001
2		3	-1.6967	0.1008	220	-16.83	<.0001	Tukey-Kramer	<.0001
1	902	2	-0.2217	0.09131	254	-2.43	0.0159	Tukey-Kramer	0.9991
1		3	-2.2483	0.09131	254	-24.62	<.0001	Tukey-Kramer	<.0001
2		3	-2.0267	0.09131	254	-22.19	<.0001	Tukey-Kramer	<.0001
1	904	2	0.1317	0.1144	266	1.15	0.2507	Tukey-Kramer	1
1		3	-2.2183	0.1144	266	-19.4	<.0001	Tukey-Kramer	<.0001
2		3	-2.35	0.1144	266	-20.55	<.0001	Tukey-Kramer	<.0001
1	906	2	0.18	0.1174	264	1.53	0.1264	Tukey-Kramer	1
1		3	-2.09	0.1174	264	-17.81	<.0001	Tukey-Kramer	<.0001
2		3	-2.27	0.1174	264	-19.34	<.0001	Tukey-Kramer	<.0001
1	908	2	-0.1467	0.1029	252	-1.43	0.1551	Tukey-Kramer	1
1		3	-1.9567	0.1029	252	-19.02	<.0001	Tukey-Kramer	<.0001
2		3	-1.81	0.1029	252	-17.6	<.0001	Tukey-Kramer	<.0001
1	910	2	-0.48	0.1256	247	-3.82	0.0002	Tukey-Kramer	0.2345
1		3	-1.78	0.1256	247	-14.17	<.0001	Tukey-Kramer	<.0001
2		3	-1.3	0.1256	247	-10.35	<.0001	Tukey-Kramer	<.0001
1	912	2	-0.445	0.1073	251	-4.15	<.0001	Tukey-Kramer	0.0848
1		3	-2.125	0.1073	251	-19.81	<.0001	Tukey-Kramer	<.0001
2		3	-1.68	0.1073	251	-15.66	<.0001	Tukey-Kramer	<.0001
1	914	2	-0.3283	0.1139	262	-2.88	0.0043	Tukey-Kramer	0.9478
1		3	-2.4217	0.1139	262	-21.26	<.0001	Tukey-Kramer	<.0001
2		3	-2.0933	0.1139	262	-18.37	<.0001	Tukey-Kramer	<.0001
1	916	2	-0.08667	0.1161	270	-0.75	0.456	Tukey-Kramer	1
1		3	-2.53	0.1161	270	-21.79	<.0001	Tukey-Kramer	<.0001
2		3	-2.4433	0.1161	270	-21.05	<.0001	Tukey-Kramer	<.0001
1	918	2	0.2367	0.1265	281	1.87	0.0624	Tukey-Kramer	1
1		3	-2.4267	0.1265	281	-19.18	<.0001	Tukey-Kramer	<.0001
2		3	-2.6633	0.1265	281	-21.05	<.0001	Tukey-Kramer	<.0001
1	920	2	0.5933	0.1607	293	3.69	0.0003	Tukey-Kramer	0.3272
1		3	-2.3067	0.1607	293	-14.35	<.0001	Tukey-Kramer	<.0001
2		3	-2.9	0.1607	293	-18.04	<.0001	Tukey-Kramer	<.0001
1	922	2	-0.1167	0.1415	297	-0.82	0.4103	Tukey-Kramer	1
1		3	-2.3433	0.1415	297	-16.56	<.0001	Tukey-Kramer	<.0001
2		3	-2.2267	0.1415	297	-15.74	<.0001	Tukey-Kramer	<.0001

Table 22: Continued

1	924	2	-0.8933	0.1406	294	-6.35	<.0001	Tukey-Kramer	<.0001
1		3	-2.3667	0.1406	294	-16.84	<.0001	Tukey-Kramer	<.0001
2		3	-1.4733	0.1406	294	-10.48	<.0001	Tukey-Kramer	<.0001
1	926	2	-1.22	0.137	284	-8.9	<.0001	Tukey-Kramer	<.0001
1		3	-1.9333	0.137	284	-14.11	<.0001	Tukey-Kramer	<.0001
2		3	-0.7133	0.137	284	-5.21	<.0001	Tukey-Kramer	0.0009
1	928	2	-0.975	0.1493	277	-6.53	<.0001	Tukey-Kramer	<.0001
1		3	-1.055	0.1493	277	-7.06	<.0001	Tukey-Kramer	<.0001
2		3	-0.08	0.1493	277	-0.54	0.5926	Tukey-Kramer	1
1	930	2	-0.7783	0.1984	249	-3.92	0.0001	Tukey-Kramer	0.1746
1		3	-0.295	0.1984	249	-1.49	0.1382	Tukey-Kramer	1
2		3	0.4833	0.1984	249	2.44	0.0155	Tukey-Kramer	0.999



Table 23: Theoretical Read Range Forward (m) Scenario 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	6.52	0.05727	230	113.85	<.0001
1	2		6.99	0.05727	230	122.05	<.0001
1	3		8.5	0.05727	230	148.42	<.0001
1	1	902	6.4067	0.04414	256	145.14	<.0001
1	2		6.64	0.04414	256	150.42	<.0001
1	3		8.2833	0.04414	256	187.65	<.0001
1	1	904	6.305	0.04841	266	130.24	<.0001
1	2		6.2267	0.04841	266	128.62	<.0001
1	3		8.02	0.04841	266	165.67	<.0001
1	1	906	6.1633	0.04618	271	133.46	<.0001
1	2		6.03	0.04618	271	130.58	<.0001
1	3		7.8067	0.04618	271	169.05	<.0001
1	1	908	5.9767	0.04687	269	127.52	<.0001
1	2		6.08	0.04687	269	129.73	<.0001
1	3		7.4167	0.04687	269	158.25	<.0001
1	1	910	5.8133	0.05849	272	99.39	<.0001
1	2		6.14	0.05849	272	104.97	<.0001
1	3		7.0467	0.05849	272	120.47	<.0001
1	1	912	5.7133	0.04547	274	125.66	<.0001
1	2		5.9767	0.04547	274	131.45	<.0001
1	3		7.19	0.04547	274	158.14	<.0001
1	1	914	5.6317	0.0438	284	128.56	<.0001
1	2		5.8333	0.0438	284	133.17	<.0001
1	3		7.3767	0.0438	284	168.4	<.0001
1	1	916	5.6233	0.0447	290	125.8	<.0001
1	2		5.6633	0.0447	290	126.7	<.0001
1	3		7.43	0.0447	290	166.22	<.0001
1	1	918	5.695	0.03992	283	142.67	<.0001
1	2		5.52	0.03992	283	138.28	<.0001
1	3		7.4433	0.03992	283	186.46	<.0001
1	1	920	5.7817	0.04942	274	116.99	<.0001
1	2		5.35	0.04942	274	108.25	<.0001
1	3		7.4467	0.04942	274	150.67	<.0001
1	1	922	5.5133	0.03724	260	148.06	<.0001
1	2		5.6267	0.03724	260	151.1	<.0001
1	3		7.26	0.03724	260	194.96	<.0001

Table 23: Continued

1	1	924	5.2567	0.03611	252	145.56	<.0001
1	2		5.8133	0.03611	252	160.97	<.0001
1	3		6.8867	0.03611	252	190.69	<.0001
1	1	926	5.31	0.03879	248	136.89	<.0001
1	2		6.0767	0.03879	248	156.66	<.0001
1	3		6.5333	0.03879	248	168.43	<.0001
1	1	928	5.6317	0.04469	252	126.02	<.0001
1	2		6.3267	0.04469	252	141.58	<.0001
1	3		6.3667	0.04469	252	142.47	<.0001
1	1	930	6.0083	0.05986	234	100.38	<.0001
1	2		6.5633	0.05986	234	109.65	<.0001
1	3		6.1167	0.05986	234	102.19	<.0001

Table 24: Theoretical Read Range Forward (m) Scenario 1 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-0.47	0.08099	230	-5.8	<.0001	Tukey-Kramer	<.0001
1		3	-1.98	0.08099	230	-24.45	<.0001	Tukey-Kramer	<.0001
2		3	-1.51	0.08099	230	-18.64	<.0001	Tukey-Kramer	<.0001
1	902	2	-0.2333	0.06243	256	-3.74	0.0002	Tukey-Kramer	0.2918
1		3	-1.8767	0.06243	256	-30.06	<.0001	Tukey-Kramer	<.0001
2		3	-1.6433	0.06243	256	-26.32	<.0001	Tukey-Kramer	<.0001
1	904	2	0.07833	0.06846	266	1.14	0.2536	Tukey-Kramer	1
1		3	-1.715	0.06846	266	-25.05	<.0001	Tukey-Kramer	<.0001
2		3	-1.7933	0.06846	266	-26.19	<.0001	Tukey-Kramer	<.0001
1	906	2	0.1333	0.06531	271	2.04	0.0422	Tukey-Kramer	1
1		3	-1.6433	0.06531	271	-25.16	<.0001	Tukey-Kramer	<.0001
2		3	-1.7767	0.06531	271	-27.2	<.0001	Tukey-Kramer	<.0001
1	908	2	-0.1033	0.06628	269	-1.56	0.1202	Tukey-Kramer	1
1		3	-1.44	0.06628	269	-21.73	<.0001	Tukey-Kramer	<.0001
2		3	-1.3367	0.06628	269	-20.17	<.0001	Tukey-Kramer	<.0001
1	910	2	-0.3267	0.08272	272	-3.95	0.0001	Tukey-Kramer	0.1619
1		3	-1.2333	0.08272	272	-14.91	<.0001	Tukey-Kramer	<.0001
2		3	-0.9067	0.08272	272	-10.96	<.0001	Tukey-Kramer	<.0001
1	912	2	-0.2633	0.0643	274	-4.1	<.0001	Tukey-Kramer	0.1015
1		3	-1.4767	0.0643	274	-22.97	<.0001	Tukey-Kramer	<.0001
2		3	-1.2133	0.0643	274	-18.87	<.0001	Tukey-Kramer	<.0001
1	914	2	-0.2017	0.06195	284	-3.26	0.0013	Tukey-Kramer	0.7208
1		3	-1.745	0.06195	284	-28.17	<.0001	Tukey-Kramer	<.0001
2		3	-1.5433	0.06195	284	-24.91	<.0001	Tukey-Kramer	<.0001
1	916	2	-0.04	0.06322	290	-0.63	0.5274	Tukey-Kramer	1
1		3	-1.8067	0.06322	290	-28.58	<.0001	Tukey-Kramer	<.0001
2		3	-1.7667	0.06322	290	-27.95	<.0001	Tukey-Kramer	<.0001
1	918	2	0.175	0.05645	283	3.1	0.0021	Tukey-Kramer	0.8409
1		3	-1.7483	0.05645	283	-30.97	<.0001	Tukey-Kramer	<.0001
2		3	-1.9233	0.05645	283	-34.07	<.0001	Tukey-Kramer	<.0001
1	920	2	0.4317	0.06989	274	6.18	<.0001	Tukey-Kramer	<.0001
1		3	-1.665	0.06989	274	-23.82	<.0001	Tukey-Kramer	<.0001
2		3	-2.0967	0.06989	274	-30	<.0001	Tukey-Kramer	<.0001
1	922	2	-0.1133	0.05266	260	-2.15	0.0323	Tukey-Kramer	1
1		3	-1.7467	0.05266	260	-33.17	<.0001	Tukey-Kramer	<.0001
2		3	-1.6333	0.05266	260	-31.02	<.0001	Tukey-Kramer	<.0001

Table 24: Continued

1	924	2	-0.5567	0.05107	252	-10.9	<.0001	Tukey-Kramer	<.0001
1		3	-1.63	0.05107	252	-31.92	<.0001	Tukey-Kramer	<.0001
2		3	-1.0733	0.05107	252	-21.02	<.0001	Tukey-Kramer	<.0001
1	926	2	-0.7667	0.05486	248	-13.98	<.0001	Tukey-Kramer	<.0001
1		3	-1.2233	0.05486	248	-22.3	<.0001	Tukey-Kramer	<.0001
2		3	-0.4567	0.05486	248	-8.32	<.0001	Tukey-Kramer	<.0001
1	928	2	-0.695	0.0632	252	-11	<.0001	Tukey-Kramer	<.0001
1		3	-0.735	0.0632	252	-11.63	<.0001	Tukey-Kramer	<.0001
2		3	-0.04	0.0632	252	-0.63	0.5273	Tukey-Kramer	1
1	930	2	-0.555	0.08465	234	-6.56	<.0001	Tukey-Kramer	<.0001
1		3	-0.1083	0.08465	234	-1.28	0.2019	Tukey-Kramer	1
2		3	0.4467	0.08465	234	5.28	<.0001	Tukey-Kramer	0.0006

Table 25: Absolute Backscatter Power (dBm) Scenario 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	50.6417	0.1075	215	470.92	<.0001
1	2		50.49	0.1075	215	469.51	<.0001
1	3		47.8967	0.1075	215	445.39	<.0001
1	1	902	50.74	0.08893	248	570.54	<.0001
1	2		50.365	0.08893	248	566.32	<.0001
1	3		47.9633	0.08893	248	539.32	<.0001
1	1	904	50.87	0.1069	263	476.01	<.0001
1	2		50.2383	0.1069	263	470.1	<.0001
1	3		48.0267	0.1069	263	449.4	<.0001
1	1	906	50.8417	0.108	263	470.88	<.0001
1	2		50.1	0.108	263	464.01	<.0001
1	3		48.1733	0.108	263	446.16	<.0001
1	1	908	50.68	0.09665	248	524.35	<.0001
1	2		49.9567	0.09665	248	516.87	<.0001
1	3		48.4	0.09665	248	500.76	<.0001
1	1	910	50.4917	0.1201	237	420.27	<.0001
1	2		49.825	0.1201	237	414.72	<.0001
1	3		48.68	0.1201	237	405.19	<.0001
1	1	912	50.7567	0.09783	242	518.8	<.0001
1	2		49.77	0.09783	242	508.72	<.0001
1	3		48.5933	0.09783	242	496.69	<.0001
1	1	914	51.0217	0.1226	254	416.31	<.0001
1	2		49.6883	0.1226	254	405.43	<.0001
1	3		48.49	0.1226	254	395.65	<.0001
1	1	916	50.845	0.129	251	394.05	<.0001
1	2		49.355	0.129	251	382.5	<.0001
1	3		48.47	0.129	251	375.64	<.0001
1	1	918	50.1483	0.1203	246	416.93	<.0001
1	2		48.5683	0.1203	246	403.79	<.0001
1	3		48.5667	0.1203	246	403.78	<.0001
1	1	920	49.4467	0.1382	258	357.68	<.0001
1	2		47.9267	0.1382	258	346.68	<.0001
1	3		48.64	0.1382	258	351.84	<.0001
1	1	922	49.6633	0.09647	271	514.83	<.0001
1	2		48.4283	0.09647	271	502.02	<.0001
1	3		48.4933	0.09647	271	502.7	<.0001

Table 25: Continued

1	1	924	49.9167	0.0857	282	582.45	<.0001
1	2		48.8317	0.0857	282	569.79	<.0001
1	3		48.3533	0.0857	282	564.21	<.0001
1	1	926	49.83	0.08378	287	594.77	<.0001
1	2		48.87	0.08378	287	583.31	<.0001
1	3		48.23	0.08378	287	575.67	<.0001
1	1	928	49.38	0.09099	293	542.7	<.0001
1	2		48.5617	0.09099	293	533.71	<.0001
1	3		48.11	0.09099	293	528.74	<.0001
1	1	930	48.95	0.1227	266	398.96	<.0001
1	2		48.2583	0.1227	266	393.32	<.0001
1	3		48.0133	0.1227	266	391.33	<.0001

Table 26: Absolute Backscatter Power (dBm) Scenario 1 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.1517	0.1521	215	1	0.3198	Tukey-Kramer	1
1		3	2.745	0.1521	215	18.05	<.0001	Tukey-Kramer	<.0001
2		3	2.5933	0.1521	215	17.05	<.0001	Tukey-Kramer	<.0001
1	902	2	0.375	0.1258	248	2.98	0.0032	Tukey-Kramer	0.9083
1		3	2.7767	0.1258	248	22.08	<.0001	Tukey-Kramer	<.0001
2		3	2.4017	0.1258	248	19.1	<.0001	Tukey-Kramer	<.0001
1	904	2	0.6317	0.1511	263	4.18	<.0001	Tukey-Kramer	0.0761
1		3	2.8433	0.1511	263	18.81	<.0001	Tukey-Kramer	<.0001
2		3	2.2117	0.1511	263	14.63	<.0001	Tukey-Kramer	<.0001
1	906	2	0.7417	0.1527	263	4.86	<.0001	Tukey-Kramer	0.0047
1		3	2.6683	0.1527	263	17.47	<.0001	Tukey-Kramer	<.0001
2		3	1.9267	0.1527	263	12.62	<.0001	Tukey-Kramer	<.0001
1	908	2	0.7233	0.1367	248	5.29	<.0001	Tukey-Kramer	0.0006
1		3	2.28	0.1367	248	16.68	<.0001	Tukey-Kramer	<.0001
2		3	1.5567	0.1367	248	11.39	<.0001	Tukey-Kramer	<.0001
1	910	2	0.6667	0.1699	237	3.92	0.0001	Tukey-Kramer	0.1748
1		3	1.8117	0.1699	237	10.66	<.0001	Tukey-Kramer	<.0001
2		3	1.145	0.1699	237	6.74	<.0001	Tukey-Kramer	<.0001
1	912	2	0.9867	0.1384	242	7.13	<.0001	Tukey-Kramer	<.0001
1		3	2.1633	0.1384	242	15.64	<.0001	Tukey-Kramer	<.0001
2		3	1.1767	0.1384	242	8.5	<.0001	Tukey-Kramer	<.0001
1	914	2	1.3333	0.1733	254	7.69	<.0001	Tukey-Kramer	<.0001
1		3	2.5317	0.1733	254	14.61	<.0001	Tukey-Kramer	<.0001
2		3	1.1983	0.1733	254	6.91	<.0001	Tukey-Kramer	<.0001
1	916	2	1.49	0.1825	251	8.17	<.0001	Tukey-Kramer	<.0001
1		3	2.375	0.1825	251	13.02	<.0001	Tukey-Kramer	<.0001
2		3	0.885	0.1825	251	4.85	<.0001	Tukey-Kramer	0.0049
1	918	2	1.58	0.1701	246	9.29	<.0001	Tukey-Kramer	<.0001
1		3	1.5817	0.1701	246	9.3	<.0001	Tukey-Kramer	<.0001
2		3	0.001667	0.1701	246	0.01	0.9922	Tukey-Kramer	1
1	920	2	1.52	0.1955	258	7.77	<.0001	Tukey-Kramer	<.0001
1		3	0.8067	0.1955	258	4.13	<.0001	Tukey-Kramer	0.0916
2		3	-0.7133	0.1955	258	-3.65	0.0003	Tukey-Kramer	0.3618
1	922	2	1.235	0.1364	271	9.05	<.0001	Tukey-Kramer	<.0001
1		3	1.17	0.1364	271	8.58	<.0001	Tukey-Kramer	<.0001
2		3	-0.065	0.1364	271	-0.48	0.6341	Tukey-Kramer	1

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Table 26: Continued

1	924	2	1.085	0.1212	282	8.95	<.0001	Tukey-Kramer	<.0001
1		3	1.5633	0.1212	282	12.9	<.0001	Tukey-Kramer	<.0001
2		3	0.4783	0.1212	282	3.95	0.0001	Tukey-Kramer	0.1632
1	926	2	0.96	0.1185	287	8.1	<.0001	Tukey-Kramer	<.0001
1		3	1.6	0.1185	287	13.5	<.0001	Tukey-Kramer	<.0001
2		3	0.64	0.1185	287	5.4	<.0001	Tukey-Kramer	0.0003
1	928	2	0.8183	0.1287	293	6.36	<.0001	Tukey-Kramer	<.0001
1		3	1.27	0.1287	293	9.87	<.0001	Tukey-Kramer	<.0001
2		3	0.4517	0.1287	293	3.51	0.0005	Tukey-Kramer	0.4846
1	930	2	0.6917	0.1735	266	3.99	<.0001	Tukey-Kramer	0.1446
1		3	0.9367	0.1735	266	5.4	<.0001	Tukey-Kramer	0.0003
2		3	0.245	0.1735	266	1.41	0.1591	Tukey-Kramer	1

Table 27: Absolute Received Power (dBm) Scenario 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	79.51	1.3084	2157	60.77	<.0001
1	2		82.44	1.3084	2157	63.01	<.0001
1	3		82.4267	1.3084	2157	63	<.0001
1	1	902	79.4067	1.3084	2157	60.69	<.0001
1	2		82.1967	1.3084	2157	62.82	<.0001
1	3		82.4267	1.3084	2157	63	<.0001
1	1	904	79.46	1.3084	2157	60.73	<.0001
1	2		81.9333	1.3084	2157	62.62	<.0001
1	3		82.42	1.3084	2157	63	<.0001
1	1	906	77.82	1.3084	2157	59.48	<.0001
1	2		81.8967	1.3084	2157	62.6	<.0001
1	3		82.4233	1.3084	2157	63	<.0001
1	1	908	77.9333	1.3084	2157	59.57	<.0001
1	2		82.09	1.3084	2157	62.74	<.0001
1	3		82.4233	1.3084	2157	63	<.0001
1	1	910	79.2833	1.3084	2157	60.6	<.0001
1	2		82.26	1.3084	2157	62.87	<.0001
1	3		82.4333	1.3084	2157	63.01	<.0001
1	1	912	79.2833	1.3084	2157	60.6	<.0001
1	2		82.3233	1.3084	2157	62.92	<.0001
1	3		82.3833	1.3084	2157	62.97	<.0001
1	1	914	79.25	1.3084	2157	60.57	<.0001
1	2		82.37	1.3084	2157	62.96	<.0001
1	3		82.3467	1.3084	2157	62.94	<.0001
1	1	916	79.22	1.3084	2157	60.55	<.0001
1	2		82.3867	1.3084	2157	62.97	<.0001
1	3		82.32	1.3084	2157	62.92	<.0001
1	1	918	79.22	1.3084	2157	60.55	<.0001
1	2		82.38	1.3084	2157	62.96	<.0001
1	3		82.3267	1.3084	2157	62.92	<.0001
1	1	920	79.2133	1.3084	2157	60.54	<.0001
1	2		82.36	1.3084	2157	62.95	<.0001
1	3		82.3367	1.3084	2157	62.93	<.0001
1	1	922	79.0133	1.3084	2157	60.39	<.0001
1	2		82.37	1.3084	2157	62.96	<.0001
1	3		82.37	1.3084	2157	62.96	<.0001

Table 27: Continued

1	1	924	78.9067	1.3084	2157	60.31	<.0001
1	2		82.3633	1.3084	2157	62.95	<.0001
1	3		82.41	1.3084	2157	62.99	<.0001
1	1	926	78.0667	1.3084	2157	59.67	<.0001
1	2		81.3667	1.3084	2157	62.19	<.0001
1	3		82.44	1.3084	2157	63.01	<.0001
1	1	928	74.05	1.3084	2157	56.6	<.0001
1	2		79.4733	1.3084	2157	60.74	<.0001
1	3		82.4367	1.3084	2157	63.01	<.0001
1	1	930	65.09	1.3084	2157	49.75	<.0001
1	2		77.5633	1.3084	2157	59.28	<.0001
1	3		82.44	1.3084	2157	63.01	<.0001

Table 28: Absolute Received Power (dBm) Scenario 1 Comparisons

loc	fre	loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-2.93	1.8503	2157	-1.58	0.1134	Tukey-Kramer	1
1		3	-2.9167	1.8503	2157	-1.58	0.1151	Tukey-Kramer	1
2		3	0.01333	1.8503	2157	0.01	0.9943	Tukey-Kramer	1
1	902	2	-2.79	1.8503	2157	-1.51	0.1317	Tukey-Kramer	1
1		3	-3.02	1.8503	2157	-1.63	0.1028	Tukey-Kramer	1
2		3	-0.23	1.8503	2157	-0.12	0.9011	Tukey-Kramer	1
1	904	2	-2.4733	1.8503	2157	-1.34	0.1815	Tukey-Kramer	1
1		3	-2.96	1.8503	2157	-1.6	0.1098	Tukey-Kramer	1
2		3	-0.4867	1.8503	2157	-0.26	0.7926	Tukey-Kramer	1
1	906	2	-4.0767	1.8503	2157	-2.2	0.0277	Tukey-Kramer	1
1		3	-4.6033	1.8503	2157	-2.49	0.0129	Tukey-Kramer	0.9983
2		3	-0.5267	1.8503	2157	-0.28	0.7759	Tukey-Kramer	1
1	908	2	-4.1567	1.8503	2157	-2.25	0.0248	Tukey-Kramer	0.9999
1		3	-4.49	1.8503	2157	-2.43	0.0153	Tukey-Kramer	0.9992
2		3	-0.3333	1.8503	2157	-0.18	0.8571	Tukey-Kramer	1
1	910	2	-2.9767	1.8503	2157	-1.61	0.1078	Tukey-Kramer	1
1		3	-3.15	1.8503	2157	-1.7	0.0888	Tukey-Kramer	1
2		3	-0.1733	1.8503	2157	-0.09	0.9254	Tukey-Kramer	1
1	912	2	-3.04	1.8503	2157	-1.64	0.1005	Tukey-Kramer	1
1		3	-3.1	1.8503	2157	-1.68	0.094	Tukey-Kramer	1
2		3	-0.06	1.8503	2157	-0.03	0.9741	Tukey-Kramer	1
1	914	2	-3.12	1.8503	2157	-1.69	0.0919	Tukey-Kramer	1
1		3	-3.0967	1.8503	2157	-1.67	0.0944	Tukey-Kramer	1
2		3	0.02333	1.8503	2157	0.01	0.9899	Tukey-Kramer	1
1	916	2	-3.1667	1.8503	2157	-1.71	0.0871	Tukey-Kramer	1
1		3	-3.1	1.8503	2157	-1.68	0.094	Tukey-Kramer	1
2		3	0.06667	1.8503	2157	0.04	0.9713	Tukey-Kramer	1
1	918	2	-3.16	1.8503	2157	-1.71	0.0878	Tukey-Kramer	1
1		3	-3.1067	1.8503	2157	-1.68	0.0933	Tukey-Kramer	1
2		3	0.05333	1.8503	2157	0.03	0.977	Tukey-Kramer	1
1	920	2	-3.1467	1.8503	2157	-1.7	0.0892	Tukey-Kramer	1
1		3	-3.1233	1.8503	2157	-1.69	0.0916	Tukey-Kramer	1
2		3	0.02333	1.8503	2157	0.01	0.9899	Tukey-Kramer	1
1	922	2	-3.3567	1.8503	2157	-1.81	0.0698	Tukey-Kramer	1
1		3	-3.3567	1.8503	2157	-1.81	0.0698	Tukey-Kramer	1
2		3	2.04E-14	1.8503	2157	0	1	Tukey-Kramer	1

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2

Table 28: Continued

1	924	2	-3.4567	1.8503	2157	-1.87	0.0619	Tukey-Kramer	1
1		3	-3.5033	1.8503	2157	-1.89	0.0584	Tukey-Kramer	1
2		3	-0.04667	1.8503	2157	-0.03	0.9799	Tukey-Kramer	1
1	926	2	-3.3	1.8503	2157	-1.78	0.0746	Tukey-Kramer	1
1		3	-4.3733	1.8503	2157	-2.36	0.0182	Tukey-Kramer	0.9996
2		3	-1.0733	1.8503	2157	-0.58	0.5619	Tukey-Kramer	1
1	928	2	-5.4233	1.8503	2157	-2.93	0.0034	Tukey-Kramer	0.9311
1		3	-8.3867	1.8503	2157	-4.53	<.0001	Tukey-Kramer	0.0192
2		3	-2.9633	1.8503	2157	-1.6	0.1094	Tukey-Kramer	1
1	930	2	-12.4733	1.8503	2157	-6.74	<.0001	Tukey-Kramer	<.0001
1		3	-17.35	1.8503	2157	-9.38	<.0001	Tukey-Kramer	<.0001
2		3	-4.8767	1.8503	2157	-2.64	0.0085	Tukey-Kramer	0.9921

Table 29: Absolute Delta RCS (dBsqm) Scenario 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	22.53	0.06879	241	327.52	<.0001
1	2		20.73	0.06879	241	301.35	<.0001
1	3		17.48	0.06879	241	254.1	<.0001
1	1	902	22.8033	0.05175	284	440.61	<.0001
1	2		21.5733	0.05175	284	416.84	<.0001
1	3		17.79	0.05175	284	343.74	<.0001
1	1	904	23.0733	0.05928	300	389.23	<.0001
1	2		22.56	0.05928	300	380.57	<.0001
1	3		18.08	0.05928	300	304.99	<.0001
1	1	906	23.2533	0.06073	298	382.9	<.0001
1	2		22.8433	0.06073	298	376.14	<.0001
1	3		18.5133	0.06073	298	304.85	<.0001
1	1	908	23.3183	0.05707	275	408.59	<.0001
1	2		22.3967	0.05707	275	392.44	<.0001
1	3		19.1367	0.05707	275	335.32	<.0001
1	1	910	23.3967	0.08024	250	291.6	<.0001
1	2		21.9467	0.08024	250	273.53	<.0001
1	3		19.72	0.08024	250	245.78	<.0001
1	1	912	23.7817	0.06471	243	367.49	<.0001
1	2		22.2767	0.06471	243	344.23	<.0001
1	3		19.49	0.06471	243	301.17	<.0001
1	1	914	24.2	0.08271	267	292.58	<.0001
1	2		22.5833	0.08271	267	273.04	<.0001
1	3		19.2333	0.08271	267	232.53	<.0001
1	1	916	23.975	0.08333	271	287.7	<.0001
1	2		22.8033	0.08333	271	273.64	<.0001
1	3		19.15	0.08333	271	229.8	<.0001
1	1	918	23.095	0.07213	246	320.2	<.0001
1	2		23	0.07213	246	318.88	<.0001
1	3		19.24	0.07213	246	266.75	<.0001
1	1	920	22.3333	0.07515	249	297.18	<.0001
1	2		23.13	0.07515	249	307.78	<.0001
1	3		19.31	0.07515	249	256.95	<.0001
1	1	922	22.9417	0.05087	278	450.96	<.0001
1	2		22.8	0.05087	278	448.17	<.0001
1	3		19.4933	0.05087	278	383.18	<.0001

Table 29: Continued

1	1	924	23.5817	0.05668	282	416.02	<.0001
1	2		22.4733	0.05668	282	396.46	<.0001
1	3		19.7033	0.05668	282	347.6	<.0001
1	1	926	23.355	0.05673	250	411.7	<.0001
1	2		21.8133	0.05673	250	384.52	<.0001
1	3		19.9067	0.05673	250	350.91	<.0001
1	1	928	22.4083	0.05403	219	414.75	<.0001
1	2		20.8467	0.05403	219	385.85	<.0001
1	3		20.1167	0.05403	219	372.34	<.0001
1	1	930	21.4183	0.07357	200	291.13	<.0001
1	2		19.8733	0.07357	200	270.13	<.0001
1	3		20.35	0.07357	200	276.6	<.0001

Table 30: Absolute Delta RCS (dBsqm) Scenario 1 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	1.8	0.09728	241	18.5	<.0001	Tukey-Kramer	<.0001
1		3	5.05	0.09728	241	51.91	<.0001	Tukey-Kramer	<.0001
2		3	3.25	0.09728	241	33.41	<.0001	Tukey-Kramer	<.0001
1	902	2	1.23	0.07319	284	16.81	<.0001	Tukey-Kramer	<.0001
1		3	5.0133	0.07319	284	68.5	<.0001	Tukey-Kramer	<.0001
2		3	3.7833	0.07319	284	51.69	<.0001	Tukey-Kramer	<.0001
1	904	2	0.5133	0.08383	300	6.12	<.0001	Tukey-Kramer	<.0001
1		3	4.9933	0.08383	300	59.56	<.0001	Tukey-Kramer	<.0001
2		3	4.48	0.08383	300	53.44	<.0001	Tukey-Kramer	<.0001
1	906	2	0.41	0.08589	298	4.77	<.0001	Tukey-Kramer	0.0069
1		3	4.74	0.08589	298	55.19	<.0001	Tukey-Kramer	<.0001
2		3	4.33	0.08589	298	50.42	<.0001	Tukey-Kramer	<.0001
1	908	2	0.9217	0.08071	275	11.42	<.0001	Tukey-Kramer	<.0001
1		3	4.1817	0.08071	275	51.81	<.0001	Tukey-Kramer	<.0001
2		3	3.26	0.08071	275	40.39	<.0001	Tukey-Kramer	<.0001
1	910	2	1.45	0.1135	250	12.78	<.0001	Tukey-Kramer	<.0001
1		3	3.6767	0.1135	250	32.4	<.0001	Tukey-Kramer	<.0001
2		3	2.2267	0.1135	250	19.62	<.0001	Tukey-Kramer	<.0001
1	912	2	1.505	0.09152	243	16.44	<.0001	Tukey-Kramer	<.0001
1		3	4.2917	0.09152	243	46.89	<.0001	Tukey-Kramer	<.0001
2		3	2.7867	0.09152	243	30.45	<.0001	Tukey-Kramer	<.0001
1	914	2	1.6167	0.117	267	13.82	<.0001	Tukey-Kramer	<.0001
1		3	4.9667	0.117	267	42.46	<.0001	Tukey-Kramer	<.0001
2		3	3.35	0.117	267	28.64	<.0001	Tukey-Kramer	<.0001
1	916	2	1.1717	0.1178	271	9.94	<.0001	Tukey-Kramer	<.0001
1		3	4.825	0.1178	271	40.94	<.0001	Tukey-Kramer	<.0001
2		3	3.6533	0.1178	271	31	<.0001	Tukey-Kramer	<.0001
1	918	2	0.095	0.102	246	0.93	0.3526	Tukey-Kramer	1
1		3	3.855	0.102	246	37.79	<.0001	Tukey-Kramer	<.0001
2		3	3.76	0.102	246	36.86	<.0001	Tukey-Kramer	<.0001
1	920	2	-0.7967	0.1063	249	-7.5	<.0001	Tukey-Kramer	<.0001
1		3	3.0233	0.1063	249	28.45	<.0001	Tukey-Kramer	<.0001
2		3	3.82	0.1063	249	35.94	<.0001	Tukey-Kramer	<.0001
1	922	2	0.1417	0.07195	278	1.97	0.0499	Tukey-Kramer	1
1		3	3.4483	0.07195	278	47.93	<.0001	Tukey-Kramer	<.0001
2		3	3.3067	0.07195	278	45.96	<.0001	Tukey-Kramer	<.0001

Table 30: Continued

1	924	2	1.1083	0.08016	282	13.83	<.0001	Tukey-Kramer	<.0001
1		3	3.8783	0.08016	282	48.38	<.0001	Tukey-Kramer	<.0001
2		3	2.77	0.08016	282	34.55	<.0001	Tukey-Kramer	<.0001
1	926	2	1.5417	0.08023	250	19.22	<.0001	Tukey-Kramer	<.0001
1		3	3.4483	0.08023	250	42.98	<.0001	Tukey-Kramer	<.0001
2		3	1.9067	0.08023	250	23.77	<.0001	Tukey-Kramer	<.0001
1	928	2	1.5617	0.07641	219	20.44	<.0001	Tukey-Kramer	<.0001
1		3	2.2917	0.07641	219	29.99	<.0001	Tukey-Kramer	<.0001
2		3	0.73	0.07641	219	9.55	<.0001	Tukey-Kramer	<.0001
1	930	2	1.545	0.104	200	14.85	<.0001	Tukey-Kramer	<.0001
1		3	1.0683	0.104	200	10.27	<.0001	Tukey-Kramer	<.0001
2		3	-0.4767	0.104	200	-4.58	<.0001	Tukey-Kramer	0.016

Table 31: Absolute Power on Tag Reverse (dBm) Scenario 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	17.6533	0.1007	226	175.29	<.0001
1	2		16.43	0.1007	226	163.14	<.0001
1	3		14.92	0.1007	226	148.15	<.0001
1	1	902	17.77	0.08459	262	210.08	<.0001
1	2		16.8133	0.08459	262	198.77	<.0001
1	3		14.97	0.08459	262	176.97	<.0001
1	1	904	17.8967	0.1024	276	174.74	<.0001
1	2		17.2567	0.1024	276	168.49	<.0001
1	3		15.02	0.1024	276	146.65	<.0001
1	1	906	17.8583	0.1052	274	169.73	<.0001
1	2		17.2733	0.1052	274	164.17	<.0001
1	3		15.1633	0.1052	274	144.12	<.0001
1	1	908	17.6633	0.09129	257	193.5	<.0001
1	2		16.8867	0.09129	257	184.99	<.0001
1	3		15.4167	0.09129	257	168.88	<.0001
1	1	910	17.48	0.1161	247	150.62	<.0001
1	2		16.5067	0.1161	247	142.24	<.0001
1	3		15.6567	0.1161	247	134.91	<.0001
1	1	912	17.7483	0.09585	250	185.17	<.0001
1	2		16.5933	0.09585	250	173.12	<.0001
1	3		15.55	0.09585	250	162.23	<.0001
1	1	914	17.9983	0.1161	266	155.05	<.0001
1	2		16.6967	0.1161	266	143.84	<.0001
1	3		15.43	0.1161	266	132.93	<.0001
1	1	916	17.77	0.1181	267	150.49	<.0001
1	2		16.72	0.1181	267	141.6	<.0001
1	3		15.42	0.1181	267	130.59	<.0001
1	1	918	17.0667	0.1069	258	159.72	<.0001
1	2		16.6367	0.1069	258	155.7	<.0001
1	3		15.49	0.1069	258	144.97	<.0001
1	1	920	16.395	0.1356	254	120.9	<.0001
1	2		16.57	0.1356	254	122.19	<.0001
1	3		15.5667	0.1356	254	114.79	<.0001
1	1	922	16.5967	0.1028	254	161.46	<.0001
1	2		16.6067	0.1028	254	161.55	<.0001
1	3		15.4167	0.1028	254	149.98	<.0001

Table 31: Continued

1	1	924	16.8017	0.09421	258	178.35	<.0001
1	2		16.6133	0.09421	258	176.35	<.0001
1	3		15.25	0.09421	258	161.87	<.0001
1	1	926	16.6883	0.09469	264	176.24	<.0001
1	2		16.32	0.09469	264	172.35	<.0001
1	3		15.1067	0.09469	264	159.53	<.0001
1	1	928	16.2433	0.09708	276	167.32	<.0001
1	2		15.6233	0.09708	276	160.93	<.0001
1	3		14.9767	0.09708	276	154.27	<.0001
1	1	930	15.8283	0.1285	254	123.16	<.0001
1	2		14.99	0.1285	254	116.63	<.0001
1	3		14.8467	0.1285	254	115.52	<.0001

Table 32: Absolute Power on Tag Reverse (dBm) Scenario 1 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	1.2233	0.1424	226	8.59	<.0001	Tukey-Kramer	<.0001
1		3	2.7333	0.1424	226	19.19	<.0001	Tukey-Kramer	<.0001
2		3	1.51	0.1424	226	10.6	<.0001	Tukey-Kramer	<.0001
1	902	2	0.9567	0.1196	262	8	<.0001	Tukey-Kramer	<.0001
1		3	2.8	0.1196	262	23.41	<.0001	Tukey-Kramer	<.0001
2		3	1.8433	0.1196	262	15.41	<.0001	Tukey-Kramer	<.0001
1	904	2	0.64	0.1448	276	4.42	<.0001	Tukey-Kramer	0.0312
1		3	2.8767	0.1448	276	19.86	<.0001	Tukey-Kramer	<.0001
2		3	2.2367	0.1448	276	15.44	<.0001	Tukey-Kramer	<.0001
1	906	2	0.585	0.1488	274	3.93	0.0001	Tukey-Kramer	0.1707
1		3	2.695	0.1488	274	18.11	<.0001	Tukey-Kramer	<.0001
2		3	2.11	0.1488	274	14.18	<.0001	Tukey-Kramer	<.0001
1	908	2	0.7767	0.1291	257	6.02	<.0001	Tukey-Kramer	<.0001
1		3	2.2467	0.1291	257	17.4	<.0001	Tukey-Kramer	<.0001
2		3	1.47	0.1291	257	11.39	<.0001	Tukey-Kramer	<.0001
1	910	2	0.9733	0.1641	247	5.93	<.0001	Tukey-Kramer	<.0001
1		3	1.8233	0.1641	247	11.11	<.0001	Tukey-Kramer	<.0001
2		3	0.85	0.1641	247	5.18	<.0001	Tukey-Kramer	0.001
1	912	2	1.155	0.1356	250	8.52	<.0001	Tukey-Kramer	<.0001
1		3	2.1983	0.1356	250	16.22	<.0001	Tukey-Kramer	<.0001
2		3	1.0433	0.1356	250	7.7	<.0001	Tukey-Kramer	<.0001
1	914	2	1.3017	0.1642	266	7.93	<.0001	Tukey-Kramer	<.0001
1		3	2.5683	0.1642	266	15.65	<.0001	Tukey-Kramer	<.0001
2		3	1.2667	0.1642	266	7.72	<.0001	Tukey-Kramer	<.0001
1	916	2	1.05	0.167	267	6.29	<.0001	Tukey-Kramer	<.0001
1		3	2.35	0.167	267	14.07	<.0001	Tukey-Kramer	<.0001
2		3	1.3	0.167	267	7.78	<.0001	Tukey-Kramer	<.0001
1	918	2	0.43	0.1511	258	2.85	0.0048	Tukey-Kramer	0.9585
1		3	1.5767	0.1511	258	10.43	<.0001	Tukey-Kramer	<.0001
2		3	1.1467	0.1511	258	7.59	<.0001	Tukey-Kramer	<.0001
1	920	2	-0.175	0.1918	254	-0.91	0.3624	Tukey-Kramer	1
1		3	0.8283	0.1918	254	4.32	<.0001	Tukey-Kramer	0.0457
2		3	1.0033	0.1918	254	5.23	<.0001	Tukey-Kramer	0.0008
1	922	2	-0.01	0.1454	254	-0.07	0.9452	Tukey-Kramer	1
1		3	1.18	0.1454	254	8.12	<.0001	Tukey-Kramer	<.0001
2		3	1.19	0.1454	254	8.19	<.0001	Tukey-Kramer	<.0001

Table 32: Continued

1	924	2	0.1883	0.1332	258	1.41	0.1587	Tukey-Kramer	1
1		3	1.5517	0.1332	258	11.65	<.0001	Tukey-Kramer	<.0001
2		3	1.3633	0.1332	258	10.23	<.0001	Tukey-Kramer	<.0001
1	926	2	0.3683	0.1339	264	2.75	0.0064	Tukey-Kramer	0.9788
1		3	1.5817	0.1339	264	11.81	<.0001	Tukey-Kramer	<.0001
2		3	1.2133	0.1339	264	9.06	<.0001	Tukey-Kramer	<.0001
1	928	2	0.62	0.1373	276	4.52	<.0001	Tukey-Kramer	0.021
1		3	1.2667	0.1373	276	9.23	<.0001	Tukey-Kramer	<.0001
2		3	0.6467	0.1373	276	4.71	<.0001	Tukey-Kramer	0.0092
1	930	2	0.8383	0.1818	254	4.61	<.0001	Tukey-Kramer	0.0141
1		3	0.9817	0.1818	254	5.4	<.0001	Tukey-Kramer	0.0003
2		3	0.1433	0.1818	254	0.79	0.4311	Tukey-Kramer	1



Table 33: Theoretical Read Range Reverse (m) Scenario 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	17.4067	0.2375	227	73.28	<.0001
1	2		20.1467	0.2375	227	84.82	<.0001
1	3		23.8333	0.2375	227	100.34	<.0001
1	1	902	17.1533	0.2029	264	84.54	<.0001
1	2		19.2567	0.2029	264	94.91	<.0001
1	3		23.7	0.2029	264	116.8	<.0001
1	1	904	16.8933	0.2605	278	64.85	<.0001
1	2		18.2433	0.2605	278	70.03	<.0001
1	3		23.5333	0.2605	278	90.34	<.0001
1	1	906	16.925	0.2628	276	64.41	<.0001
1	2		18.1533	0.2628	276	69.09	<.0001
1	3		23.1133	0.2628	276	87.97	<.0001
1	1	908	17.2433	0.2238	257	77.05	<.0001
1	2		18.93	0.2238	257	84.59	<.0001
1	3		22.4	0.2238	257	100.09	<.0001
1	1	910	17.56	0.2846	243	61.7	<.0001
1	2		19.72	0.2846	243	69.29	<.0001
1	3		21.72	0.2846	243	76.32	<.0001
1	1	912	16.96	0.2423	247	70.01	<.0001
1	2		19.4667	0.2423	247	80.35	<.0001
1	3		21.9267	0.2423	247	90.51	<.0001
1	1	914	16.4317	0.3164	261	51.93	<.0001
1	2		19.2	0.3164	261	60.68	<.0001
1	3		22.18	0.3164	261	70.1	<.0001
1	1	916	16.955	0.3331	257	50.9	<.0001
1	2		19.1367	0.3331	257	57.45	<.0001
1	3		22.16	0.3331	257	66.53	<.0001
1	1	918	18.3633	0.2761	257	66.51	<.0001
1	2		19.2467	0.2761	257	69.71	<.0001
1	3		21.9033	0.2761	257	79.33	<.0001
1	1	920	19.7867	0.3315	275	59.68	<.0001
1	2		19.3533	0.3315	275	58.37	<.0001
1	3		21.68	0.3315	275	65.39	<.0001
1	1	922	19.2267	0.2409	281	79.81	<.0001
1	2		19.23	0.2409	281	79.82	<.0001
1	3		22.04	0.2409	281	91.48	<.0001

Table 33: Continued

1	1	924	18.7083	0.2227	281	84.02	<.0001
1	2		19.1267	0.2227	281	85.89	<.0001
1	3		22.4033	0.2227	281	100.61	<.0001
1	1	926	18.9267	0.2202	278	85.95	<.0001
1	2		19.88	0.2202	278	90.27	<.0001
1	3		22.7233	0.2202	278	103.19	<.0001
1	1	928	19.9217	0.2607	275	76.41	<.0001
1	2		21.4967	0.2607	275	82.45	<.0001
1	3		23.0367	0.2607	275	88.36	<.0001
1	1	930	20.8983	0.3552	246	58.84	<.0001
1	2		23.0267	0.3552	246	64.83	<.0001
1	3		23.3	0.3552	246	65.6	<.0001

Table 34: Theoretical Read Range Reverse (m) Scenario 1 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-2.74	0.3359	227	-8.16	<.0001	Tukey-Kramer	<.0001
1		3	-6.4267	0.3359	227	-19.13	<.0001	Tukey-Kramer	<.0001
2		3	-3.6867	0.3359	227	-10.98	<.0001	Tukey-Kramer	<.0001
1	902	2	-2.1033	0.2869	264	-7.33	<.0001	Tukey-Kramer	<.0001
1		3	-6.5467	0.2869	264	-22.81	<.0001	Tukey-Kramer	<.0001
2		3	-4.4433	0.2869	264	-15.48	<.0001	Tukey-Kramer	<.0001
1	904	2	-1.35	0.3684	278	-3.66	0.0003	Tukey-Kramer	0.3487
1		3	-6.64	0.3684	278	-18.02	<.0001	Tukey-Kramer	<.0001
2		3	-5.29	0.3684	278	-14.36	<.0001	Tukey-Kramer	<.0001
1	906	2	-1.2283	0.3716	276	-3.31	0.0011	Tukey-Kramer	0.6762
1		3	-6.1883	0.3716	276	-16.65	<.0001	Tukey-Kramer	<.0001
2		3	-4.96	0.3716	276	-13.35	<.0001	Tukey-Kramer	<.0001
1	908	2	-1.6867	0.3165	257	-5.33	<.0001	Tukey-Kramer	0.0005
1		3	-5.1567	0.3165	257	-16.29	<.0001	Tukey-Kramer	<.0001
2		3	-3.47	0.3165	257	-10.96	<.0001	Tukey-Kramer	<.0001
1	910	2	-2.16	0.4025	243	-5.37	<.0001	Tukey-Kramer	0.0004
1		3	-4.16	0.4025	243	-10.34	<.0001	Tukey-Kramer	<.0001
2		3	-2	0.4025	243	-4.97	<.0001	Tukey-Kramer	0.0028
1	912	2	-2.5067	0.3426	247	-7.32	<.0001	Tukey-Kramer	<.0001
1		3	-4.9667	0.3426	247	-14.5	<.0001	Tukey-Kramer	<.0001
2		3	-2.46	0.3426	247	-7.18	<.0001	Tukey-Kramer	<.0001
1	914	2	-2.7683	0.4475	261	-6.19	<.0001	Tukey-Kramer	<.0001
1		3	-5.7483	0.4475	261	-12.85	<.0001	Tukey-Kramer	<.0001
2		3	-2.98	0.4475	261	-6.66	<.0001	Tukey-Kramer	<.0001
1	916	2	-2.1817	0.471	257	-4.63	<.0001	Tukey-Kramer	0.0129
1		3	-5.205	0.471	257	-11.05	<.0001	Tukey-Kramer	<.0001
2		3	-3.0233	0.471	257	-6.42	<.0001	Tukey-Kramer	<.0001
1	918	2	-0.8833	0.3905	257	-2.26	0.0245	Tukey-Kramer	0.9999
1		3	-3.54	0.3905	257	-9.07	<.0001	Tukey-Kramer	<.0001
2		3	-2.6567	0.3905	257	-6.8	<.0001	Tukey-Kramer	<.0001
1	920	2	0.4333	0.4689	275	0.92	0.3562	Tukey-Kramer	1
1		3	-1.8933	0.4689	275	-4.04	<.0001	Tukey-Kramer	0.1226
2		3	-2.3267	0.4689	275	-4.96	<.0001	Tukey-Kramer	0.0029
1	922	2	-0.00333	0.3407	281	-0.01	0.9922	Tukey-Kramer	1
1		3	-2.8133	0.3407	281	-8.26	<.0001	Tukey-Kramer	<.0001
2		3	-2.81	0.3407	281	-8.25	<.0001	Tukey-Kramer	<.0001

Table 34: Continued

1	924	2	-0.4183	0.3149	281	-1.33	0.1851	Tukey-Kramer	1
1		3	-3.695	0.3149	281	-11.73	<.0001	Tukey-Kramer	<.0001
2		3	-3.2767	0.3149	281	-10.4	<.0001	Tukey-Kramer	<.0001
1	926	2	-0.9533	0.3114	278	-3.06	0.0024	Tukey-Kramer	0.8655
1		3	-3.7967	0.3114	278	-12.19	<.0001	Tukey-Kramer	<.0001
2		3	-2.8433	0.3114	278	-9.13	<.0001	Tukey-Kramer	<.0001
1	928	2	-1.575	0.3687	275	-4.27	<.0001	Tukey-Kramer	0.0546
1		3	-3.115	0.3687	275	-8.45	<.0001	Tukey-Kramer	<.0001
2		3	-1.54	0.3687	275	-4.18	<.0001	Tukey-Kramer	0.0768
1	930	2	-2.1283	0.5023	246	-4.24	<.0001	Tukey-Kramer	0.062
1		3	-2.4017	0.5023	246	-4.78	<.0001	Tukey-Kramer	0.0067
2		3	-0.2733	0.5023	246	-0.54	0.5868	Tukey-Kramer	1

Appendix E: Scenario 2 Tables – Combination of Ambient and Identified RF Noise

Table 12: Transmit Power (dBm) Scenario 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
2	1	900	14.2833	0.07243	215	197.2	<.0001
2	2		12.3	0.07243	215	169.82	<.0001
2	3		12.0333	0.07243	215	166.14	<.0001
2	1	902	14.72	0.06779	249	217.15	<.0001
2	2		12.6067	0.06779	249	185.97	<.0001
2	3		12.1133	0.06779	249	178.7	<.0001
2	1	904	15.1667	0.08463	261	179.22	<.0001
2	2		12.91	0.08463	261	152.55	<.0001
2	3		12.1933	0.08463	261	144.08	<.0001
2	1	906	15.3967	0.08354	258	184.3	<.0001
2	2		13.37	0.08354	258	160.04	<.0001
2	3		12.4767	0.08354	258	149.35	<.0001
2	1	908	15.425	0.0734	247	210.15	<.0001
2	2		13.9667	0.0734	247	190.28	<.0001
2	3		12.93	0.0734	247	176.16	<.0001
2	1	910	15.4467	0.08972	246	172.16	<.0001
2	2		14.5667	0.08972	246	162.35	<.0001
2	3		13.4	0.08972	246	149.35	<.0001
2	1	912	15.77	0.0711	254	221.79	<.0001
2	2		15.1117	0.0711	254	212.53	<.0001
2	3		13.3433	0.0711	254	187.66	<.0001
2	1	914	16.0867	0.08047	266	199.92	<.0001
2	2		15.6333	0.08047	266	194.28	<.0001
2	3		13.3167	0.08047	266	165.49	<.0001
2	1	916	16.2933	0.08486	273	192	<.0001
2	2		16.0333	0.08486	273	188.94	<.0001
2	3		13.3033	0.08486	273	156.77	<.0001
2	1	918	16.4067	0.09041	284	181.48	<.0001
2	2		16.23	0.09041	284	179.52	<.0001
2	3		13.2967	0.09041	284	147.08	<.0001
2	1	920	16.5133	0.1165	295	141.78	<.0001
2	2		16.4	0.1165	295	140.81	<.0001
2	3		13.3	0.1165	295	114.19	<.0001
2	1	922	16.9533	0.09568	299	177.19	<.0001
2	2		15.97	0.09568	299	166.92	<.0001
2	3		13.6167	0.09568	299	142.32	<.0001

Table 12: Continued

2	1	924	17.3917	0.09556	295	182	<.0001
2	2		15.59	0.09556	295	163.15	<.0001
2	3		13.9333	0.09556	295	145.81	<.0001
2	1	926	17.295	0.09565	285	180.81	<.0001
2	2		14.8933	0.09565	285	155.71	<.0001
2	3		14.1733	0.09565	285	148.18	<.0001
2	1	928	16.6283	0.103	278	161.39	<.0001
2	2		14.045	0.103	278	136.32	<.0001
2	3		14.2967	0.103	278	138.76	<.0001
2	1	930	16.035	0.1393	252	115.13	<.0001
2	2		13.1867	0.1393	252	94.68	<.0001
2	3		14.4833	0.1393	252	103.99	<.0001

Table 13: Transmit Power (dBm) Scenario 2 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	1.9833	0.1024	215	19.36	<.0001	Tukey-Kramer	<.0001
1		3	2.25	0.1024	215	21.97	<.0001	Tukey-Kramer	<.0001
2		3	0.2667	0.1024	215	2.6	0.0099	Tukey-Kramer	0.994
1	902	2	2.1133	0.09587	249	22.04	<.0001	Tukey-Kramer	<.0001
1		3	2.6067	0.09587	249	27.19	<.0001	Tukey-Kramer	<.0001
2		3	0.4933	0.09587	249	5.15	<.0001	Tukey-Kramer	0.0012
1	904	2	2.2567	0.1197	261	18.86	<.0001	Tukey-Kramer	<.0001
1		3	2.9733	0.1197	261	24.84	<.0001	Tukey-Kramer	<.0001
2		3	0.7167	0.1197	261	5.99	<.0001	Tukey-Kramer	<.0001
1	906	2	2.0267	0.1181	258	17.15	<.0001	Tukey-Kramer	<.0001
1		3	2.92	0.1181	258	24.72	<.0001	Tukey-Kramer	<.0001
2		3	0.8933	0.1181	258	7.56	<.0001	Tukey-Kramer	<.0001
1	908	2	1.4583	0.1038	247	14.05	<.0001	Tukey-Kramer	<.0001
1		3	2.495	0.1038	247	24.04	<.0001	Tukey-Kramer	<.0001
2		3	1.0367	0.1038	247	9.99	<.0001	Tukey-Kramer	<.0001
1	910	2	0.88	0.1269	246	6.94	<.0001	Tukey-Kramer	<.0001
1		3	2.0467	0.1269	246	16.13	<.0001	Tukey-Kramer	<.0001
2		3	1.1667	0.1269	246	9.19	<.0001	Tukey-Kramer	<.0001
1	912	2	0.6583	0.1006	254	6.55	<.0001	Tukey-Kramer	<.0001
1		3	2.4267	0.1006	254	24.13	<.0001	Tukey-Kramer	<.0001
2		3	1.7683	0.1006	254	17.59	<.0001	Tukey-Kramer	<.0001
1	914	2	0.4533	0.1138	266	3.98	<.0001	Tukey-Kramer	0.1456
1		3	2.77	0.1138	266	24.34	<.0001	Tukey-Kramer	<.0001
2		3	2.3167	0.1138	266	20.36	<.0001	Tukey-Kramer	<.0001
1	916	2	0.26	0.12	273	2.17	0.0311	Tukey-Kramer	1
1		3	2.99	0.12	273	24.91	<.0001	Tukey-Kramer	<.0001
2		3	2.73	0.12	273	22.75	<.0001	Tukey-Kramer	<.0001
1	918	2	0.1767	0.1279	284	1.38	0.1681	Tukey-Kramer	1
1		3	3.11	0.1279	284	24.32	<.0001	Tukey-Kramer	<.0001
2		3	2.9333	0.1279	284	22.94	<.0001	Tukey-Kramer	<.0001
1	920	2	0.1133	0.1647	295	0.69	0.4919	Tukey-Kramer	1
1		3	3.2133	0.1647	295	19.51	<.0001	Tukey-Kramer	<.0001
2		3	3.1	0.1647	295	18.82	<.0001	Tukey-Kramer	<.0001
1	922	2	0.9833	0.1353	299	7.27	<.0001	Tukey-Kramer	<.0001
1		3	3.3367	0.1353	299	24.66	<.0001	Tukey-Kramer	<.0001
2		3	2.3533	0.1353	299	17.39	<.0001	Tukey-Kramer	<.0001

Table 13: Continued

1	924	2	1.8017	0.1351	295	13.33	<.0001	Tukey-Kramer	<.0001
1		3	3.4583	0.1351	295	25.59	<.0001	Tukey-Kramer	<.0001
2		3	1.6567	0.1351	295	12.26	<.0001	Tukey-Kramer	<.0001
1	926	2	2.4017	0.1353	285	17.75	<.0001	Tukey-Kramer	<.0001
1		3	3.1217	0.1353	285	23.08	<.0001	Tukey-Kramer	<.0001
2		3	0.72	0.1353	285	5.32	<.0001	Tukey-Kramer	0.0005
1	928	2	2.5833	0.1457	278	17.73	<.0001	Tukey-Kramer	<.0001
1		3	2.3317	0.1457	278	16	<.0001	Tukey-Kramer	<.0001
2		3	-0.2517	0.1457	278	-1.73	0.0852	Tukey-Kramer	1
1	930	2	2.8483	0.197	252	14.46	<.0001	Tukey-Kramer	<.0001
1		3	1.5517	0.197	252	7.88	<.0001	Tukey-Kramer	<.0001
2		3	-1.2967	0.197	252	-6.58	<.0001	Tukey-Kramer	<.0001

Table 35: Electric Field Strength (V/m) Scenario 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
2	1	900	1.5187	0.01532	165	99.12	<.0001
2	2		1.206	0.01532	165	78.71	<.0001
2	3		1.1567	0.01532	165	75.49	<.0001
2	1	902	1.6087	0.02764	184	58.2	<.0001
2	2		1.2837	0.02764	184	46.44	<.0001
2	3		1.17	0.02764	184	42.33	<.0001
2	1	904	1.6948	0.01965	224	86.26	<.0001
2	2		1.2967	0.01965	224	66	<.0001
2	3		1.1967	0.01965	224	60.91	<.0001
2	1	906	1.743	0.0163	247	106.91	<.0001
2	2		1.3717	0.0163	247	84.13	<.0001
2	3		1.2367	0.0163	247	75.85	<.0001
2	1	908	1.7417	0.01309	249	133.07	<.0001
2	2		1.4603	0.01309	249	111.58	<.0001
2	3		1.305	0.01309	249	99.71	<.0001
2	1	910	1.744	0.01521	256	114.65	<.0001
2	2		1.5683	0.01521	256	103.1	<.0001
2	3		1.3667	0.01521	256	89.84	<.0001
2	1	912	1.8163	0.01333	273	136.26	<.0001
2	2		1.674	0.01333	273	125.59	<.0001
2	3		1.3633	0.01333	273	102.28	<.0001
2	1	914	1.8897	0.01541	290	122.66	<.0001
2	2		1.7943	0.01541	290	116.47	<.0001
2	3		1.365	0.01541	290	88.6	<.0001
2	1	916	1.9433	0.0168	301	115.7	<.0001
2	2		1.8777	0.0168	301	111.79	<.0001
2	3		1.3567	0.0168	301	80.77	<.0001
2	1	918	1.9747	0.01951	316	101.21	<.0001
2	2		1.9257	0.01951	316	98.7	<.0001
2	3		1.3617	0.01951	316	69.79	<.0001
2	1	920	2.0113	0.02568	332	78.33	<.0001
2	2		1.9737	0.02568	332	76.86	<.0001
2	3		1.3617	0.02568	332	53.03	<.0001
2	1	922	2.1115	0.02235	336	94.49	<.0001
2	2		1.8757	0.02235	336	83.94	<.0001
2	3		1.4317	0.02235	336	64.07	<.0001

Table 35: Continued

2	1	924	2.2183	0.02353	328	94.28	<.0001
2	2		1.784	0.02353	328	75.82	<.0001
2	3		1.4767	0.02353	328	62.76	<.0001
2	1	926	2.2067	0.02341	311	94.26	<.0001
2	2		1.6613	0.02341	311	70.96	<.0001
2	3		1.515	0.02341	311	64.71	<.0001
2	1	928	2.0437	0.02256	295	90.6	<.0001
2	2		1.4973	0.02256	295	66.38	<.0001
2	3		1.555	0.02256	295	68.94	<.0001
2	1	930	1.9047	0.03025	258	62.97	<.0001
2	2		1.34	0.03025	258	44.3	<.0001
2	3		1.5783	0.03025	258	52.18	<.0001

Table 36: Electric Field Strength (V/m) Scenario 2 Comparisons

loc	fre	loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.3127	0.02167	165	14.43	<.0001	Tukey-Kramer	<.0001
1		3	0.362	0.02167	165	16.71	<.0001	Tukey-Kramer	<.0001
2		3	0.04933	0.02167	165	2.28	0.0241	Tukey-Kramer	0.9999
1	902	2	0.325	0.03909	184	8.31	<.0001	Tukey-Kramer	<.0001
1		3	0.4387	0.03909	184	11.22	<.0001	Tukey-Kramer	<.0001
2		3	0.1137	0.03909	184	2.91	0.0041	Tukey-Kramer	0.9388
1	904	2	0.3982	0.02779	224	14.33	<.0001	Tukey-Kramer	<.0001
1		3	0.4982	0.02779	224	17.93	<.0001	Tukey-Kramer	<.0001
2		3	0.1	0.02779	224	3.6	0.0004	Tukey-Kramer	0.4041
1	906	2	0.3713	0.02306	247	16.11	<.0001	Tukey-Kramer	<.0001
1		3	0.5063	0.02306	247	21.96	<.0001	Tukey-Kramer	<.0001
2		3	0.135	0.02306	247	5.86	<.0001	Tukey-Kramer	<.0001
1	908	2	0.2813	0.01851	249	15.2	<.0001	Tukey-Kramer	<.0001
1		3	0.4367	0.01851	249	23.59	<.0001	Tukey-Kramer	<.0001
2		3	0.1553	0.01851	249	8.39	<.0001	Tukey-Kramer	<.0001
1	910	2	0.1757	0.02151	256	8.17	<.0001	Tukey-Kramer	<.0001
1		3	0.3773	0.02151	256	17.54	<.0001	Tukey-Kramer	<.0001
2		3	0.2017	0.02151	256	9.37	<.0001	Tukey-Kramer	<.0001
1	912	2	0.1423	0.01885	273	7.55	<.0001	Tukey-Kramer	<.0001
1		3	0.453	0.01885	273	24.03	<.0001	Tukey-Kramer	<.0001
2		3	0.3107	0.01885	273	16.48	<.0001	Tukey-Kramer	<.0001
1	914	2	0.09533	0.02179	290	4.38	<.0001	Tukey-Kramer	0.0369
1		3	0.5247	0.02179	290	24.08	<.0001	Tukey-Kramer	<.0001
2		3	0.4293	0.02179	290	19.71	<.0001	Tukey-Kramer	<.0001
1	916	2	0.06567	0.02375	301	2.76	0.0061	Tukey-Kramer	0.9764
1		3	0.5867	0.02375	301	24.7	<.0001	Tukey-Kramer	<.0001
2		3	0.521	0.02375	301	21.93	<.0001	Tukey-Kramer	<.0001
1	918	2	0.049	0.02759	316	1.78	0.0767	Tukey-Kramer	1
1		3	0.613	0.02759	316	22.22	<.0001	Tukey-Kramer	<.0001
2		3	0.564	0.02759	316	20.44	<.0001	Tukey-Kramer	<.0001
1	920	2	0.03767	0.03631	332	1.04	0.3004	Tukey-Kramer	1
1		3	0.6497	0.03631	332	17.89	<.0001	Tukey-Kramer	<.0001
2		3	0.612	0.03631	332	16.85	<.0001	Tukey-Kramer	<.0001
1	922	2	0.2358	0.0316	336	7.46	<.0001	Tukey-Kramer	<.0001
1		3	0.6798	0.0316	336	21.51	<.0001	Tukey-Kramer	<.0001
2		3	0.444	0.0316	336	14.05	<.0001	Tukey-Kramer	<.0001

Table 36: Continued

1	924	2	0.4343	0.03328	328	13.05	<.0001	Tukey-Kramer	<.0001
1		3	0.7417	0.03328	328	22.29	<.0001	Tukey-Kramer	<.0001
2		3	0.3073	0.03328	328	9.24	<.0001	Tukey-Kramer	<.0001
1	926	2	0.5453	0.03311	311	16.47	<.0001	Tukey-Kramer	<.0001
1		3	0.6917	0.03311	311	20.89	<.0001	Tukey-Kramer	<.0001
2		3	0.1463	0.03311	311	4.42	<.0001	Tukey-Kramer	0.031
1	928	2	0.5463	0.0319	295	17.13	<.0001	Tukey-Kramer	<.0001
1		3	0.4887	0.0319	295	15.32	<.0001	Tukey-Kramer	<.0001
2		3	-0.05767	0.0319	295	-1.81	0.0717	Tukey-Kramer	1
1	930	2	0.5647	0.04278	258	13.2	<.0001	Tukey-Kramer	<.0001
1		3	0.3263	0.04278	258	7.63	<.0001	Tukey-Kramer	<.0001
2		3	-0.2383	0.04278	258	-5.57	<.0001	Tukey-Kramer	0.0001

Table 37: Absolute Power on Tag Forward (dBm) Scenario 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
2	1	900	12.6967	0.07129	220	178.11	<.0001
2	2		14.6667	0.07129	220	205.74	<.0001
2	3		14.9667	0.07129	220	209.95	<.0001
2	1	902	12.2617	0.06457	254	189.9	<.0001
2	2		14.3667	0.06457	254	222.5	<.0001
2	3		14.86	0.06457	254	230.14	<.0001
2	1	904	11.8267	0.08087	266	146.24	<.0001
2	2		14.08	0.08087	266	174.1	<.0001
2	3		14.77	0.08087	266	182.63	<.0001
2	1	906	11.6067	0.083	264	139.84	<.0001
2	2		13.63	0.083	264	164.22	<.0001
2	3		14.4733	0.083	264	174.38	<.0001
2	1	908	11.58	0.07273	252	159.21	<.0001
2	2		13.1	0.07273	252	180.11	<.0001
2	3		14.0833	0.07273	252	193.63	<.0001
2	1	910	11.5533	0.08883	247	130.06	<.0001
2	2		12.47	0.08883	247	140.37	<.0001
2	3		13.6367	0.08883	247	153.51	<.0001
2	1	912	11.2383	0.07585	251	148.16	<.0001
2	2		11.97	0.07585	251	157.81	<.0001
2	3		13.72	0.07585	251	180.88	<.0001
2	1	914	10.9117	0.08056	262	135.45	<.0001
2	2		11.4033	0.08056	262	141.55	<.0001
2	3		13.7733	0.08056	262	170.97	<.0001
2	1	916	10.7467	0.08209	270	130.92	<.0001
2	2		11.0233	0.08209	270	134.29	<.0001
2	3		13.7867	0.08209	270	167.95	<.0001
2	1	918	10.6567	0.08946	281	119.12	<.0001
2	2		10.83	0.08946	281	121.06	<.0001
2	3		13.7667	0.08946	281	153.89	<.0001
2	1	920	10.6317	0.1137	293	93.54	<.0001
2	2		10.62	0.1137	293	93.44	<.0001
2	3		13.7433	0.1137	293	120.92	<.0001
2	1	922	10.25	0.1001	297	102.45	<.0001
2	2		11.1033	0.1001	297	110.98	<.0001
2	3		13.41	0.1001	297	134.03	<.0001

Table 37: Continued

2	1	924	9.8067	0.0994	294	98.66	<.0001
2	2		11.58	0.0994	294	116.5	<.0001
2	3		13.16	0.0994	294	132.39	<.0001
2	1	926	9.8917	0.09691	284	102.07	<.0001
2	2		12.22	0.09691	284	126.1	<.0001
2	3		12.96	0.09691	284	133.74	<.0001
2	1	928	10.51	0.1056	277	99.52	<.0001
2	2		13.1467	0.1056	277	124.49	<.0001
2	3		12.81	0.1056	277	121.3	<.0001
2	1	930	11.02	0.1403	249	78.57	<.0001
2	2		14.0267	0.1403	249	100.01	<.0001
2	3		12.6767	0.1403	249	90.38	<.0001

Table 38: Absolute Power on Tag Forward (dBm) Scenario 2 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-1.97	0.1008	220	-19.54	<.0001	Tukey-Kramer	<.0001
1		3	-2.27	0.1008	220	-22.52	<.0001	Tukey-Kramer	<.0001
2		3	-0.3	0.1008	220	-2.98	0.0032	Tukey-Kramer	0.9111
1	902	2	-2.105	0.09131	254	-23.05	<.0001	Tukey-Kramer	<.0001
1		3	-2.5983	0.09131	254	-28.45	<.0001	Tukey-Kramer	<.0001
2		3	-0.4933	0.09131	254	-5.4	<.0001	Tukey-Kramer	0.0003
1	904	2	-2.2533	0.1144	266	-19.7	<.0001	Tukey-Kramer	<.0001
1		3	-2.9433	0.1144	266	-25.73	<.0001	Tukey-Kramer	<.0001
2		3	-0.69	0.1144	266	-6.03	<.0001	Tukey-Kramer	<.0001
1	906	2	-2.0233	0.1174	264	-17.24	<.0001	Tukey-Kramer	<.0001
1		3	-2.8667	0.1174	264	-24.42	<.0001	Tukey-Kramer	<.0001
2		3	-0.8433	0.1174	264	-7.18	<.0001	Tukey-Kramer	<.0001
1	908	2	-1.52	0.1029	252	-14.78	<.0001	Tukey-Kramer	<.0001
1		3	-2.5033	0.1029	252	-24.34	<.0001	Tukey-Kramer	<.0001
2		3	-0.9833	0.1029	252	-9.56	<.0001	Tukey-Kramer	<.0001
1	910	2	-0.9167	0.1256	247	-7.3	<.0001	Tukey-Kramer	<.0001
1		3	-2.0833	0.1256	247	-16.58	<.0001	Tukey-Kramer	<.0001
2		3	-1.1667	0.1256	247	-9.29	<.0001	Tukey-Kramer	<.0001
1	912	2	-0.7317	0.1073	251	-6.82	<.0001	Tukey-Kramer	<.0001
1		3	-2.4817	0.1073	251	-23.13	<.0001	Tukey-Kramer	<.0001
2		3	-1.75	0.1073	251	-16.31	<.0001	Tukey-Kramer	<.0001
1	914	2	-0.4917	0.1139	262	-4.32	<.0001	Tukey-Kramer	0.0463
1		3	-2.8617	0.1139	262	-25.12	<.0001	Tukey-Kramer	<.0001
2		3	-2.37	0.1139	262	-20.8	<.0001	Tukey-Kramer	<.0001
1	916	2	-0.2767	0.1161	270	-2.38	0.0179	Tukey-Kramer	0.9995
1		3	-3.04	0.1161	270	-26.19	<.0001	Tukey-Kramer	<.0001
2		3	-2.7633	0.1161	270	-23.8	<.0001	Tukey-Kramer	<.0001
1	918	2	-0.1733	0.1265	281	-1.37	0.1718	Tukey-Kramer	1
1		3	-3.11	0.1265	281	-24.58	<.0001	Tukey-Kramer	<.0001
2		3	-2.9367	0.1265	281	-23.21	<.0001	Tukey-Kramer	<.0001
1	920	2	0.01167	0.1607	293	0.07	0.9422	Tukey-Kramer	1
1		3	-3.1117	0.1607	293	-19.36	<.0001	Tukey-Kramer	<.0001
2		3	-3.1233	0.1607	293	-19.43	<.0001	Tukey-Kramer	<.0001
1	922	2	-0.8533	0.1415	297	-6.03	<.0001	Tukey-Kramer	<.0001
1		3	-3.16	0.1415	297	-22.33	<.0001	Tukey-Kramer	<.0001
2		3	-2.3067	0.1415	297	-16.3	<.0001	Tukey-Kramer	<.0001

Table 38: Continued

1	924	2	-1.7733	0.1406	294	-12.61	<.0001	Tukey-Kramer	<.0001
1		3	-3.3533	0.1406	294	-23.85	<.0001	Tukey-Kramer	<.0001
2		3	-1.58	0.1406	294	-11.24	<.0001	Tukey-Kramer	<.0001
1	926	2	-2.3283	0.137	284	-16.99	<.0001	Tukey-Kramer	<.0001
1		3	-3.0683	0.137	284	-22.39	<.0001	Tukey-Kramer	<.0001
2		3	-0.74	0.137	284	-5.4	<.0001	Tukey-Kramer	0.0003
1	928	2	-2.6367	0.1493	277	-17.66	<.0001	Tukey-Kramer	<.0001
1		3	-2.3	0.1493	277	-15.4	<.0001	Tukey-Kramer	<.0001
2		3	0.3367	0.1493	277	2.25	0.025	Tukey-Kramer	0.9999
1	930	2	-3.0067	0.1984	249	-15.16	<.0001	Tukey-Kramer	<.0001
1		3	-1.6567	0.1984	249	-8.35	<.0001	Tukey-Kramer	<.0001
2		3	1.35	0.1984	249	6.81	<.0001	Tukey-Kramer	<.0001

Table 39: Theoretical Read Range Forward (m) Scenario 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
2	1	900	6.99	0.05727	230	122.05	<.0001
2	2		8.1967	0.05727	230	143.12	<.0001
2	3		8.47	0.05727	230	147.9	<.0001
2	1	902	6.64	0.04414	256	150.42	<.0001
2	2		7.91	0.04414	256	179.19	<.0001
2	3		8.37	0.04414	256	189.61	<.0001
2	1	904	6.2267	0.04841	266	128.62	<.0001
2	2		7.6233	0.04841	266	157.47	<.0001
2	3		8.2867	0.04841	266	171.17	<.0001
2	1	906	6.03	0.04618	271	130.58	<.0001
2	2		7.2633	0.04618	271	157.28	<.0001
2	3		8.0267	0.04618	271	173.81	<.0001
2	1	908	6.08	0.04687	269	129.73	<.0001
2	2		6.77	0.04687	269	144.45	<.0001
2	3		7.66	0.04687	269	163.44	<.0001
2	1	910	6.14	0.05849	272	104.97	<.0001
2	2		6.33	0.05849	272	108.22	<.0001
2	3		7.2567	0.05849	272	124.06	<.0001
2	1	912	5.9767	0.04547	274	131.45	<.0001
2	2		5.9333	0.04547	274	130.5	<.0001
2	3		7.2867	0.04547	274	160.26	<.0001
2	1	914	5.8333	0.0438	284	133.17	<.0001
2	2		5.5633	0.0438	284	127	<.0001
2	3		7.3133	0.0438	284	166.95	<.0001
2	1	916	5.6633	0.0447	290	126.7	<.0001
2	2		5.2733	0.0447	290	117.97	<.0001
2	3		7.3167	0.0447	290	163.68	<.0001
2	1	918	5.52	0.03992	283	138.28	<.0001
2	2		5.1767	0.03992	283	129.68	<.0001
2	3		7.2867	0.03992	283	182.54	<.0001
2	1	920	5.35	0.04942	274	108.25	<.0001
2	2		5.0467	0.04942	274	102.11	<.0001
2	3		7.2667	0.04942	274	147.03	<.0001
2	1	922	5.6267	0.03724	260	151.1	<.0001
2	2		5.33	0.03724	260	143.13	<.0001
2	3		7.0367	0.03724	260	188.96	<.0001

Table 39: Continued

2	1	924	5.8133	0.03611	252	160.97	<.0001
2	2		5.5867	0.03611	252	154.7	<.0001
2	3		6.7833	0.03611	252	187.83	<.0001
2	1	926	6.0767	0.03879	248	156.66	<.0001
2	2		6.0933	0.03879	248	157.08	<.0001
2	3		6.5867	0.03879	248	169.8	<.0001
2	1	928	6.3267	0.04469	252	141.58	<.0001
2	2		6.71	0.04469	252	150.16	<.0001
2	3		6.4867	0.04469	252	145.16	<.0001
2	1	930	6.5633	0.05986	234	109.65	<.0001
2	2		7.3733	0.05986	234	123.18	<.0001
2	3		6.35	0.05986	234	106.08	<.0001

Table 40: Theoretical Read Range Forward (m) Scenario 2 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-1.2067	0.08099	230	-14.9	<.0001	Tukey-Kramer	<.0001
1		3	-1.48	0.08099	230	-18.27	<.0001	Tukey-Kramer	<.0001
2		3	-0.2733	0.08099	230	-3.37	0.0009	Tukey-Kramer	0.6121
1	902	2	-1.27	0.06243	256	-20.34	<.0001	Tukey-Kramer	<.0001
1		3	-1.73	0.06243	256	-27.71	<.0001	Tukey-Kramer	<.0001
2		3	-0.46	0.06243	256	-7.37	<.0001	Tukey-Kramer	<.0001
1	904	2	-1.3967	0.06846	266	-20.4	<.0001	Tukey-Kramer	<.0001
1		3	-2.06	0.06846	266	-30.09	<.0001	Tukey-Kramer	<.0001
2		3	-0.6633	0.06846	266	-9.69	<.0001	Tukey-Kramer	<.0001
1	906	2	-1.2333	0.06531	271	-18.88	<.0001	Tukey-Kramer	<.0001
1		3	-1.9967	0.06531	271	-30.57	<.0001	Tukey-Kramer	<.0001
2		3	-0.7633	0.06531	271	-11.69	<.0001	Tukey-Kramer	<.0001
1	908	2	-0.69	0.06628	269	-10.41	<.0001	Tukey-Kramer	<.0001
1		3	-1.58	0.06628	269	-23.84	<.0001	Tukey-Kramer	<.0001
2		3	-0.89	0.06628	269	-13.43	<.0001	Tukey-Kramer	<.0001
1	910	2	-0.19	0.08272	272	-2.3	0.0224	Tukey-Kramer	0.9999
1		3	-1.1167	0.08272	272	-13.5	<.0001	Tukey-Kramer	<.0001
2		3	-0.9267	0.08272	272	-11.2	<.0001	Tukey-Kramer	<.0001
1	912	2	0.04333	0.0643	274	0.67	0.5009	Tukey-Kramer	1
1		3	-1.31	0.0643	274	-20.37	<.0001	Tukey-Kramer	<.0001
2		3	-1.3533	0.0643	274	-21.05	<.0001	Tukey-Kramer	<.0001
1	914	2	0.27	0.06195	284	4.36	<.0001	Tukey-Kramer	0.0393
1		3	-1.48	0.06195	284	-23.89	<.0001	Tukey-Kramer	<.0001
2		3	-1.75	0.06195	284	-28.25	<.0001	Tukey-Kramer	<.0001
1	916	2	0.39	0.06322	290	6.17	<.0001	Tukey-Kramer	<.0001
1		3	-1.6533	0.06322	290	-26.15	<.0001	Tukey-Kramer	<.0001
2		3	-2.0433	0.06322	290	-32.32	<.0001	Tukey-Kramer	<.0001
1	918	2	0.3433	0.05645	283	6.08	<.0001	Tukey-Kramer	<.0001
1		3	-1.7667	0.05645	283	-31.29	<.0001	Tukey-Kramer	<.0001
2		3	-2.11	0.05645	283	-37.38	<.0001	Tukey-Kramer	<.0001
1	920	2	0.3033	0.06989	274	4.34	<.0001	Tukey-Kramer	0.0422
1		3	-1.9167	0.06989	274	-27.42	<.0001	Tukey-Kramer	<.0001
2		3	-2.22	0.06989	274	-31.76	<.0001	Tukey-Kramer	<.0001
1	922	2	0.2967	0.05266	260	5.63	<.0001	Tukey-Kramer	<.0001
1		3	-1.41	0.05266	260	-26.77	<.0001	Tukey-Kramer	<.0001
2		3	-1.7067	0.05266	260	-32.41	<.0001	Tukey-Kramer	<.0001

Table 40: Continued

1	924	2	0.2267	0.05107	252	4.44	<.0001	Tukey-Kramer	0.0288
1		3	-0.97	0.05107	252	-18.99	<.0001	Tukey-Kramer	<.0001
2		3	-1.1967	0.05107	252	-23.43	<.0001	Tukey-Kramer	<.0001
1	926	2	-0.01667	0.05486	248	-0.3	0.7615	Tukey-Kramer	1
1		3	-0.51	0.05486	248	-9.3	<.0001	Tukey-Kramer	<.0001
2		3	-0.4933	0.05486	248	-8.99	<.0001	Tukey-Kramer	<.0001
1	928	2	-0.3833	0.0632	252	-6.07	<.0001	Tukey-Kramer	<.0001
1		3	-0.16	0.0632	252	-2.53	0.012	Tukey-Kramer	0.9971
2		3	0.2233	0.0632	252	3.53	0.0005	Tukey-Kramer	0.4625
1	930	2	-0.81	0.08465	234	-9.57	<.0001	Tukey-Kramer	<.0001
1		3	0.2133	0.08465	234	2.52	0.0124	Tukey-Kramer	0.9974
2		3	1.0233	0.08465	234	12.09	<.0001	Tukey-Kramer	<.0001

Table 41: Absolute Backscatter Power (dBm) Scenario 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
2	1	900	49.4067	0.1075	215	459.43	<.0001
2	2		48.635	0.1075	215	452.26	<.0001
2	3		47.7467	0.1075	215	444	<.0001
2	1	902	49.8233	0.08893	248	560.23	<.0001
2	2		48.5417	0.08893	248	545.82	<.0001
2	3		47.95	0.08893	248	539.17	<.0001
2	1	904	50.24	0.1069	263	470.11	<.0001
2	2		48.3467	0.1069	263	452.4	<.0001
2	3		48.1567	0.1069	263	450.62	<.0001
2	1	906	50.2733	0.108	263	465.61	<.0001
2	2		48.53	0.108	263	449.47	<.0001
2	3		48.3467	0.108	263	447.77	<.0001
2	1	908	49.8967	0.09665	248	516.25	<.0001
2	2		48.985	0.09665	248	506.81	<.0001
2	3		48.5067	0.09665	248	501.86	<.0001
2	1	910	49.5333	0.1201	237	412.29	<.0001
2	2		49.4717	0.1201	237	411.78	<.0001
2	3		48.6767	0.1201	237	405.16	<.0001
2	1	912	49.62	0.09783	242	507.18	<.0001
2	2		49.5367	0.09783	242	506.33	<.0001
2	3		48.4433	0.09783	242	495.16	<.0001
2	1	914	49.72	0.1226	254	405.69	<.0001
2	2		49.5567	0.1226	254	404.36	<.0001
2	3		48.21	0.1226	254	393.37	<.0001
2	1	916	49.7633	0.129	251	385.67	<.0001
2	2		49.78	0.129	251	385.8	<.0001
2	3		48.1533	0.129	251	373.19	<.0001
2	1	918	49.6933	0.1203	246	413.15	<.0001
2	2		50.18	0.1203	246	417.19	<.0001
2	3		48.23	0.1203	246	400.98	<.0001
2	1	920	49.6267	0.1382	258	358.98	<.0001
2	2		50.5733	0.1382	258	365.83	<.0001
2	3		48.3067	0.1382	258	349.43	<.0001
2	1	922	49.6633	0.09647	271	514.83	<.0001
2	2		49.4867	0.09647	271	513	<.0001
2	3		48.2267	0.09647	271	499.93	<.0001

Table 41: Continued

2	1	924	49.7133	0.0857	282	580.08	<.0001
2	2		48.4417	0.0857	282	565.24	<.0001
2	3		48.1467	0.0857	282	561.8	<.0001
2	1	926	49.44	0.08378	287	590.12	<.0001
2	2		47.7947	0.08378	287	570.48	<.0001
2	3		48.1667	0.08378	287	574.92	<.0001
2	1	928	48.7867	0.09099	293	536.18	<.0001
2	2		47.5733	0.09099	293	522.84	<.0001
2	3		48.24	0.09099	293	530.17	<.0001
2	1	930	48.1633	0.1227	266	392.55	<.0001
2	2		47.345	0.1227	266	385.88	<.0001
2	3		48.3667	0.1227	266	394.21	<.0001

Table 42: Absolute Backscatter Power (dBm) Scenario 2 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.7717	0.1521	215	5.07	<.0001	Tukey-Kramer	0.0017
1		3	1.66	0.1521	215	10.92	<.0001	Tukey-Kramer	<.0001
2		3	0.8883	0.1521	215	5.84	<.0001	Tukey-Kramer	<.0001
1	902	2	1.2817	0.1258	248	10.19	<.0001	Tukey-Kramer	<.0001
1		3	1.8733	0.1258	248	14.89	<.0001	Tukey-Kramer	<.0001
2		3	0.5917	0.1258	248	4.7	<.0001	Tukey-Kramer	0.0094
1	904	2	1.8933	0.1511	263	12.53	<.0001	Tukey-Kramer	<.0001
1		3	2.0833	0.1511	263	13.78	<.0001	Tukey-Kramer	<.0001
2		3	0.19	0.1511	263	1.26	0.2098	Tukey-Kramer	1
1	906	2	1.7433	0.1527	263	11.42	<.0001	Tukey-Kramer	<.0001
1		3	1.9267	0.1527	263	12.62	<.0001	Tukey-Kramer	<.0001
2		3	0.1833	0.1527	263	1.2	0.231	Tukey-Kramer	1
1	908	2	0.9117	0.1367	248	6.67	<.0001	Tukey-Kramer	<.0001
1		3	1.39	0.1367	248	10.17	<.0001	Tukey-Kramer	<.0001
2		3	0.4783	0.1367	248	3.5	0.0006	Tukey-Kramer	0.4944
1	910	2	0.06167	0.1699	237	0.36	0.717	Tukey-Kramer	1
1		3	0.8567	0.1699	237	5.04	<.0001	Tukey-Kramer	0.002
2		3	0.795	0.1699	237	4.68	<.0001	Tukey-Kramer	0.0105
1	912	2	0.08333	0.1384	242	0.6	0.5475	Tukey-Kramer	1
1		3	1.1767	0.1384	242	8.5	<.0001	Tukey-Kramer	<.0001
2		3	1.0933	0.1384	242	7.9	<.0001	Tukey-Kramer	<.0001
1	914	2	0.1633	0.1733	254	0.94	0.3469	Tukey-Kramer	1
1		3	1.51	0.1733	254	8.71	<.0001	Tukey-Kramer	<.0001
2		3	1.3467	0.1733	254	7.77	<.0001	Tukey-Kramer	<.0001
1	916	2	-0.01667	0.1825	251	-0.09	0.9273	Tukey-Kramer	1
1		3	1.61	0.1825	251	8.82	<.0001	Tukey-Kramer	<.0001
2		3	1.6267	0.1825	251	8.91	<.0001	Tukey-Kramer	<.0001
1	918	2	-0.4867	0.1701	246	-2.86	0.0046	Tukey-Kramer	0.9542
1		3	1.4633	0.1701	246	8.6	<.0001	Tukey-Kramer	<.0001
2		3	1.95	0.1701	246	11.46	<.0001	Tukey-Kramer	<.0001
1	920	2	-0.9467	0.1955	258	-4.84	<.0001	Tukey-Kramer	0.0051
1		3	1.32	0.1955	258	6.75	<.0001	Tukey-Kramer	<.0001
2		3	2.2667	0.1955	258	11.59	<.0001	Tukey-Kramer	<.0001
1	922	2	0.1767	0.1364	271	1.29	0.1964	Tukey-Kramer	1
1		3	1.4367	0.1364	271	10.53	<.0001	Tukey-Kramer	<.0001
2		3	1.26	0.1364	271	9.24	<.0001	Tukey-Kramer	<.0001

Table 42: Continued

1	924	2	1.2717	0.1212	282	10.49	<.0001	Tukey-Kramer	<.0001
1		3	1.5667	0.1212	282	12.93	<.0001	Tukey-Kramer	<.0001
2		3	0.295	0.1212	282	2.43	0.0156	Tukey-Kramer	0.9991
1	926	2	1.6453	0.1185	287	13.89	<.0001	Tukey-Kramer	<.0001
1		3	1.2733	0.1185	287	10.75	<.0001	Tukey-Kramer	<.0001
2		3	-0.372	0.1185	287	-3.14	0.0019	Tukey-Kramer	0.8132
1	928	2	1.2133	0.1287	293	9.43	<.0001	Tukey-Kramer	<.0001
1		3	0.5467	0.1287	293	4.25	<.0001	Tukey-Kramer	0.0595
2		3	-0.6667	0.1287	293	-5.18	<.0001	Tukey-Kramer	0.001
1	930	2	0.8183	0.1735	266	4.72	<.0001	Tukey-Kramer	0.009
1		3	-0.2033	0.1735	266	-1.17	0.2423	Tukey-Kramer	1
2		3	-1.0217	0.1735	266	-5.89	<.0001	Tukey-Kramer	<.0001

Table 43: Absolute Received Power (dBm) Scenario 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
2	1	900	66	1.3084	2157	50.45	<.0001
2	2		64.9667	1.3084	2157	49.66	<.0001
2	3		64.7667	1.3084	2157	49.5	<.0001
2	1	902	55.6667	1.3084	2157	42.55	<.0001
2	2		56.9667	1.3084	2157	43.54	<.0001
2	3		57.3	1.3084	2157	43.8	<.0001
2	1	904	44.5333	1.3084	2157	34.04	<.0001
2	2		48.6	1.3084	2157	37.15	<.0001
2	3		49.5333	1.3084	2157	37.86	<.0001
2	1	906	45.9333	1.3084	2157	35.11	<.0001
2	2		43	1.3084	2157	32.87	<.0001
2	3		43.9333	1.3084	2157	33.58	<.0001
2	1	908	39.2	1.3084	2157	29.96	<.0001
2	2		39.7	1.3084	2157	30.34	<.0001
2	3		41.2	1.3084	2157	31.49	<.0001
2	1	910	43.9667	1.3084	2157	33.6	<.0001
2	2		37.1	1.3084	2157	28.36	<.0001
2	3		38.2667	1.3084	2157	29.25	<.0001
2	1	912	41.5	1.3084	2157	31.72	<.0001
2	2		35.7667	1.3084	2157	27.34	<.0001
2	3		38.5667	1.3084	2157	29.48	<.0001
2	1	914	36.6	1.3084	2157	27.97	<.0001
2	2		34.7	1.3084	2157	26.52	<.0001
2	3		38.4667	1.3084	2157	29.4	<.0001
2	1	916	45.1333	1.3084	2157	34.5	<.0001
2	2		33.6	1.3084	2157	25.68	<.0001
2	3		39.3	1.3084	2157	30.04	<.0001
2	1	918	43.1	1.3084	2157	32.94	<.0001
2	2		32.1667	1.3084	2157	24.59	<.0001
2	3		40.3667	1.3084	2157	30.85	<.0001
2	1	920	44.0333	1.3084	2157	33.66	<.0001
2	2		30.9667	1.3084	2157	23.67	<.0001
2	3		41.8	1.3084	2157	31.95	<.0001
2	1	922	38.4	1.3084	2157	29.35	<.0001
2	2		32.6667	1.3084	2157	24.97	<.0001
2	3		40.9333	1.3084	2157	31.29	<.0001

Table 43: Continued

2	1	924	37.6333	1.3084	2157	28.76	<.0001
2	2		34.0667	1.3084	2157	26.04	<.0001
2	3		39.8	1.3084	2157	30.42	<.0001
2	1	926	39.1	1.3084	2157	29.88	<.0001
2	2		39.3667	1.3084	2157	30.09	<.0001
2	3		44.3333	1.3084	2157	33.88	<.0001
2	1	928	42.1333	1.3084	2157	32.2	<.0001
2	2		48.6333	1.3084	2157	37.17	<.0001
2	3		54.2667	1.3084	2157	41.48	<.0001
2	1	930	57.4667	1.3084	2157	43.92	<.0001
2	2		57.9667	1.3084	2157	44.3	<.0001
2	3		63.7667	1.3084	2157	48.74	<.0001

Table 44: Absolute Received Power (dBm) Scenario 2 Comparisons

loc	fre	loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	1.0333	1.8503	2157	0.56	0.5766	Tukey-Kramer	1
1		3	1.2333	1.8503	2157	0.67	0.5051	Tukey-Kramer	1
2		3	0.2	1.8503	2157	0.11	0.9139	Tukey-Kramer	1
1	902	2	-1.3	1.8503	2157	-0.7	0.4824	Tukey-Kramer	1
1		3	-1.6333	1.8503	2157	-0.88	0.3775	Tukey-Kramer	1
2		3	-0.3333	1.8503	2157	-0.18	0.8571	Tukey-Kramer	1
1	904	2	-4.0667	1.8503	2157	-2.2	0.0281	Tukey-Kramer	1
1		3	-5	1.8503	2157	-2.7	0.0069	Tukey-Kramer	0.9859
2		3	-0.9333	1.8503	2157	-0.5	0.614	Tukey-Kramer	1
1	906	2	2.9333	1.8503	2157	1.59	0.113	Tukey-Kramer	1
1		3	2	1.8503	2157	1.08	0.2799	Tukey-Kramer	1
2		3	-0.9333	1.8503	2157	-0.5	0.614	Tukey-Kramer	1
1	908	2	-0.5	1.8503	2157	-0.27	0.787	Tukey-Kramer	1
1		3	-2	1.8503	2157	-1.08	0.2799	Tukey-Kramer	1
2		3	-1.5	1.8503	2157	-0.81	0.4176	Tukey-Kramer	1
1	910	2	6.8667	1.8503	2157	3.71	0.0002	Tukey-Kramer	0.3106
1		3	5.7	1.8503	2157	3.08	0.0021	Tukey-Kramer	0.8543
2		3	-1.1667	1.8503	2157	-0.63	0.5284	Tukey-Kramer	1
1	912	2	5.7333	1.8503	2157	3.1	0.002	Tukey-Kramer	0.8426
1		3	2.9333	1.8503	2157	1.59	0.113	Tukey-Kramer	1
2		3	-2.8	1.8503	2157	-1.51	0.1304	Tukey-Kramer	1
1	914	2	1.9	1.8503	2157	1.03	0.3046	Tukey-Kramer	1
1		3	-1.8667	1.8503	2157	-1.01	0.3132	Tukey-Kramer	1
2		3	-3.7667	1.8503	2157	-2.04	0.0419	Tukey-Kramer	1
1	916	2	11.5333	1.8503	2157	6.23	<.0001	Tukey-Kramer	<.0001
1		3	5.8333	1.8503	2157	3.15	0.0016	Tukey-Kramer	0.8045
2		3	-5.7	1.8503	2157	-3.08	0.0021	Tukey-Kramer	0.8543
1	918	2	10.9333	1.8503	2157	5.91	<.0001	Tukey-Kramer	<.0001
1		3	2.7333	1.8503	2157	1.48	0.1398	Tukey-Kramer	1
2		3	-8.2	1.8503	2157	-4.43	<.0001	Tukey-Kramer	0.029
1	920	2	13.0667	1.8503	2157	7.06	<.0001	Tukey-Kramer	<.0001
1		3	2.2333	1.8503	2157	1.21	0.2276	Tukey-Kramer	1
2		3	-10.8333	1.8503	2157	-5.85	<.0001	Tukey-Kramer	<.0001
1	922	2	5.7333	1.8503	2157	3.1	0.002	Tukey-Kramer	0.8426
1		3	-2.5333	1.8503	2157	-1.37	0.1711	Tukey-Kramer	1
2		3	-8.2667	1.8503	2157	-4.47	<.0001	Tukey-Kramer	0.0251

Table 44: Continued

1	924	2	3.5667	1.8503	2157	1.93	0.054	Tukey-Kramer	1
1		3	-2.1667	1.8503	2157	-1.17	0.2417	Tukey-Kramer	1
2		3	-5.7333	1.8503	2157	-3.1	0.002	Tukey-Kramer	0.8426
1	926	2	-0.2667	1.8503	2157	-0.14	0.8854	Tukey-Kramer	1
1		3	-5.2333	1.8503	2157	-2.83	0.0047	Tukey-Kramer	0.9636
2		3	-4.9667	1.8503	2157	-2.68	0.0073	Tukey-Kramer	0.9879
1	928	2	-6.5	1.8503	2157	-3.51	0.0005	Tukey-Kramer	0.4813
1		3	-12.1333	1.8503	2157	-6.56	<.0001	Tukey-Kramer	<.0001
2		3	-5.6333	1.8503	2157	-3.04	0.0024	Tukey-Kramer	0.8762
1	930	2	-0.5	1.8503	2157	-0.27	0.787	Tukey-Kramer	1
1		3	-6.3	1.8503	2157	-3.4	0.0007	Tukey-Kramer	0.5836
2		3	-5.8	1.8503	2157	-3.13	0.0017	Tukey-Kramer	0.8177

Table 45: Absolute Delta RCS (dBsqm) Scenario 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
2	1	900	22.4133	0.06879	241	325.82	<.0001
2	2		18.6367	0.06879	241	270.92	<.0001
2	3		17.31	0.06879	241	251.63	<.0001
2	1	902	22.6833	0.05175	284	438.29	<.0001
2	2		18.78	0.05175	284	362.87	<.0001
2	3		17.66	0.05175	284	341.23	<.0001
2	1	904	22.9933	0.05928	300	387.88	<.0001
2	2		18.92	0.05928	300	319.16	<.0001
2	3		17.9867	0.05928	300	303.42	<.0001
2	1	906	23.0933	0.06073	298	380.26	<.0001
2	2		19.5033	0.06073	298	321.15	<.0001
2	3		18.4567	0.06073	298	303.91	<.0001
2	1	908	22.9767	0.05707	275	402.6	<.0001
2	2		20.53	0.05707	275	359.73	<.0001
2	3		19.05	0.05707	275	333.8	<.0001
2	1	910	22.8333	0.08024	250	284.58	<.0001
2	2		21.5667	0.08024	250	268.79	<.0001
2	3		19.63	0.08024	250	244.66	<.0001
2	1	912	23.12	0.06471	243	357.27	<.0001
2	2		22.1833	0.06471	243	342.79	<.0001
2	3		19.38	0.06471	243	299.47	<.0001
2	1	914	23.415	0.08271	267	283.09	<.0001
2	2		22.87	0.08271	267	276.5	<.0001
2	3		19.1133	0.08271	267	231.08	<.0001
2	1	916	23.2733	0.08333	271	279.28	<.0001
2	2		23.4533	0.08333	271	281.44	<.0001
2	3		19.0067	0.08333	271	228.08	<.0001
2	1	918	22.7217	0.07213	246	315.03	<.0001
2	2		24.0333	0.07213	246	333.21	<.0001
2	3		19.11	0.07213	246	264.95	<.0001
2	1	920	22.24	0.07515	249	295.94	<.0001
2	2		24.6167	0.07515	249	327.56	<.0001
2	3		19.2567	0.07515	249	256.24	<.0001
2	1	922	22.9683	0.05087	278	451.48	<.0001
2	2		23.0767	0.05087	278	453.61	<.0001
2	3		19.44	0.05087	278	382.13	<.0001

Table 45: Continued

2	1	924	23.7667	0.05668	282	419.28	<.0001
2	2		21.56	0.05668	282	380.35	<.0001
2	3		19.6333	0.05668	282	346.36	<.0001
2	1	926	23.678	0.05673	250	417.39	<.0001
2	2		20.2267	0.05673	250	356.55	<.0001
2	3		19.8467	0.05673	250	349.86	<.0001
2	1	928	22.8483	0.05403	219	422.9	<.0001
2	2		19.1167	0.05403	219	353.83	<.0001
2	3		20.1	0.05403	219	372.03	<.0001
2	1	930	21.7833	0.07357	200	296.09	<.0001
2	2		18.0133	0.07357	200	244.84	<.0001
2	3		20.39	0.07357	200	277.15	<.0001

Table 46: Absolute Delta RCS (dBsqm) Scenario 2 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	3.7767	0.09728	241	38.82	<.0001	Tukey-Kramer	<.0001
1		3	5.1033	0.09728	241	52.46	<.0001	Tukey-Kramer	<.0001
2		3	1.3267	0.09728	241	13.64	<.0001	Tukey-Kramer	<.0001
1	902	2	3.9033	0.07319	284	53.33	<.0001	Tukey-Kramer	<.0001
1		3	5.0233	0.07319	284	68.63	<.0001	Tukey-Kramer	<.0001
2		3	1.12	0.07319	284	15.3	<.0001	Tukey-Kramer	<.0001
1	904	2	4.0733	0.08383	300	48.59	<.0001	Tukey-Kramer	<.0001
1		3	5.0067	0.08383	300	59.72	<.0001	Tukey-Kramer	<.0001
2		3	0.9333	0.08383	300	11.13	<.0001	Tukey-Kramer	<.0001
1	906	2	3.59	0.08589	298	41.8	<.0001	Tukey-Kramer	<.0001
1		3	4.6367	0.08589	298	53.99	<.0001	Tukey-Kramer	<.0001
2		3	1.0467	0.08589	298	12.19	<.0001	Tukey-Kramer	<.0001
1	908	2	2.4467	0.08071	275	30.31	<.0001	Tukey-Kramer	<.0001
1		3	3.9267	0.08071	275	48.65	<.0001	Tukey-Kramer	<.0001
2		3	1.48	0.08071	275	18.34	<.0001	Tukey-Kramer	<.0001
1	910	2	1.2667	0.1135	250	11.16	<.0001	Tukey-Kramer	<.0001
1		3	3.2033	0.1135	250	28.23	<.0001	Tukey-Kramer	<.0001
2		3	1.9367	0.1135	250	17.07	<.0001	Tukey-Kramer	<.0001
1	912	2	0.9367	0.09152	243	10.23	<.0001	Tukey-Kramer	<.0001
1		3	3.74	0.09152	243	40.87	<.0001	Tukey-Kramer	<.0001
2		3	2.8033	0.09152	243	30.63	<.0001	Tukey-Kramer	<.0001
1	914	2	0.545	0.117	267	4.66	<.0001	Tukey-Kramer	0.0115
1		3	4.3017	0.117	267	36.77	<.0001	Tukey-Kramer	<.0001
2		3	3.7567	0.117	267	32.12	<.0001	Tukey-Kramer	<.0001
1	916	2	-0.18	0.1178	271	-1.53	0.1278	Tukey-Kramer	1
1		3	4.2667	0.1178	271	36.2	<.0001	Tukey-Kramer	<.0001
2		3	4.4467	0.1178	271	37.73	<.0001	Tukey-Kramer	<.0001
1	918	2	-1.3117	0.102	246	-12.86	<.0001	Tukey-Kramer	<.0001
1		3	3.6117	0.102	246	35.41	<.0001	Tukey-Kramer	<.0001
2		3	4.9233	0.102	246	48.27	<.0001	Tukey-Kramer	<.0001
1	920	2	-2.3767	0.1063	249	-22.36	<.0001	Tukey-Kramer	<.0001
1		3	2.9833	0.1063	249	28.07	<.0001	Tukey-Kramer	<.0001
2		3	5.36	0.1063	249	50.43	<.0001	Tukey-Kramer	<.0001
1	922	2	-0.1083	0.07195	278	-1.51	0.1333	Tukey-Kramer	1
1		3	3.5283	0.07195	278	49.04	<.0001	Tukey-Kramer	<.0001
2		3	3.6367	0.07195	278	50.55	<.0001	Tukey-Kramer	<.0001

Table 46: Continued

1	924	2	2.2067	0.08016	282	27.53	<.0001	Tukey-Kramer	<.0001
1		3	4.1333	0.08016	282	51.56	<.0001	Tukey-Kramer	<.0001
2		3	1.9267	0.08016	282	24.03	<.0001	Tukey-Kramer	<.0001
1	926	2	3.4513	0.08023	250	43.02	<.0001	Tukey-Kramer	<.0001
1		3	3.8313	0.08023	250	47.76	<.0001	Tukey-Kramer	<.0001
2		3	0.38	0.08023	250	4.74	<.0001	Tukey-Kramer	0.0082
1	928	2	3.7317	0.07641	219	48.84	<.0001	Tukey-Kramer	<.0001
1		3	2.7483	0.07641	219	35.97	<.0001	Tukey-Kramer	<.0001
2		3	-0.9833	0.07641	219	-12.87	<.0001	Tukey-Kramer	<.0001
1	930	2	3.77	0.104	200	36.23	<.0001	Tukey-Kramer	<.0001
1		3	1.3933	0.104	200	13.39	<.0001	Tukey-Kramer	<.0001
2		3	-2.3767	0.104	200	-22.84	<.0001	Tukey-Kramer	<.0001

Table 47: Absolute Power on Tag Reverse (dBm) Scenario 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
2	1	900	17.52	0.1007	226	173.96	<.0001
2	2		15.7367	0.1007	226	156.26	<.0001
2	3		14.7733	0.1007	226	146.69	<.0001
2	1	902	17.37	0.08459	262	205.35	<.0001
2	2		15.5467	0.08459	262	183.79	<.0001
2	3		14.9633	0.08459	262	176.9	<.0001
2	1	904	17.2183	0.1024	276	168.11	<.0001
2	2		15.3867	0.1024	276	150.23	<.0001
2	3		15.1567	0.1024	276	147.98	<.0001
2	1	906	17.0783	0.1052	274	162.32	<.0001
2	2		15.5133	0.1052	274	147.45	<.0001
2	3		15.34	0.1052	274	145.8	<.0001
2	1	908	16.935	0.09129	257	185.52	<.0001
2	2		15.9767	0.09129	257	175.02	<.0001
2	3		15.4667	0.09129	257	169.43	<.0001
2	1	910	16.8017	0.1161	247	144.78	<.0001
2	2		16.44	0.1161	247	141.66	<.0001
2	3		15.6533	0.1161	247	134.88	<.0001
2	1	912	16.74	0.09585	250	174.65	<.0001
2	2		16.4767	0.09585	250	171.9	<.0001
2	3		15.4133	0.09585	250	160.81	<.0001
2	1	914	16.6667	0.1161	266	143.58	<.0001
2	2		16.52	0.1161	266	142.32	<.0001
2	3		15.1767	0.1161	266	130.74	<.0001
2	1	916	16.2683	0.1181	267	137.77	<.0001
2	2		16.74	0.1181	267	141.77	<.0001
2	3		15.0867	0.1181	267	127.77	<.0001
2	1	918	15.605	0.1069	258	146.05	<.0001
2	2		17.13	0.1069	258	160.32	<.0001
2	3		15.1767	0.1069	258	142.04	<.0001
2	1	920	14.9567	0.1356	254	110.29	<.0001
2	2		17.5	0.1356	254	129.05	<.0001
2	3		15.26	0.1356	254	112.53	<.0001
2	1	922	15.3483	0.1028	254	149.31	<.0001
2	2		16.5067	0.1028	254	160.58	<.0001
2	3		15.15	0.1028	254	147.38	<.0001



Table 47: Continued

2	1	924	15.7217	0.09421	258	166.88	<.0001
2	2		15.33	0.09421	258	162.72	<.0001
2	3		15.0567	0.09421	258	159.82	<.0001
2	1	926	15.7467	0.09469	264	166.29	<.0001
2	2		14.73	0.09469	264	155.56	<.0001
2	3		15.0467	0.09469	264	158.9	<.0001
2	1	928	15.45	0.09708	276	159.15	<.0001
2	2		14.4167	0.09708	276	148.5	<.0001
2	3		15.1167	0.09708	276	155.72	<.0001
2	1	930	15.14	0.1285	254	117.8	<.0001
2	2		14.2033	0.1285	254	110.51	<.0001
2	3		15.1933	0.1285	254	118.21	<.0001

Table 48: Absolute Power on Tag Reverse (dBm) Scenario 2 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	1.7833	0.1424	226	12.52	<.0001	Tukey-Kramer	<.0001
1		3	2.7467	0.1424	226	19.28	<.0001	Tukey-Kramer	<.0001
2		3	0.9633	0.1424	226	6.76	<.0001	Tukey-Kramer	<.0001
1	902	2	1.8233	0.1196	262	15.24	<.0001	Tukey-Kramer	<.0001
1		3	2.4067	0.1196	262	20.12	<.0001	Tukey-Kramer	<.0001
2		3	0.5833	0.1196	262	4.88	<.0001	Tukey-Kramer	0.0043
1	904	2	1.8317	0.1448	276	12.65	<.0001	Tukey-Kramer	<.0001
1		3	2.0617	0.1448	276	14.23	<.0001	Tukey-Kramer	<.0001
2		3	0.23	0.1448	276	1.59	0.1135	Tukey-Kramer	1
1	906	2	1.565	0.1488	274	10.52	<.0001	Tukey-Kramer	<.0001
1		3	1.7383	0.1488	274	11.68	<.0001	Tukey-Kramer	<.0001
2		3	0.1733	0.1488	274	1.16	0.2451	Tukey-Kramer	1
1	908	2	0.9583	0.1291	257	7.42	<.0001	Tukey-Kramer	<.0001
1		3	1.4683	0.1291	257	11.37	<.0001	Tukey-Kramer	<.0001
2		3	0.51	0.1291	257	3.95	0.0001	Tukey-Kramer	0.1613
1	910	2	0.3617	0.1641	247	2.2	0.0285	Tukey-Kramer	1
1		3	1.1483	0.1641	247	7	<.0001	Tukey-Kramer	<.0001
2		3	0.7867	0.1641	247	4.79	<.0001	Tukey-Kramer	0.0063
1	912	2	0.2633	0.1356	250	1.94	0.0532	Tukey-Kramer	1
1		3	1.3267	0.1356	250	9.79	<.0001	Tukey-Kramer	<.0001
2		3	1.0633	0.1356	250	7.84	<.0001	Tukey-Kramer	<.0001
1	914	2	0.1467	0.1642	266	0.89	0.3724	Tukey-Kramer	1
1		3	1.49	0.1642	266	9.08	<.0001	Tukey-Kramer	<.0001
2		3	1.3433	0.1642	266	8.18	<.0001	Tukey-Kramer	<.0001
1	916	2	-0.4717	0.167	267	-2.82	0.0051	Tukey-Kramer	0.9639
1		3	1.1817	0.167	267	7.08	<.0001	Tukey-Kramer	<.0001
2		3	1.6533	0.167	267	9.9	<.0001	Tukey-Kramer	<.0001
1	918	2	-1.525	0.1511	258	-10.09	<.0001	Tukey-Kramer	<.0001
1		3	0.4283	0.1511	258	2.83	0.005	Tukey-Kramer	0.9614
2		3	1.9533	0.1511	258	12.93	<.0001	Tukey-Kramer	<.0001
1	920	2	-2.5433	0.1918	254	-13.26	<.0001	Tukey-Kramer	<.0001
1		3	-0.3033	0.1918	254	-1.58	0.115	Tukey-Kramer	1
2		3	2.24	0.1918	254	11.68	<.0001	Tukey-Kramer	<.0001
1	922	2	-1.1583	0.1454	254	-7.97	<.0001	Tukey-Kramer	<.0001
1		3	0.1983	0.1454	254	1.36	0.1737	Tukey-Kramer	1
2		3	1.3567	0.1454	254	9.33	<.0001	Tukey-Kramer	<.0001

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Table 48: Continued

1	924	2	0.3917	0.1332	258	2.94	0.0036	Tukey-Kramer	0.9268
1		3	0.665	0.1332	258	4.99	<.0001	Tukey-Kramer	0.0025
2		3	0.2733	0.1332	258	2.05	0.0412	Tukey-Kramer	1
1	926	2	1.0167	0.1339	264	7.59	<.0001	Tukey-Kramer	<.0001
1		3	0.7	0.1339	264	5.23	<.0001	Tukey-Kramer	0.0008
2		3	-0.3167	0.1339	264	-2.36	0.0188	Tukey-Kramer	0.9996
1	928	2	1.0333	0.1373	276	7.53	<.0001	Tukey-Kramer	<.0001
1		3	0.3333	0.1373	276	2.43	0.0158	Tukey-Kramer	0.9991
2		3	-0.7	0.1373	276	-5.1	<.0001	Tukey-Kramer	0.0015
1	930	2	0.9367	0.1818	254	5.15	<.0001	Tukey-Kramer	0.0011
1		3	-0.05333	0.1818	254	-0.29	0.7694	Tukey-Kramer	1
2		3	-0.99	0.1818	254	-5.45	<.0001	Tukey-Kramer	0.0002

Table 49: Theoretical Read Range Reverse (m) Scenario 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
2	1	900	17.8017	0.2375	227	74.95	<.0001
2	2		21.7767	0.2375	227	91.68	<.0001
2	3		24.2967	0.2375	227	102.29	<.0001
2	1	902	18.11	0.2029	264	89.25	<.0001
2	2		22.1933	0.2029	264	109.38	<.0001
2	3		23.7267	0.2029	264	116.94	<.0001
2	1	904	18.4167	0.2605	278	70.7	<.0001
2	2		22.6033	0.2605	278	86.77	<.0001
2	3		23.1767	0.2605	278	88.97	<.0001
2	1	906	18.6717	0.2628	276	71.06	<.0001
2	2		22.1733	0.2628	276	84.39	<.0001
2	3		22.63	0.2628	276	86.13	<.0001
2	1	908	18.8833	0.2238	257	84.38	<.0001
2	2		20.9933	0.2238	257	93.81	<.0001
2	3		22.23	0.2238	257	99.33	<.0001
2	1	910	19.085	0.2846	243	67.06	<.0001
2	2		19.85	0.2846	243	69.75	<.0001
2	3		21.7733	0.2846	243	76.51	<.0001
2	1	912	19.2967	0.2423	247	79.65	<.0001
2	2		19.6933	0.2423	247	81.29	<.0001
2	3		22.3533	0.2423	247	92.27	<.0001
2	1	914	19.53	0.3164	261	61.72	<.0001
2	2		19.5633	0.3164	261	61.83	<.0001
2	3		22.9067	0.3164	261	72.39	<.0001
2	1	916	20.3567	0.3331	257	61.12	<.0001
2	2		19.0833	0.3331	257	57.29	<.0001
2	3		23.0567	0.3331	257	69.22	<.0001
2	1	918	21.7067	0.2761	257	78.62	<.0001
2	2		18.2467	0.2761	257	66.08	<.0001
2	3		22.7767	0.2761	257	82.49	<.0001
2	1	920	23.4667	0.3315	275	70.78	<.0001
2	2		17.4267	0.3315	275	52.56	<.0001
2	3		22.51	0.3315	275	67.89	<.0001
2	1	922	22.3717	0.2409	281	92.86	<.0001
2	2		19.9467	0.2409	281	82.79	<.0001
2	3		22.7567	0.2409	281	94.46	<.0001

Table 49: Continued

2	1	924	21.28	0.2227	281	95.56	<.0001
2	2		22.44	0.2227	281	100.77	<.0001
2	3		22.9333	0.2227	281	102.99	<.0001
2	1	926	21.2533	0.2202	278	96.51	<.0001
2	2		23.9867	0.2202	278	108.92	<.0001
2	3		22.94	0.2202	278	104.17	<.0001
2	1	928	22.1	0.2607	275	84.77	<.0001
2	2		24.59	0.2607	275	94.32	<.0001
2	3		22.6833	0.2607	275	87.01	<.0001
2	1	930	22.5633	0.3552	246	63.52	<.0001
2	2		25.18	0.3552	246	70.89	<.0001
2	3		22.4333	0.3552	246	63.16	<.0001

Table 50: Theoretical Read Range Reverse (m) Scenario 2 Comparisons

loc	fre	_loc	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-3.975	0.3359	227	-11.83	<.0001	Tukey-Kramer	<.0001
1		3	-6.495	0.3359	227	-19.34	<.0001	Tukey-Kramer	<.0001
2		3	-2.52	0.3359	227	-7.5	<.0001	Tukey-Kramer	<.0001
1	902	2	-4.0833	0.2869	264	-14.23	<.0001	Tukey-Kramer	<.0001
1		3	-5.6167	0.2869	264	-19.57	<.0001	Tukey-Kramer	<.0001
2		3	-1.5333	0.2869	264	-5.34	<.0001	Tukey-Kramer	0.0004
1	904	2	-4.1867	0.3684	278	-11.36	<.0001	Tukey-Kramer	<.0001
1		3	-4.76	0.3684	278	-12.92	<.0001	Tukey-Kramer	<.0001
2		3	-0.5733	0.3684	278	-1.56	0.1208	Tukey-Kramer	1
1	906	2	-3.5017	0.3716	276	-9.42	<.0001	Tukey-Kramer	<.0001
1		3	-3.9583	0.3716	276	-10.65	<.0001	Tukey-Kramer	<.0001
2		3	-0.4567	0.3716	276	-1.23	0.2201	Tukey-Kramer	1
1	908	2	-2.11	0.3165	257	-6.67	<.0001	Tukey-Kramer	<.0001
1		3	-3.3467	0.3165	257	-10.57	<.0001	Tukey-Kramer	<.0001
2		3	-1.2367	0.3165	257	-3.91	0.0001	Tukey-Kramer	0.1835
1	910	2	-0.765	0.4025	243	-1.9	0.0585	Tukey-Kramer	1
1		3	-2.6883	0.4025	243	-6.68	<.0001	Tukey-Kramer	<.0001
2		3	-1.9233	0.4025	243	-4.78	<.0001	Tukey-Kramer	0.0068
1	912	2	-0.3967	0.3426	247	-1.16	0.2481	Tukey-Kramer	1
1		3	-3.0567	0.3426	247	-8.92	<.0001	Tukey-Kramer	<.0001
2		3	-2.66	0.3426	247	-7.76	<.0001	Tukey-Kramer	<.0001
1	914	2	-0.03333	0.4475	261	-0.07	0.9407	Tukey-Kramer	1
1		3	-3.3767	0.4475	261	-7.55	<.0001	Tukey-Kramer	<.0001
2		3	-3.3433	0.4475	261	-7.47	<.0001	Tukey-Kramer	<.0001
1	916	2	1.2733	0.471	257	2.7	0.0073	Tukey-Kramer	0.9854
1		3	-2.7	0.471	257	-5.73	<.0001	Tukey-Kramer	<.0001
2		3	-3.9733	0.471	257	-8.44	<.0001	Tukey-Kramer	<.0001
1	918	2	3.46	0.3905	257	8.86	<.0001	Tukey-Kramer	<.0001
1		3	-1.07	0.3905	257	-2.74	0.0066	Tukey-Kramer	0.9804
2		3	-4.53	0.3905	257	-11.6	<.0001	Tukey-Kramer	<.0001
1	920	2	6.04	0.4689	275	12.88	<.0001	Tukey-Kramer	<.0001
1		3	0.9567	0.4689	275	2.04	0.0423	Tukey-Kramer	1
2		3	-5.0833	0.4689	275	-10.84	<.0001	Tukey-Kramer	<.0001
1	922	2	2.425	0.3407	281	7.12	<.0001	Tukey-Kramer	<.0001
1		3	-0.385	0.3407	281	-1.13	0.2594	Tukey-Kramer	1
2		3	-2.81	0.3407	281	-8.25	<.0001	Tukey-Kramer	<.0001

Table 50: Continued

1	924	2	-1.16	0.3149	281	-3.68	0.0003	Tukey-Kramer	0.3334
1		3	-1.6533	0.3149	281	-5.25	<.0001	Tukey-Kramer	0.0007
2		3	-0.4933	0.3149	281	-1.57	0.1183	Tukey-Kramer	1
1	926	2	-2.7333	0.3114	278	-8.78	<.0001	Tukey-Kramer	<.0001
1		3	-1.6867	0.3114	278	-5.42	<.0001	Tukey-Kramer	0.0003
2		3	1.0467	0.3114	278	3.36	0.0009	Tukey-Kramer	0.6253
1	928	2	-2.49	0.3687	275	-6.75	<.0001	Tukey-Kramer	<.0001
1		3	-0.5833	0.3687	275	-1.58	0.1148	Tukey-Kramer	1
2		3	1.9067	0.3687	275	5.17	<.0001	Tukey-Kramer	0.001
1	930	2	-2.6167	0.5023	246	-5.21	<.0001	Tukey-Kramer	0.0009
1		3	0.13	0.5023	246	0.26	0.796	Tukey-Kramer	1
2		3	2.7467	0.5023	246	5.47	<.0001	Tukey-Kramer	0.0002

Appendix F: Location 1 – Michigan State University Auto-ID Research and Testing Center Office Area Tables and Figures

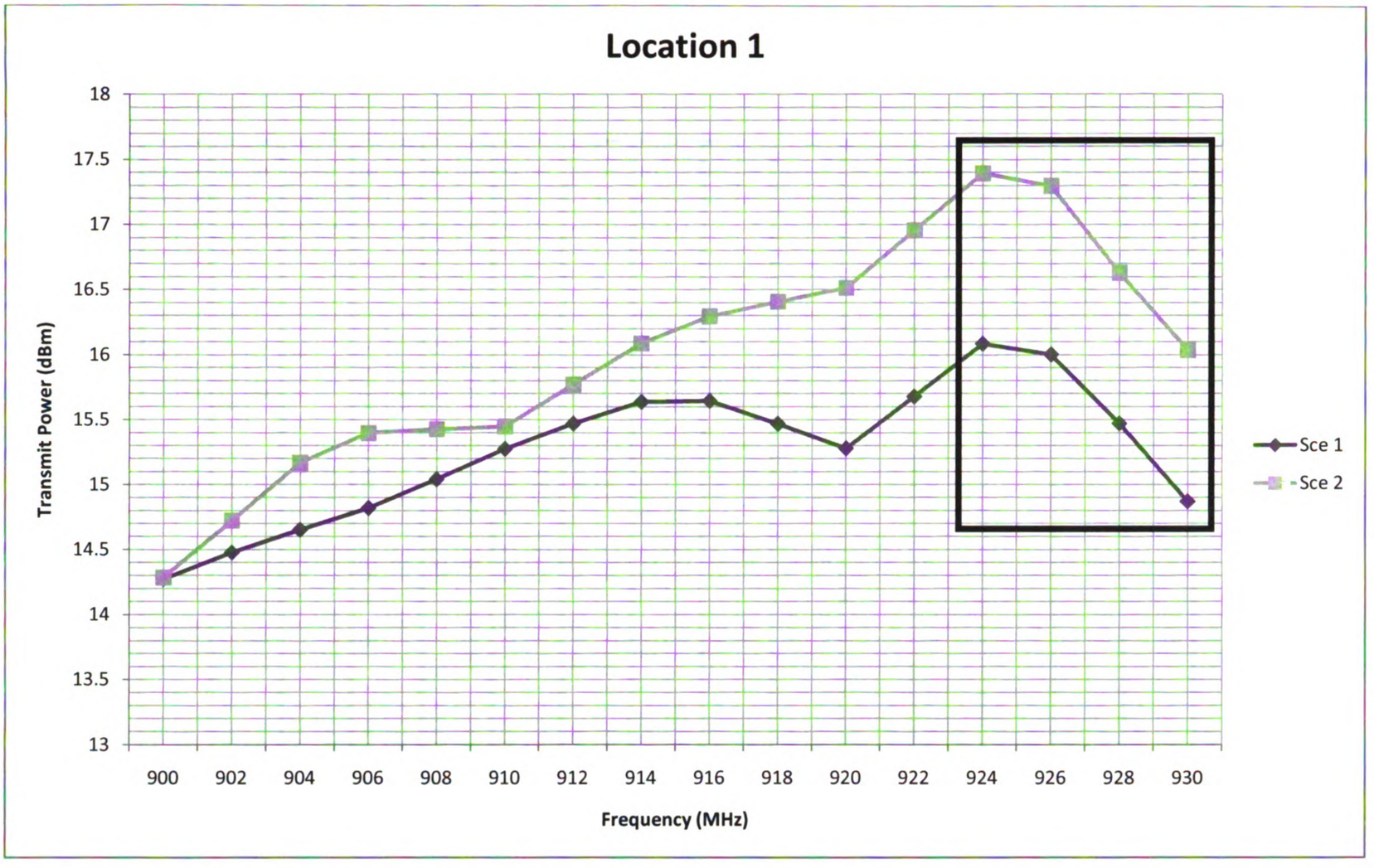

Figure 42: Location 1 - Transmit Power (dBm) vs. Frequency (MHz)

Table 51: Transmit Power (dBm) Location 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	14.27	0.07243	215	197.02	<.0001
2	1		14.2833	0.07243	215	197.2	<.0001
1	1	902	14.4767	0.06779	249	213.56	<.0001
2	1		14.72	0.06779	249	217.15	<.0001
1	1	904	14.65	0.08463	261	173.11	<.0001
2	1		15.1667	0.08463	261	179.22	<.0001
1	1	906	14.8167	0.08354	258	177.36	<.0001
2	1		15.3967	0.08354	258	184.3	<.0001
1	1	908	15.04	0.0734	247	204.91	<.0001
2	1		15.425	0.0734	247	210.15	<.0001
1	1	910	15.2733	0.08972	246	170.23	<.0001
2	1		15.4467	0.08972	246	172.16	<.0001
1	1	912	15.4683	0.0711	254	217.55	<.0001
2	1		15.77	0.0711	254	221.79	<.0001
1	1	914	15.6367	0.08047	266	194.33	<.0001
2	1		16.0867	0.08047	266	199.92	<.0001
1	1	916	15.6433	0.08486	273	184.34	<.0001
2	1		16.2933	0.08486	273	192	<.0001
1	1	918	15.4667	0.09041	284	171.08	<.0001
2	1		16.4067	0.09041	284	181.48	<.0001
1	1	920	15.2767	0.1165	295	131.17	<.0001
2	1		16.5133	0.1165	295	141.78	<.0001
1	1	922	15.6767	0.09568	299	163.85	<.0001
2	1		16.9533	0.09568	299	177.19	<.0001
1	1	924	16.0833	0.09556	295	168.31	<.0001
2	1		17.3917	0.09556	295	182	<.0001
1	1	926	16	0.09565	285	167.28	<.0001
2	1		17.295	0.09565	285	180.81	<.0001
1	1	928	15.47	0.103	278	150.15	<.0001
2	1		16.6283	0.103	278	161.39	<.0001
1	1	930	14.87	0.1393	252	106.77	<.0001
2	1		16.035	0.1393	252	115.13	<.0001

Table 52: Transmit Power (dBm) Location 1 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-0.01333	0.1024	215	-0.13	0.8966	Tukey-Kramer	1
1	902	2	-0.2433	0.09587	249	-2.54	0.0118	Tukey-Kramer	0.9969
1	904	2	-0.5167	0.1197	261	-4.32	<.0001	Tukey-Kramer	0.0461
1	906	2	-0.58	0.1181	258	-4.91	<.0001	Tukey-Kramer	0.0037
1	908	2	-0.385	0.1038	247	-3.71	0.0003	Tukey-Kramer	0.3134
1	910	2	-0.1733	0.1269	246	-1.37	0.1732	Tukey-Kramer	1
1	912	2	-0.3017	0.1006	254	-3	0.003	Tukey-Kramer	0.8993
1	914	2	-0.45	0.1138	266	-3.95	<.0001	Tukey-Kramer	0.1593
1	916	2	-0.65	0.12	273	-5.42	<.0001	Tukey-Kramer	0.0003
1	918	2	-0.94	0.1279	284	-7.35	<.0001	Tukey-Kramer	<.0001
1	920	2	-1.2367	0.1647	295	-7.51	<.0001	Tukey-Kramer	<.0001
1	922	2	-1.2767	0.1353	299	-9.44	<.0001	Tukey-Kramer	<.0001
1	924	2	-1.3083	0.1351	295	-9.68	<.0001	Tukey-Kramer	<.0001
1	926	2	-1.295	0.1353	285	-9.57	<.0001	Tukey-Kramer	<.0001
1	928	2	-1.1583	0.1457	278	-7.95	<.0001	Tukey-Kramer	<.0001
1	930	2	-1.165	0.197	252	-5.91	<.0001	Tukey-Kramer	<.0001

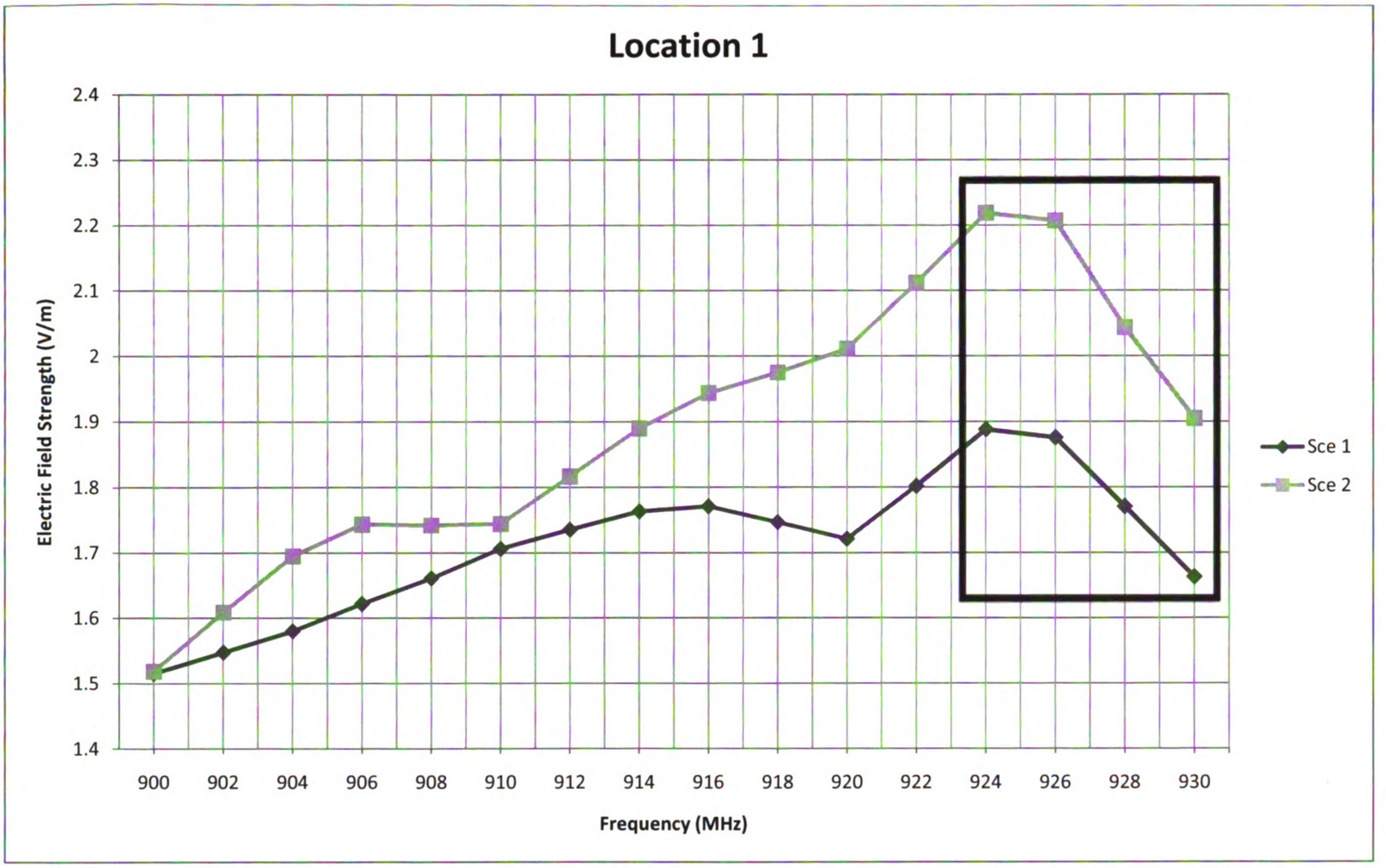

Figure 43: Location 1 - Electric Field Strength (V/m) vs. Frequency (MHz)

Table 53: Electric Field Strength (V/m) Location 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	1.515	0.01532	165	98.88	<.0001
2	1		1.5187	0.01532	165	99.12	<.0001
1	1	902	1.5472	0.02764	184	55.98	<.0001
2	1		1.6087	0.02764	184	58.2	<.0001
1	1	904	1.58	0.01965	224	80.42	<.0001
2	1		1.6948	0.01965	224	86.26	<.0001
1	1	906	1.6217	0.0163	247	99.47	<.0001
2	1		1.743	0.0163	247	106.91	<.0001
1	1	908	1.6605	0.01309	249	126.87	<.0001
2	1		1.7417	0.01309	249	133.07	<.0001
1	1	910	1.706	0.01521	256	112.15	<.0001
2	1		1.744	0.01521	256	114.65	<.0001
1	1	912	1.7352	0.01333	273	130.17	<.0001
2	1		1.8163	0.01333	273	136.26	<.0001
1	1	914	1.7628	0.01541	290	114.42	<.0001
2	1		1.8897	0.01541	290	122.66	<.0001
1	1	916	1.7708	0.0168	301	105.43	<.0001
2	1		1.9433	0.0168	301	115.7	<.0001
1	1	918	1.7463	0.01951	316	89.51	<.0001
2	1		1.9747	0.01951	316	101.21	<.0001
1	1	920	1.7208	0.02568	332	67.01	<.0001
2	1		2.0113	0.02568	332	78.33	<.0001
1	1	922	1.8017	0.02235	336	80.63	<.0001
2	1		2.1115	0.02235	336	94.49	<.0001
1	1	924	1.8878	0.02353	328	80.23	<.0001
2	1		2.2183	0.02353	328	94.28	<.0001
1	1	926	1.8753	0.02341	311	80.1	<.0001
2	1		2.2067	0.02341	311	94.26	<.0001
1	1	928	1.7702	0.02256	295	78.47	<.0001
2	1		2.0437	0.02256	295	90.6	<.0001
1	1	930	1.6625	0.03025	258	54.96	<.0001
2	1		1.9047	0.03025	258	62.97	<.0001

Table 54: Electric Field Strength (V/m) Location 1 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-0.00367	0.02167	165	-0.17	0.8658	Tukey-Kramer	1
1	902	2	-0.0615	0.03909	184	-1.57	0.1173	Tukey-Kramer	1
1	904	2	-0.1148	0.02779	224	-4.13	<.0001	Tukey-Kramer	0.0895
1	906	2	-0.1213	0.02306	247	-5.26	<.0001	Tukey-Kramer	0.0007
1	908	2	-0.08117	0.01851	249	-4.39	<.0001	Tukey-Kramer	0.0356
1	910	2	-0.038	0.02151	256	-1.77	0.0785	Tukey-Kramer	1
1	912	2	-0.08117	0.01885	273	-4.31	<.0001	Tukey-Kramer	0.0482
1	914	2	-0.1268	0.02179	290	-5.82	<.0001	Tukey-Kramer	<.0001
1	916	2	-0.1725	0.02375	301	-7.26	<.0001	Tukey-Kramer	<.0001
1	918	2	-0.2283	0.02759	316	-8.28	<.0001	Tukey-Kramer	<.0001
1	920	2	-0.2905	0.03631	332	-8	<.0001	Tukey-Kramer	<.0001
1	922	2	-0.3098	0.0316	336	-9.8	<.0001	Tukey-Kramer	<.0001
1	924	2	-0.3305	0.03328	328	-9.93	<.0001	Tukey-Kramer	<.0001
1	926	2	-0.3313	0.03311	311	-10.01	<.0001	Tukey-Kramer	<.0001
1	928	2	-0.2735	0.0319	295	-8.57	<.0001	Tukey-Kramer	<.0001
1	930	2	-0.2422	0.04278	258	-5.66	<.0001	Tukey-Kramer	<.0001

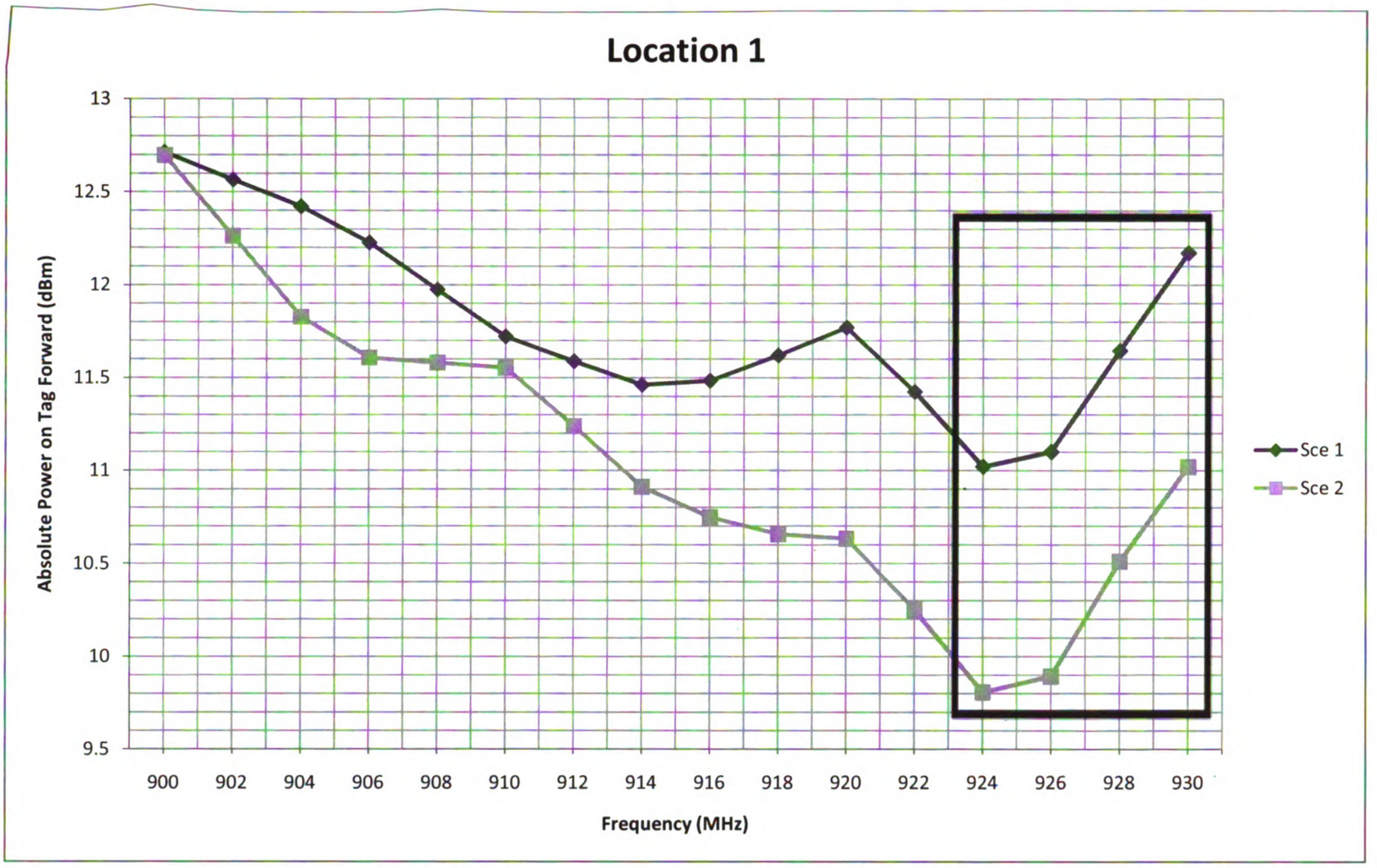

Figure 44: Location 1 - Absolute Power on Tag Forward (dBm) vs. Frequency (MHz)

Table 55: Absolute Power on Tag Forward (dBm) Location 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	12.7133	0.07129	220	178.34	<.0001
2	1		12.6967	0.07129	220	178.11	<.0001
1	1	902	12.565	0.06457	254	194.6	<.0001
2	1		12.2617	0.06457	254	189.9	<.0001
1	1	904	12.4217	0.08087	266	153.6	<.0001
2	1		11.8267	0.08087	266	146.24	<.0001
1	1	906	12.2267	0.083	264	147.31	<.0001
2	1		11.6067	0.083	264	139.84	<.0001
1	1	908	11.9733	0.07273	252	164.62	<.0001
2	1		11.58	0.07273	252	159.21	<.0001
1	1	910	11.72	0.08883	247	131.93	<.0001
2	1		11.5533	0.08883	247	130.06	<.0001
1	1	912	11.5883	0.07585	251	152.77	<.0001
2	1		11.2383	0.07585	251	148.16	<.0001
1	1	914	11.4617	0.08056	262	142.28	<.0001
2	1		10.9117	0.08056	262	135.45	<.0001
1	1	916	11.4833	0.08209	270	139.89	<.0001
2	1		10.7467	0.08209	270	130.92	<.0001
1	1	918	11.62	0.08946	281	129.89	<.0001
2	1		10.6567	0.08946	281	119.12	<.0001
1	1	920	11.77	0.1137	293	103.55	<.0001
2	1		10.6317	0.1137	293	93.54	<.0001
1	1	922	11.4233	0.1001	297	114.18	<.0001
2	1		10.25	0.1001	297	102.45	<.0001
1	1	924	11.02	0.0994	294	110.86	<.0001
2	1		9.8067	0.0994	294	98.66	<.0001
1	1	926	11.1	0.09691	284	114.54	<.0001
2	1		9.8917	0.09691	284	102.07	<.0001
1	1	928	11.645	0.1056	277	110.27	<.0001
2	1		10.51	0.1056	277	99.52	<.0001
1	1	930	12.1717	0.1403	249	86.78	<.0001
2	1		11.02	0.1403	249	78.57	<.0001

Table 56: Absolute Power on Tag Forward (dBm) Location 1 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.01667	0.1008	220	0.17	0.8688	Tukey-Kramer	1
1	902	2	0.3033	0.09131	254	3.32	0.001	Tukey-Kramer	0.6614
1	904	2	0.595	0.1144	266	5.2	<.0001	Tukey-Kramer	0.0009
1	906	2	0.62	0.1174	264	5.28	<.0001	Tukey-Kramer	0.0006
1	908	2	0.3933	0.1029	252	3.82	0.0002	Tukey-Kramer	0.2324
1	910	2	0.1667	0.1256	247	1.33	0.1859	Tukey-Kramer	1
1	912	2	0.35	0.1073	251	3.26	0.0013	Tukey-Kramer	0.7144
1	914	2	0.55	0.1139	262	4.83	<.0001	Tukey-Kramer	0.0054
1	916	2	0.7367	0.1161	270	6.35	<.0001	Tukey-Kramer	<.0001
1	918	2	0.9633	0.1265	281	7.61	<.0001	Tukey-Kramer	<.0001
1	920	2	1.1383	0.1607	293	7.08	<.0001	Tukey-Kramer	<.0001
1	922	2	1.1733	0.1415	297	8.29	<.0001	Tukey-Kramer	<.0001
1	924	2	1.2133	0.1406	294	8.63	<.0001	Tukey-Kramer	<.0001
1	926	2	1.2083	0.137	284	8.82	<.0001	Tukey-Kramer	<.0001
1	928	2	1.135	0.1493	277	7.6	<.0001	Tukey-Kramer	<.0001
1	930	2	1.1517	0.1984	249	5.81	<.0001	Tukey-Kramer	<.0001

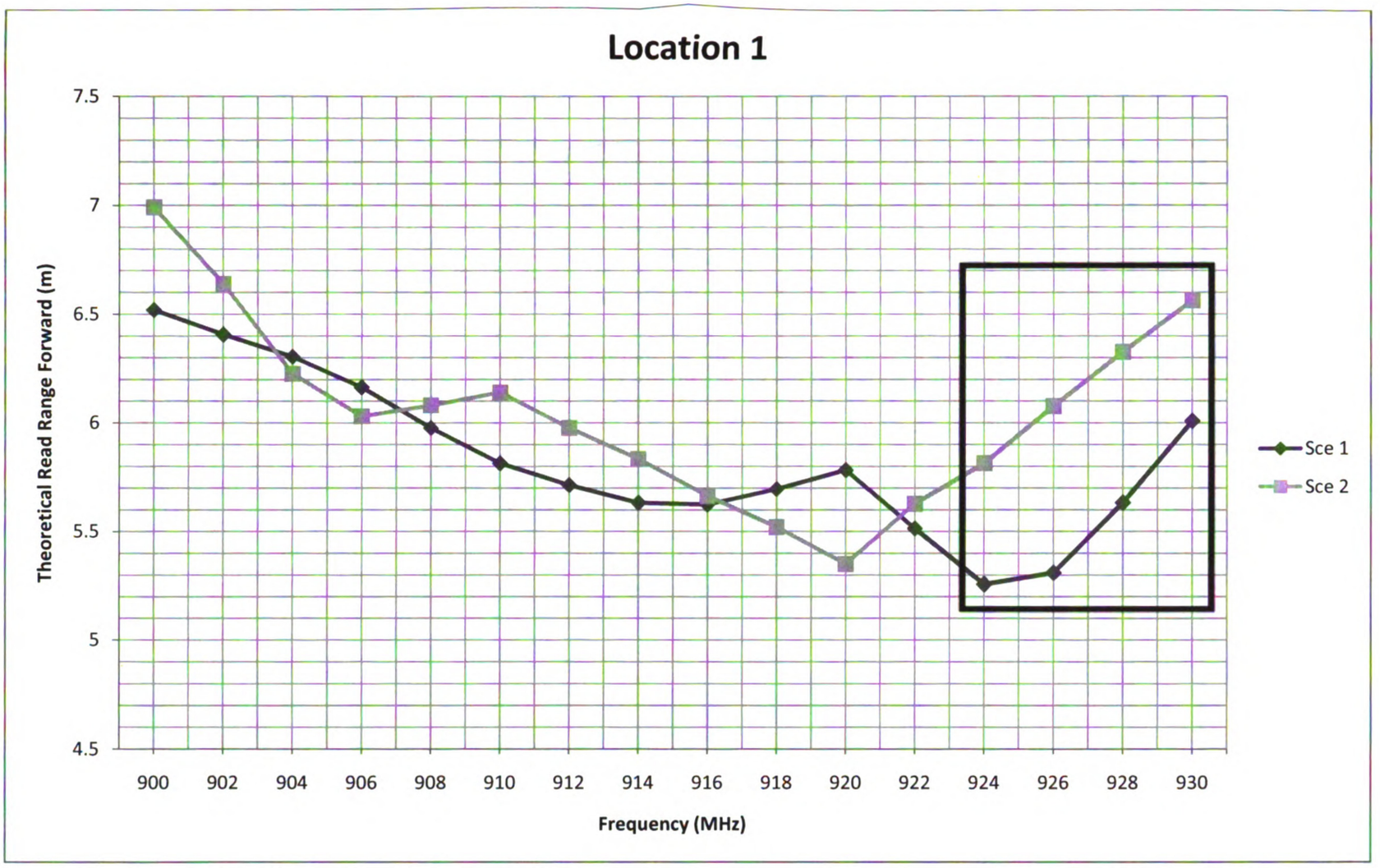

Figure 45: Location 1 - Theoretical Read Range Forward (m) vs. frequency (MHz)

Table 57: Theoretical Read Range Forward (m) Location 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	6.52	0.05727	230	113.85	<.0001
2	1		6.99	0.05727	230	122.05	<.0001
1	1	902	6.4067	0.04414	256	145.14	<.0001
2	1		6.64	0.04414	256	150.42	<.0001
1	1	904	6.305	0.04841	266	130.24	<.0001
2	1		6.2267	0.04841	266	128.62	<.0001
1	1	906	6.1633	0.04618	271	133.46	<.0001
2	1		6.03	0.04618	271	130.58	<.0001
1	1	908	5.9767	0.04687	269	127.52	<.0001
2	1		6.08	0.04687	269	129.73	<.0001
1	1	910	5.8133	0.05849	272	99.39	<.0001
2	1		6.14	0.05849	272	104.97	<.0001
1	1	912	5.7133	0.04547	274	125.66	<.0001
2	1		5.9767	0.04547	274	131.45	<.0001
1	1	914	5.6317	0.0438	284	128.56	<.0001
2	1		5.8333	0.0438	284	133.17	<.0001
1	1	916	5.6233	0.0447	290	125.8	<.0001
2	1		5.6633	0.0447	290	126.7	<.0001
1	1	918	5.695	0.03992	283	142.67	<.0001
2	1		5.52	0.03992	283	138.28	<.0001
1	1	920	5.7817	0.04942	274	116.99	<.0001
2	1		5.35	0.04942	274	108.25	<.0001
1	1	922	5.5133	0.03724	260	148.06	<.0001
2	1		5.6267	0.03724	260	151.1	<.0001
1	1	924	5.2567	0.03611	252	145.56	<.0001
2	1		5.8133	0.03611	252	160.97	<.0001
1	1	926	5.31	0.03879	248	136.89	<.0001
2	1		6.0767	0.03879	248	156.66	<.0001
1	1	928	5.6317	0.04469	252	126.02	<.0001
2	1		6.3267	0.04469	252	141.58	<.0001
1	1	930	6.0083	0.05986	234	100.38	<.0001
2	1		6.5633	0.05986	234	109.65	<.0001

Table 58: Theoretical Read Range Forward (m) Location 1 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-0.47	0.08099	230	-5.8	<.0001	Tukey-Kramer	<.0001
1	902	2	-0.2333	0.06243	256	-3.74	0.0002	Tukey-Kramer	0.2918
1	904	2	0.07833	0.06846	266	1.14	0.2536	Tukey-Kramer	1
1	906	2	0.1333	0.06531	271	2.04	0.0422	Tukey-Kramer	1
1	908	2	-0.1033	0.06628	269	-1.56	0.1202	Tukey-Kramer	1
1	910	2	-0.3267	0.08272	272	-3.95	0.0001	Tukey-Kramer	0.1619
1	912	2	-0.2633	0.0643	274	-4.1	<.0001	Tukey-Kramer	0.1015
1	914	2	-0.2017	0.06195	284	-3.26	0.0013	Tukey-Kramer	0.7208
1	916	2	-0.04	0.06322	290	-0.63	0.5274	Tukey-Kramer	1
1	918	2	0.175	0.05645	283	3.1	0.0021	Tukey-Kramer	0.8409
1	920	2	0.4317	0.06989	274	6.18	<.0001	Tukey-Kramer	<.0001
1	922	2	-0.1133	0.05266	260	-2.15	0.0323	Tukey-Kramer	1
1	924	2	-0.5567	0.05107	252	-10.9	<.0001	Tukey-Kramer	<.0001
1	926	2	-0.7667	0.05486	248	-13.98	<.0001	Tukey-Kramer	<.0001
1	928	2	-0.695	0.0632	252	-11	<.0001	Tukey-Kramer	<.0001
1	930	2	-0.555	0.08465	234	-6.56	<.0001	Tukey-Kramer	<.0001

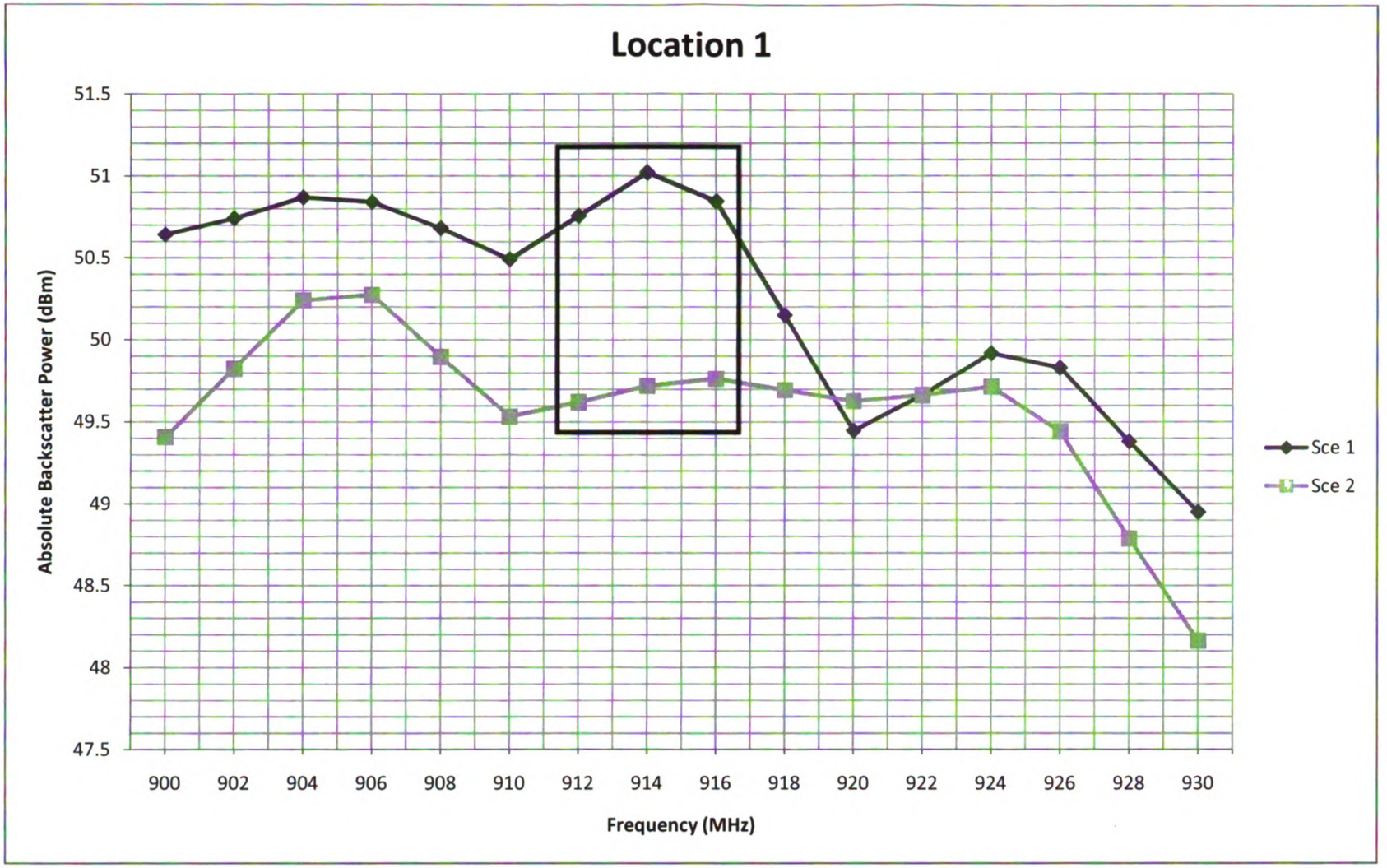

Figure 46: Location 1 - Absolute Backscatter Power (dBm) vs. Frequency (MHz)

Table 59: Absolute Backscatter Power (dBm) Location 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	50.6417	0.1075	215	470.92	<.0001
2	1		49.4067	0.1075	215	459.43	<.0001
1	1	902	50.74	0.08893	248	570.54	<.0001
2	1		49.8233	0.08893	248	560.23	<.0001
1	1	904	50.87	0.1069	263	476.01	<.0001
2	1		50.24	0.1069	263	470.11	<.0001
1	1	906	50.8417	0.108	263	470.88	<.0001
2	1		50.2733	0.108	263	465.61	<.0001
1	1	908	50.68	0.09665	248	524.35	<.0001
2	1		49.8967	0.09665	248	516.25	<.0001
1	1	910	50.4917	0.1201	237	420.27	<.0001
2	1		49.5333	0.1201	237	412.29	<.0001
1	1	912	50.7567	0.09783	242	518.8	<.0001
2	1		49.62	0.09783	242	507.18	<.0001
1	1	914	51.0217	0.1226	254	416.31	<.0001
2	1		49.72	0.1226	254	405.69	<.0001
1	1	916	50.845	0.129	251	394.05	<.0001
2	1		49.7633	0.129	251	385.67	<.0001
1	1	918	50.1483	0.1203	246	416.93	<.0001
2	1		49.6933	0.1203	246	413.15	<.0001
1	1	920	49.4467	0.1382	258	357.68	<.0001
2	1		49.6267	0.1382	258	358.98	<.0001
1	1	922	49.6633	0.09647	271	514.83	<.0001
2	1		49.6633	0.09647	271	514.83	<.0001
1	1	924	49.9167	0.0857	282	582.45	<.0001
2	1		49.7133	0.0857	282	580.08	<.0001
1	1	926	49.83	0.08378	287	594.77	<.0001
2	1		49.44	0.08378	287	590.12	<.0001
1	1	928	49.38	0.09099	293	542.7	<.0001
2	1		48.7867	0.09099	293	536.18	<.0001
1	1	930	48.95	0.1227	266	398.96	<.0001
2	1		48.1633	0.1227	266	392.55	<.0001

Table 60: Absolute Backscatter Power (dBm) Location 1 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	1.235	0.1521	215	8.12	<.0001	Tukey-Kramer	<.0001
1	902	2	0.9167	0.1258	248	7.29	<.0001	Tukey-Kramer	<.0001
1	904	2	0.63	0.1511	263	4.17	<.0001	Tukey-Kramer	0.0791
1	906	2	0.5683	0.1527	263	3.72	0.0002	Tukey-Kramer	0.3036
1	908	2	0.7833	0.1367	248	5.73	<.0001	Tukey-Kramer	<.0001
1	910	2	0.9583	0.1699	237	5.64	<.0001	Tukey-Kramer	<.0001
1	912	2	1.1367	0.1384	242	8.22	<.0001	Tukey-Kramer	<.0001
1	914	2	1.3017	0.1733	254	7.51	<.0001	Tukey-Kramer	<.0001
1	916	2	1.0817	0.1825	251	5.93	<.0001	Tukey-Kramer	<.0001
1	918	2	0.455	0.1701	246	2.67	0.008	Tukey-Kramer	0.9885
1	920	2	-0.18	0.1955	258	-0.92	0.3581	Tukey-Kramer	1
1	922	2	1.47E-14	0.1364	271	0	1	Tukey-Kramer	1
1	924	2	0.2033	0.1212	282	1.68	0.0945	Tukey-Kramer	1
1	926	2	0.39	0.1185	287	3.29	0.0011	Tukey-Kramer	0.6888
1	928	2	0.5933	0.1287	293	4.61	<.0001	Tukey-Kramer	0.0141
1	930	2	0.7867	0.1735	266	4.53	<.0001	Tukey-Kramer	0.0196

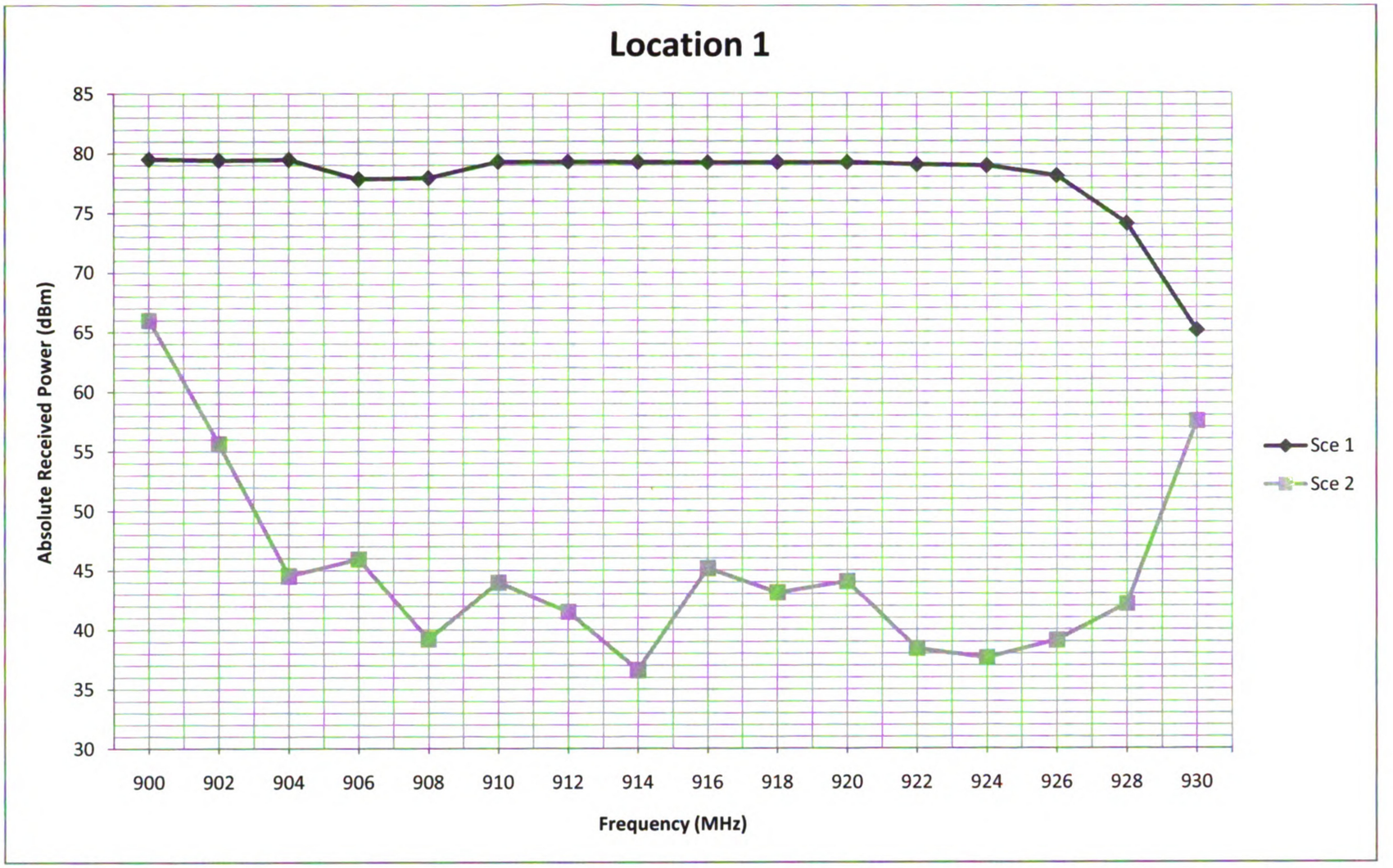

Figure 47: Location 1 - Absolute Received Power (dBm) vs. Frequency (MHz)

Table 61: Absolute Received Power (dBm) Location 1 Estimations

sce	Loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	79.51	1.3084	2157	60.77	<.0001
2	1		66	1.3084	2157	50.45	<.0001
1	1	902	79.4067	1.3084	2157	60.69	<.0001
2	1		55.6667	1.3084	2157	42.55	<.0001
1	1	904	79.46	1.3084	2157	60.73	<.0001
2	1		44.5333	1.3084	2157	34.04	<.0001
1	1	906	77.82	1.3084	2157	59.48	<.0001
2	1		45.9333	1.3084	2157	35.11	<.0001
1	1	908	77.9333	1.3084	2157	59.57	<.0001
2	1		39.2	1.3084	2157	29.96	<.0001
1	1	910	79.2833	1.3084	2157	60.6	<.0001
2	1		43.9667	1.3084	2157	33.6	<.0001
1	1	912	79.2833	1.3084	2157	60.6	<.0001
2	1		41.5	1.3084	2157	31.72	<.0001
1	1	914	79.25	1.3084	2157	60.57	<.0001
2	1		36.6	1.3084	2157	27.97	<.0001
1	1	916	79.22	1.3084	2157	60.55	<.0001
2	1		45.1333	1.3084	2157	34.5	<.0001
1	1	918	79.22	1.3084	2157	60.55	<.0001
2	1		43.1	1.3084	2157	32.94	<.0001
1	1	920	79.2133	1.3084	2157	60.54	<.0001
2	1		44.0333	1.3084	2157	33.66	<.0001
1	1	922	79.0133	1.3084	2157	60.39	<.0001
2	1		38.4	1.3084	2157	29.35	<.0001
1	1	924	78.9067	1.3084	2157	60.31	<.0001
2	1		37.6333	1.3084	2157	28.76	<.0001
1	1	926	78.0667	1.3084	2157	59.67	<.0001
2	1		39.1	1.3084	2157	29.88	<.0001
1	1	928	74.05	1.3084	2157	56.6	<.0001
2	1		42.1333	1.3084	2157	32.2	<.0001
1	1	930	65.09	1.3084	2157	49.75	<.0001
2	1		57.4667	1.3084	2157	43.92	<.0001

Table 62: Absolute Received Power (dBm) Location 1 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	13.51	1.8503	2157	7.3	<.0001	Tukey-Kramer	<.0001
1	902	2	23.74	1.8503	2157	12.83	<.0001	Tukey-Kramer	<.0001
1	904	2	34.9267	1.8503	2157	18.88	<.0001	Tukey-Kramer	<.0001
1	906	2	31.8867	1.8503	2157	17.23	<.0001	Tukey-Kramer	<.0001
1	908	2	38.7333	1.8503	2157	20.93	<.0001	Tukey-Kramer	<.0001
1	910	2	35.3167	1.8503	2157	19.09	<.0001	Tukey-Kramer	<.0001
1	912	2	37.7833	1.8503	2157	20.42	<.0001	Tukey-Kramer	<.0001
1	914	2	42.65	1.8503	2157	23.05	<.0001	Tukey-Kramer	<.0001
1	916	2	34.0867	1.8503	2157	18.42	<.0001	Tukey-Kramer	<.0001
1	918	2	36.12	1.8503	2157	19.52	<.0001	Tukey-Kramer	<.0001
1	920	2	35.18	1.8503	2157	19.01	<.0001	Tukey-Kramer	<.0001
1	922	2	40.6133	1.8503	2157	21.95	<.0001	Tukey-Kramer	<.0001
1	924	2	41.2733	1.8503	2157	22.31	<.0001	Tukey-Kramer	<.0001
1	926	2	38.9667	1.8503	2157	21.06	<.0001	Tukey-Kramer	<.0001
1	928	2	31.9167	1.8503	2157	17.25	<.0001	Tukey-Kramer	<.0001
1	930	2	7.6233	1.8503	2157	4.12	<.0001	Tukey-Kramer	0.0923

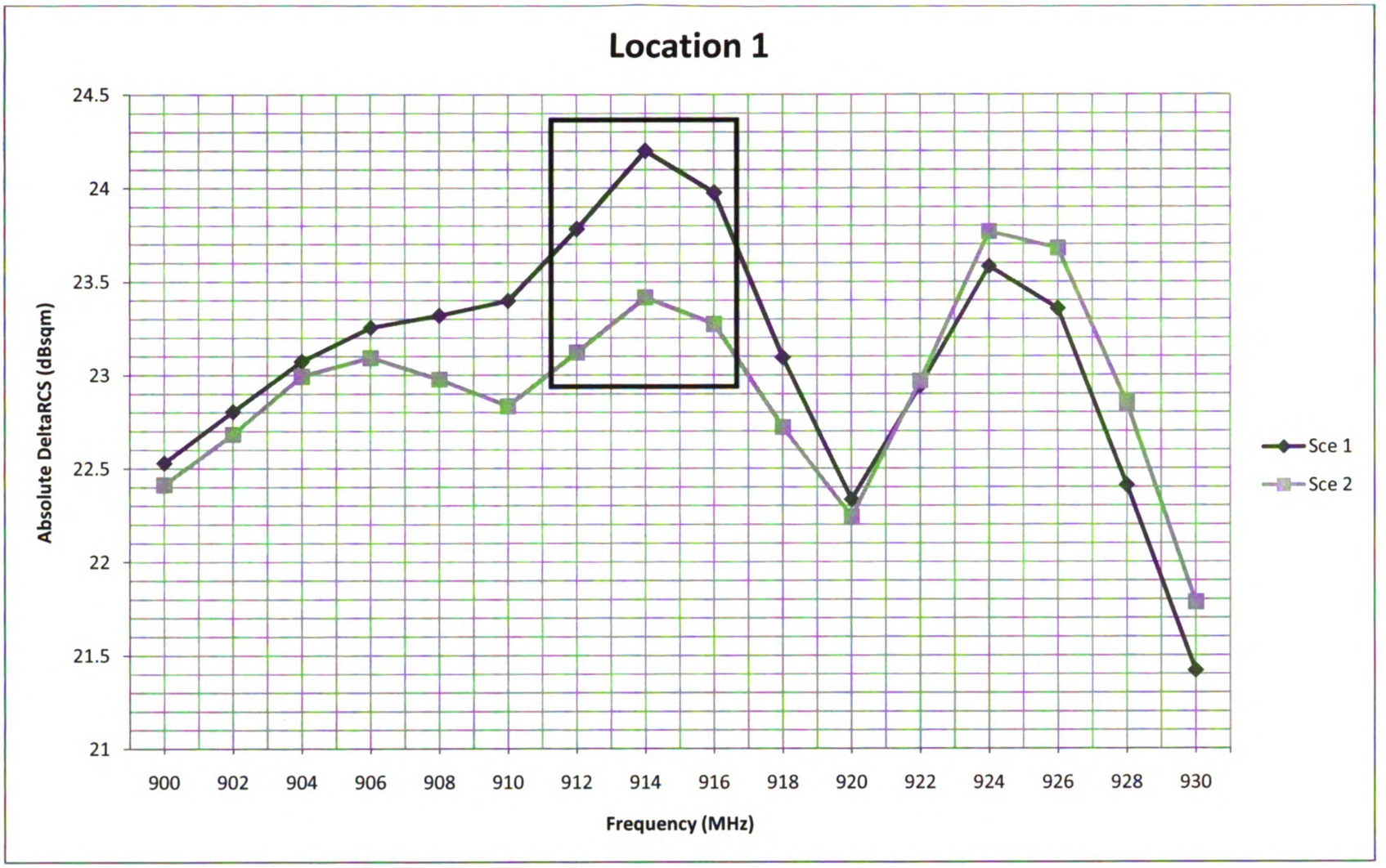

Figure 48: Location 1 - Absolute Delta RCS (dBsqm) vs. Frequency (MHz)

Table 63: Absolute Delta RCS (dBsqm) Location 1 Estimations

sce	loc	Fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	22.53	0.06879	241	327.52	<.0001
2	1		22.4133	0.06879	241	325.82	<.0001
1	1	902	22.8033	0.05175	284	440.61	<.0001
2	1		22.6833	0.05175	284	438.29	<.0001
1	1	904	23.0733	0.05928	300	389.23	<.0001
2	1		22.9933	0.05928	300	387.88	<.0001
1	1	906	23.2533	0.06073	298	382.9	<.0001
2	1		23.0933	0.06073	298	380.26	<.0001
1	1	908	23.3183	0.05707	275	408.59	<.0001
2	1		22.9767	0.05707	275	402.6	<.0001
1	1	910	23.3967	0.08024	250	291.6	<.0001
2	1		22.8333	0.08024	250	284.58	<.0001
1	1	912	23.7817	0.06471	243	367.49	<.0001
2	1		23.12	0.06471	243	357.27	<.0001
1	1	914	24.2	0.08271	267	292.58	<.0001
2	1		23.415	0.08271	267	283.09	<.0001
1	1	916	23.975	0.08333	271	287.7	<.0001
2	1		23.2733	0.08333	271	279.28	<.0001
1	1	918	23.095	0.07213	246	320.2	<.0001
2	1		22.7217	0.07213	246	315.03	<.0001
1	1	920	22.3333	0.07515	249	297.18	<.0001
2	1		22.24	0.07515	249	295.94	<.0001
1	1	922	22.9417	0.05087	278	450.96	<.0001
2	1		22.9683	0.05087	278	451.48	<.0001
1	1	924	23.5817	0.05668	282	416.02	<.0001
2	1		23.7667	0.05668	282	419.28	<.0001
1	1	926	23.355	0.05673	250	411.7	<.0001
2	1		23.678	0.05673	250	417.39	<.0001
1	1	928	22.4083	0.05403	219	414.75	<.0001
2	1		22.8483	0.05403	219	422.9	<.0001
1	1	930	21.4183	0.07357	200	291.13	<.0001
2	1		21.7833	0.07357	200	296.09	<.0001

Table 64: Absolute Delta RCS (dBsqm) Location 1 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.1167	0.09728	241	1.2	0.2316	Tukey-Kramer	1
1	902	2	0.12	0.07319	284	1.64	0.1022	Tukey-Kramer	1
1	904	2	0.08	0.08383	300	0.95	0.3407	Tukey-Kramer	1
1	906	2	0.16	0.08589	298	1.86	0.0635	Tukey-Kramer	1
1	908	2	0.3417	0.08071	275	4.23	<.0001	Tukey-Kramer	0.0629
1	910	2	0.5633	0.1135	250	4.96	<.0001	Tukey-Kramer	0.0029
1	912	2	0.6617	0.09152	243	7.23	<.0001	Tukey-Kramer	<.0001
1	914	2	0.785	0.117	267	6.71	<.0001	Tukey-Kramer	<.0001
1	916	2	0.7017	0.1178	271	5.95	<.0001	Tukey-Kramer	<.0001
1	918	2	0.3733	0.102	246	3.66	0.0003	Tukey-Kramer	0.3524
1	920	2	0.09333	0.1063	249	0.88	0.3807	Tukey-Kramer	1
1	922	2	-0.02667	0.07195	278	-0.37	0.7112	Tukey-Kramer	1
1	924	2	-0.185	0.08016	282	-2.31	0.0217	Tukey-Kramer	0.9998
1	926	2	-0.323	0.08023	250	-4.03	<.0001	Tukey-Kramer	0.1275
1	928	2	-0.44	0.07641	219	-5.76	<.0001	Tukey-Kramer	<.0001
1	930	2	-0.365	0.104	200	-3.51	0.0006	Tukey-Kramer	0.4864

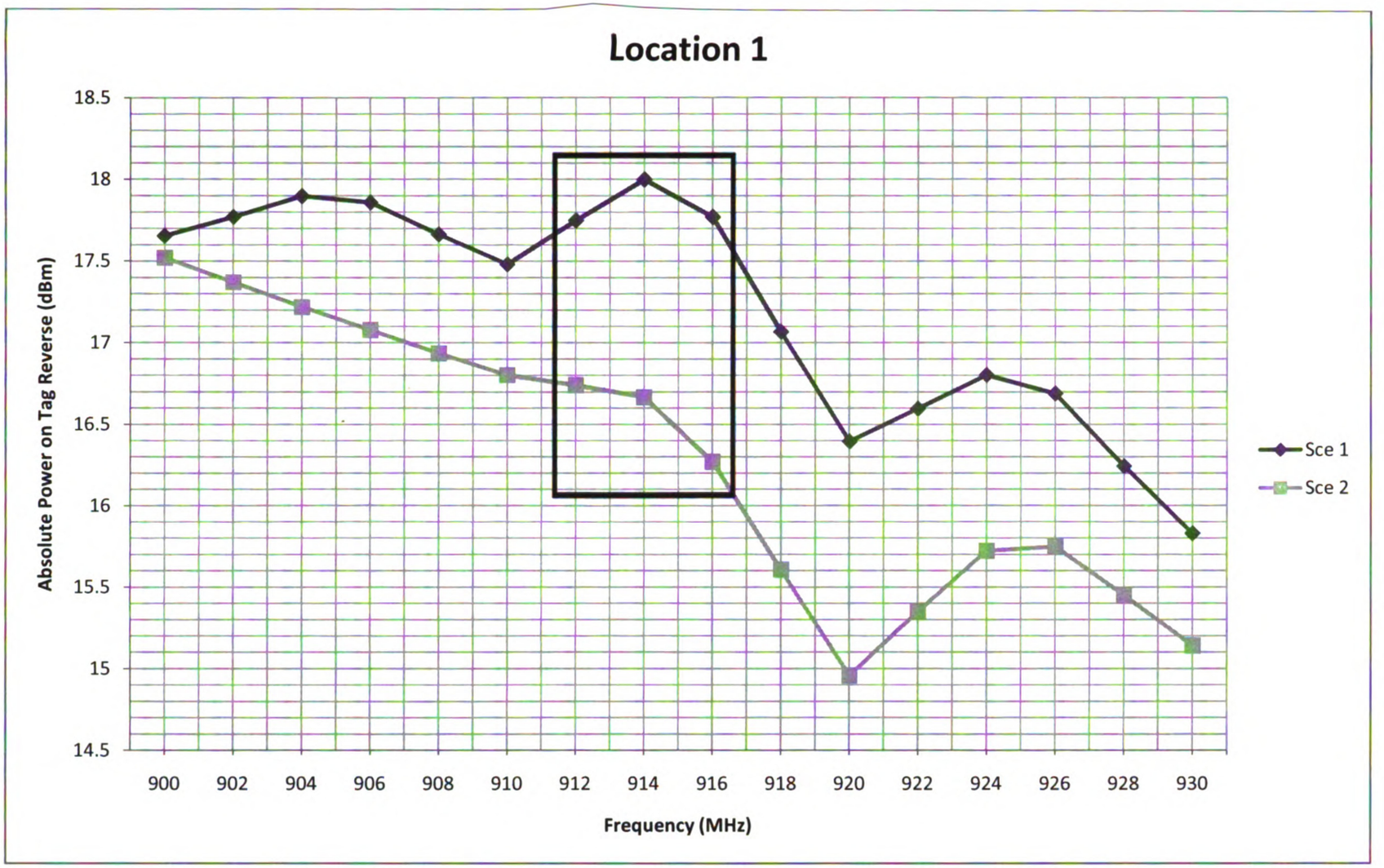

Figure 49: Location 1 - Absolute Power on Tag Reverse (dBm) vs. Frequency (MHz)

Table 65: Absolute Power on Tag Reverse (dBm) Location 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	17.6533	0.1007	226	175.29	<.0001
2	1		17.52	0.1007	226	173.96	<.0001
1	1	902	17.77	0.08459	262	210.08	<.0001
2	1		17.37	0.08459	262	205.35	<.0001
1	1	904	17.8967	0.1024	276	174.74	<.0001
2	1		17.2183	0.1024	276	168.11	<.0001
1	1	906	17.8583	0.1052	274	169.73	<.0001
2	1		17.0783	0.1052	274	162.32	<.0001
1	1	908	17.6633	0.09129	257	193.5	<.0001
2	1		16.935	0.09129	257	185.52	<.0001
1	1	910	17.48	0.1161	247	150.62	<.0001
2	1		16.8017	0.1161	247	144.78	<.0001
1	1	912	17.7483	0.09585	250	185.17	<.0001
2	1		16.74	0.09585	250	174.65	<.0001
1	1	914	17.9983	0.1161	266	155.05	<.0001
2	1		16.6667	0.1161	266	143.58	<.0001
1	1	916	17.77	0.1181	267	150.49	<.0001
2	1		16.2683	0.1181	267	137.77	<.0001
1	1	918	17.0667	0.1069	258	159.72	<.0001
2	1		15.605	0.1069	258	146.05	<.0001
1	1	920	16.395	0.1356	254	120.9	<.0001
2	1		14.9567	0.1356	254	110.29	<.0001
1	1	922	16.5967	0.1028	254	161.46	<.0001
2	1		15.3483	0.1028	254	149.31	<.0001
1	1	924	16.8017	0.09421	258	178.35	<.0001
2	1		15.7217	0.09421	258	166.88	<.0001
1	1	926	16.6883	0.09469	264	176.24	<.0001
2	1		15.7467	0.09469	264	166.29	<.0001
1	1	928	16.2433	0.09708	276	167.32	<.0001
2	1		15.45	0.09708	276	159.15	<.0001
1	1	930	15.8283	0.1285	254	123.16	<.0001
2	1		15.14	0.1285	254	117.8	<.0001

Table 66: Absolute Power on Tag Reverse (dBm) Location 1 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.1333	0.1424	226	0.94	0.3502	Tukey-Kramer	1
1	902	2	0.4	0.1196	262	3.34	0.0009	Tukey-Kramer	0.6412
1	904	2	0.6783	0.1448	276	4.68	<.0001	Tukey-Kramer	0.0104
1	906	2	0.78	0.1488	274	5.24	<.0001	Tukey-Kramer	0.0007
1	908	2	0.7283	0.1291	257	5.64	<.0001	Tukey-Kramer	<.0001
1	910	2	0.6783	0.1641	247	4.13	<.0001	Tukey-Kramer	0.0894
1	912	2	1.0083	0.1356	250	7.44	<.0001	Tukey-Kramer	<.0001
1	914	2	1.3317	0.1642	266	8.11	<.0001	Tukey-Kramer	<.0001
1	916	2	1.5017	0.167	267	8.99	<.0001	Tukey-Kramer	<.0001
1	918	2	1.4617	0.1511	258	9.67	<.0001	Tukey-Kramer	<.0001
1	920	2	1.4383	0.1918	254	7.5	<.0001	Tukey-Kramer	<.0001
1	922	2	1.2483	0.1454	254	8.59	<.0001	Tukey-Kramer	<.0001
1	924	2	1.08	0.1332	258	8.11	<.0001	Tukey-Kramer	<.0001
1	926	2	0.9417	0.1339	264	7.03	<.0001	Tukey-Kramer	<.0001
1	928	2	0.7933	0.1373	276	5.78	<.0001	Tukey-Kramer	<.0001
1	930	2	0.6883	0.1818	254	3.79	0.0002	Tukey-Kramer	0.2568

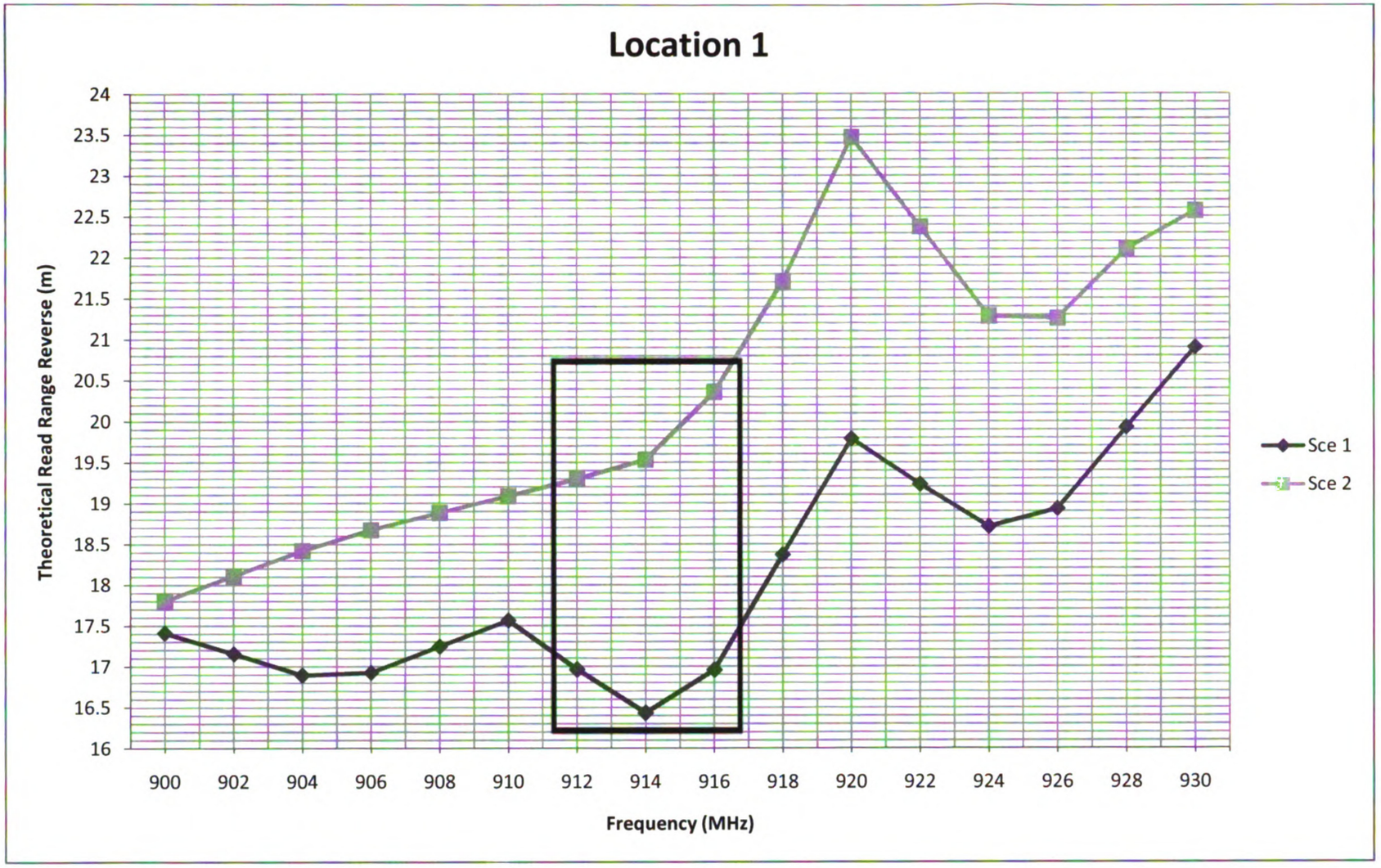

Figure 50: Location 1 - Theoretical Read Range Reverse (m) vs. Frequency (MHz)

Table 67: Theoretical Read Range Reverse (m) Location 1 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	1	900	17.4067	0.2375	227	73.28	<.0001
2	1		17.8017	0.2375	227	74.95	<.0001
1	1	902	17.1533	0.2029	264	84.54	<.0001
2	1		18.11	0.2029	264	89.25	<.0001
1	1	904	16.8933	0.2605	278	64.85	<.0001
2	1		18.4167	0.2605	278	70.7	<.0001
1	1	906	16.925	0.2628	276	64.41	<.0001
2	1		18.6717	0.2628	276	71.06	<.0001
1	1	908	17.2433	0.2238	257	77.05	<.0001
2	1		18.8833	0.2238	257	84.38	<.0001
1	1	910	17.56	0.2846	243	61.7	<.0001
2	1		19.085	0.2846	243	67.06	<.0001
1	1	912	16.96	0.2423	247	70.01	<.0001
2	1		19.2967	0.2423	247	79.65	<.0001
1	1	914	16.4317	0.3164	261	51.93	<.0001
2	1		19.53	0.3164	261	61.72	<.0001
1	1	916	16.955	0.3331	257	50.9	<.0001
2	1		20.3567	0.3331	257	61.12	<.0001
1	1	918	18.3633	0.2761	257	66.51	<.0001
2	1		21.7067	0.2761	257	78.62	<.0001
1	1	920	19.7867	0.3315	275	59.68	<.0001
2	1		23.4667	0.3315	275	70.78	<.0001
1	1	922	19.2267	0.2409	281	79.81	<.0001
2	1		22.3717	0.2409	281	92.86	<.0001
1	1	924	18.7083	0.2227	281	84.02	<.0001
2	1		21.28	0.2227	281	95.56	<.0001
1	1	926	18.9267	0.2202	278	85.95	<.0001
2	1		21.2533	0.2202	278	96.51	<.0001
1	1	928	19.9217	0.2607	275	76.41	<.0001
2	1		22.1	0.2607	275	84.77	<.0001
1	1	930	20.8983	0.3552	246	58.84	<.0001
2	1		22.5633	0.3552	246	63.52	<.0001

Table 68: Theoretical Read Range Reverse (m) Location 1 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-0.395	0.3359	227	-1.18	0.2409	Tukey-Kramer	1
1	902	2	-0.9567	0.2869	264	-3.33	0.001	Tukey-Kramer	0.6503
1	904	2	-1.5233	0.3684	278	-4.13	<.0001	Tukey-Kramer	0.0888
1	906	2	-1.7467	0.3716	276	-4.7	<.0001	Tukey-Kramer	0.0096
1	908	2	-1.64	0.3165	257	-5.18	<.0001	Tukey-Kramer	0.001
1	910	2	-1.525	0.4025	243	-3.79	0.0002	Tukey-Kramer	0.2555
1	912	2	-2.3367	0.3426	247	-6.82	<.0001	Tukey-Kramer	<.0001
1	914	2	-3.0983	0.4475	261	-6.92	<.0001	Tukey-Kramer	<.0001
1	916	2	-3.4017	0.471	257	-7.22	<.0001	Tukey-Kramer	<.0001
1	918	2	-3.3433	0.3905	257	-8.56	<.0001	Tukey-Kramer	<.0001
1	920	2	-3.68	0.4689	275	-7.85	<.0001	Tukey-Kramer	<.0001
1	922	2	-3.145	0.3407	281	-9.23	<.0001	Tukey-Kramer	<.0001
1	924	2	-2.5717	0.3149	281	-8.17	<.0001	Tukey-Kramer	<.0001
1	926	2	-2.3267	0.3114	278	-7.47	<.0001	Tukey-Kramer	<.0001
1	928	2	-2.1783	0.3687	275	-5.91	<.0001	Tukey-Kramer	<.0001
1	930	2	-1.665	0.5023	246	-3.31	0.0011	Tukey-Kramer	0.668

Appendix G: Location 2 – Michigan State University School of Packaging Machine Lab Tables and Figures

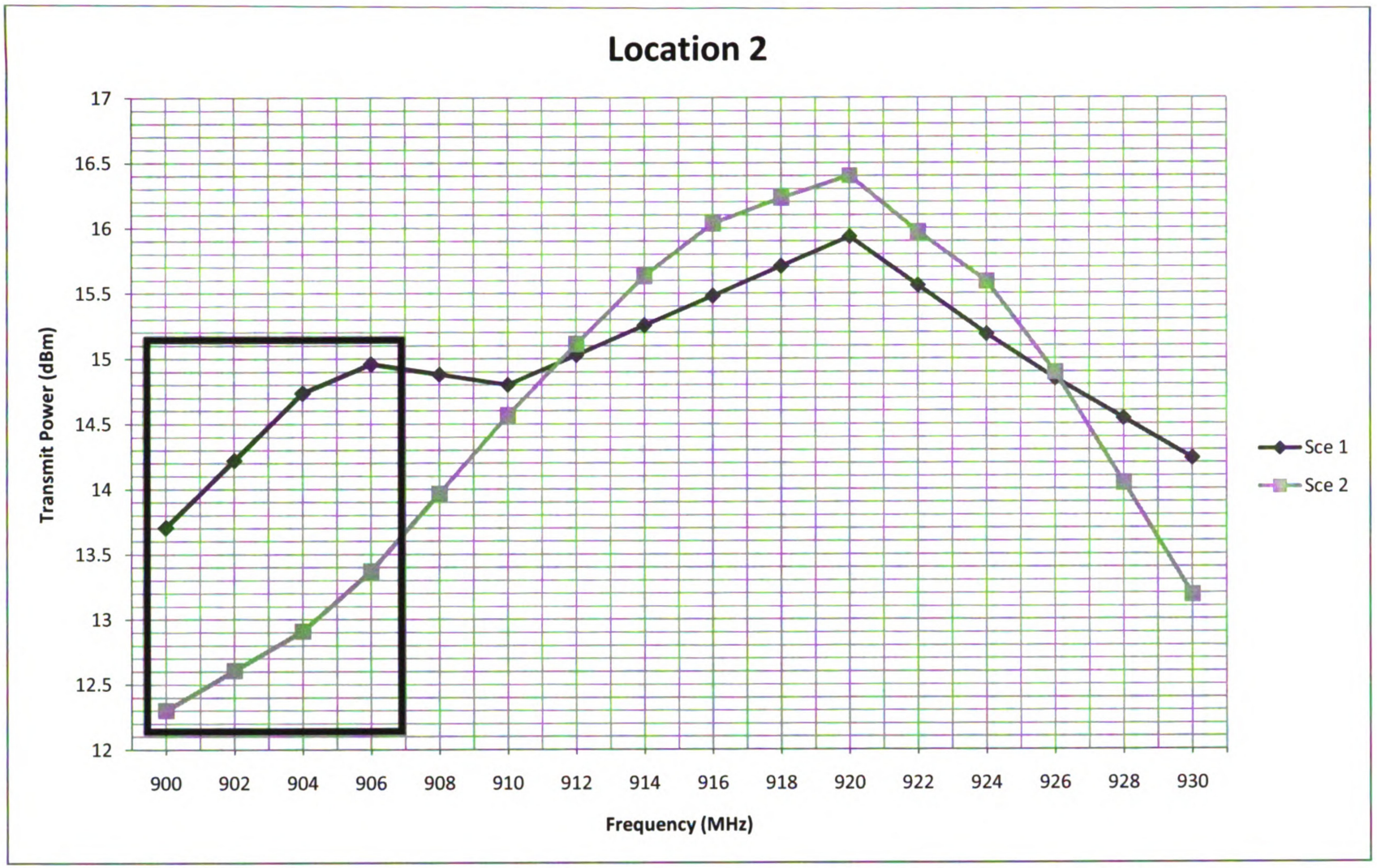

Figure 51: Location 2 - Transmit Power (dBm) vs. Frequency (MHz)

Table 69: Transmit Power (dBm) Location 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	2	900	13.7033	0.07243	215	189.2	<.0001
2	2		12.3	0.07243	215	169.82	<.0001
1	2	902	14.22	0.06779	249	209.77	<.0001
2	2		12.6067	0.06779	249	185.97	<.0001
1	2	904	14.7367	0.08463	261	174.14	<.0001
2	2		12.91	0.08463	261	152.55	<.0001
1	2	906	14.96	0.08354	258	179.08	<.0001
2	2		13.37	0.08354	258	160.04	<.0001
1	2	908	14.88	0.0734	247	202.73	<.0001
2	2		13.9667	0.0734	247	190.28	<.0001
1	2	910	14.8	0.08972	246	164.96	<.0001
2	2		14.5667	0.08972	246	162.35	<.0001
1	2	912	15.0267	0.0711	254	211.34	<.0001
2	2		15.1117	0.0711	254	212.53	<.0001
1	2	914	15.2533	0.08047	266	189.56	<.0001
2	2		15.6333	0.08047	266	194.28	<.0001
1	2	916	15.48	0.08486	273	182.42	<.0001
2	2		16.0333	0.08486	273	188.94	<.0001
1	2	918	15.7067	0.09041	284	173.73	<.0001
2	2		16.23	0.09041	284	179.52	<.0001
1	2	920	15.9333	0.1165	295	136.8	<.0001
2	2		16.4	0.1165	295	140.81	<.0001
1	2	922	15.56	0.09568	299	162.63	<.0001
2	2		15.97	0.09568	299	166.92	<.0001
1	2	924	15.1867	0.09556	295	158.93	<.0001
2	2		15.59	0.09556	295	163.15	<.0001
1	2	926	14.8467	0.09565	285	155.22	<.0001
2	2		14.8933	0.09565	285	155.71	<.0001
1	2	928	14.54	0.103	278	141.12	<.0001
2	2		14.045	0.103	278	136.32	<.0001
1	2	930	14.2333	0.1393	252	102.19	<.0001
2	2		13.1867	0.1393	252	94.68	<.0001

Table 70: Transmit Power (dBm) Location 2 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	1.4033	0.1024	215	13.7	<.0001	Tukey-Kramer	<.0001
1	902	2	1.6133	0.09587	249	16.83	<.0001	Tukey-Kramer	<.0001
1	904	2	1.8267	0.1197	261	15.26	<.0001	Tukey-Kramer	<.0001
1	906	2	1.59	0.1181	258	13.46	<.0001	Tukey-Kramer	<.0001
1	908	2	0.9133	0.1038	247	8.8	<.0001	Tukey-Kramer	<.0001
1	910	2	0.2333	0.1269	246	1.84	0.0671	Tukey-Kramer	1
1	912	2	-0.085	0.1006	254	-0.85	0.3987	Tukey-Kramer	1
1	914	2	-0.38	0.1138	266	-3.34	0.001	Tukey-Kramer	0.6453
1	916	2	-0.5533	0.12	273	-4.61	<.0001	Tukey-Kramer	0.0141
1	918	2	-0.5233	0.1279	284	-4.09	<.0001	Tukey-Kramer	0.1023
1	920	2	-0.4667	0.1647	295	-2.83	0.0049	Tukey-Kramer	0.9618
1	922	2	-0.41	0.1353	299	-3.03	0.0027	Tukey-Kramer	0.8834
1	924	2	-0.4033	0.1351	295	-2.98	0.0031	Tukey-Kramer	0.9069
1	926	2	-0.04667	0.1353	285	-0.34	0.7304	Tukey-Kramer	1
1	928	2	0.495	0.1457	278	3.4	0.0008	Tukey-Kramer	0.591
1	930	2	1.0467	0.197	252	5.31	<.0001	Tukey-Kramer	0.0005

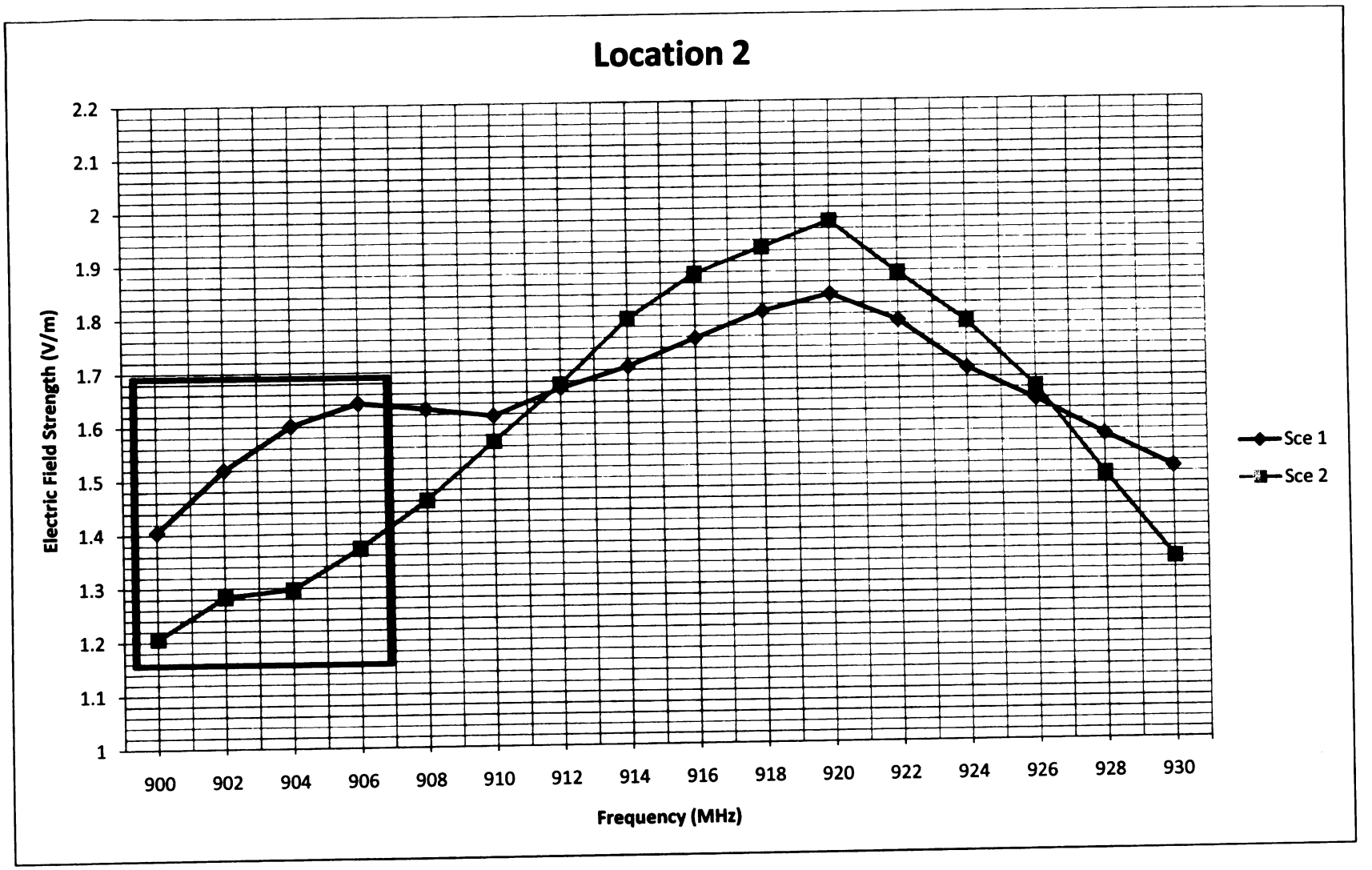

Figure 52: Location 2 - Electric Field Strength (V/m) vs. Frequency (MHz)

Table 71: Electric Field Strength (V/m) Location 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	2	900	1.405	0.01532	165	91.7	<.0001
2	2		1.206	0.01532	165	78.71	<.0001
1	2	902	1.52	0.02764	184	55	<.0001
2	2		1.2837	0.02764	184	46.44	<.0001
1	2	904	1.6013	0.01965	224	81.51	<.0001
2	2		1.2967	0.01965	224	66	<.0001
1	2	906	1.642	0.0163	247	100.71	<.0001
2	2		1.3717	0.0163	247	84.13	<.0001
1	2	908	1.63	0.01309	249	124.54	<.0001
2	2		1.4603	0.01309	249	111.58	<.0001
1	2	910	1.616	0.01521	256	106.23	<.0001
2	2		1.5683	0.01521	256	103.1	<.0001
1	2	912	1.6663	0.01333	273	125.01	<.0001
2	2		1.674	0.01333	273	125.59	<.0001
1	2	914	1.7053	0.01541	290	110.69	<.0001
2	2		1.7943	0.01541	290	116.47	<.0001
1	2	916	1.7567	0.0168	301	104.59	<.0001
2	2		1.8777	0.0168	301	111.79	<.0001
1	2	918	1.806	0.01951	316	92.57	<.0001
2	2		1.9257	0.01951	316	98.7	<.0001
1	2	920	1.8367	0.02568	332	71.53	<.0001
2	2		1.9737	0.02568	332	76.86	<.0001
1	2	922	1.7863	0.02235	336	79.94	<.0001
2	2		1.8757	0.02235	336	83.94	<.0001
1	2	924	1.6967	0.02353	328	72.11	<.0001
2	2		1.784	0.02353	328	75.82	<.0001
1	2	926	1.637	0.02341	311	69.92	<.0001
2	2		1.6613	0.02341	311	70.96	<.0001
1	2	928	1.571	0.02256	295	69.64	<.0001
2	2		1.4973	0.02256	295	66.38	<.0001
1	2	930	1.509	0.03025	258	49.89	<.0001
2	2		1.34	0.03025	258	44.3	<.0001

Table 72: Electric Field Strength (V/m) Location 2 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.199	0.02167	165	9.18	<.0001	Tukey-Kramer	<.0001
1	902	2	0.2363	0.03909	184	6.05	<.0001	Tukey-Kramer	<.0001
1	904	2	0.3047	0.02779	224	10.97	<.0001	Tukey-Kramer	<.0001
1	906	2	0.2703	0.02306	247	11.72	<.0001	Tukey-Kramer	<.0001
1	908	2	0.1697	0.01851	249	9.17	<.0001	Tukey-Kramer	<.0001
1	910	2	0.04767	0.02151	256	2.22	0.0276	Tukey-Kramer	1
1	912	2	-0.00767	0.01885	273	-0.41	0.6845	Tukey-Kramer	1
1	914	2	-0.089	0.02179	290	-4.08	<.0001	Tukey-Kramer	0.1053
1	916	2	-0.121	0.02375	301	-5.09	<.0001	Tukey-Kramer	0.0015
1	918	2	-0.1197	0.02759	316	-4.34	<.0001	Tukey-Kramer	0.0428
1	920	2	-0.137	0.03631	332	-3.77	0.0002	Tukey-Kramer	0.2669
1	922	2	-0.08933	0.0316	336	-2.83	0.005	Tukey-Kramer	0.9633
1	924	2	-0.08733	0.03328	328	-2.62	0.0091	Tukey-Kramer	0.9927
1	926	2	-0.02433	0.03311	311	-0.73	0.4629	Tukey-Kramer	1
1	928	2	0.07367	0.0319	295	2.31	0.0216	Tukey-Kramer	0.9998
1	930	2	0.169	0.04278	258	3.95	0.0001	Tukey-Kramer	0.1613

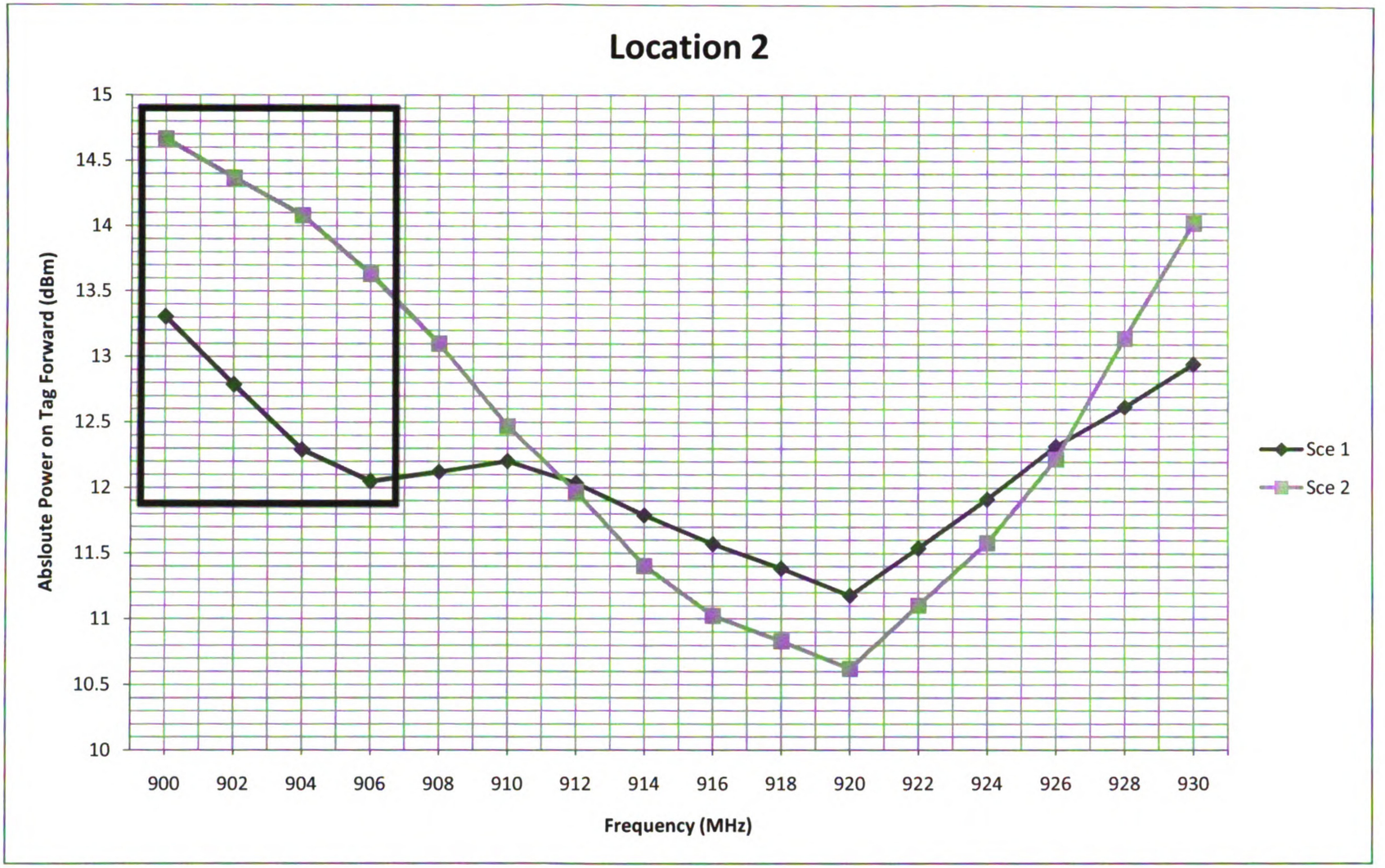

Figure 53: Location 2 - Absolute Power on Tag Forward (dBm) vs. Frequency (MHz)

Table 73: Absolute Power on Tag Forward (dBm) Location 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	2	900	13.3033	0.07129	220	186.62	<.0001
2	2		14.6667	0.07129	220	205.74	<.0001
1	2	902	12.7867	0.06457	254	198.03	<.0001
2	2		14.3667	0.06457	254	222.5	<.0001
1	2	904	12.29	0.08087	266	151.97	<.0001
2	2		14.08	0.08087	266	174.1	<.0001
1	2	906	12.0467	0.083	264	145.14	<.0001
2	2		13.63	0.083	264	164.22	<.0001
1	2	908	12.12	0.07273	252	166.63	<.0001
2	2		13.1	0.07273	252	180.11	<.0001
1	2	910	12.2	0.08883	247	137.34	<.0001
2	2		12.47	0.08883	247	140.37	<.0001
1	2	912	12.0333	0.07585	251	158.64	<.0001
2	2		11.97	0.07585	251	157.81	<.0001
1	2	914	11.79	0.08056	262	146.35	<.0001
2	2		11.4033	0.08056	262	141.55	<.0001
1	2	916	11.57	0.08209	270	140.95	<.0001
2	2		11.0233	0.08209	270	134.29	<.0001
1	2	918	11.3833	0.08946	281	127.25	<.0001
2	2		10.83	0.08946	281	121.06	<.0001
1	2	920	11.1767	0.1137	293	98.33	<.0001
2	2		10.62	0.1137	293	93.44	<.0001
1	2	922	11.54	0.1001	297	115.34	<.0001
2	2		11.1033	0.1001	297	110.98	<.0001
1	2	924	11.9133	0.0994	294	119.85	<.0001
2	2		11.58	0.0994	294	116.5	<.0001
1	2	926	12.32	0.09691	284	127.13	<.0001
2	2		12.22	0.09691	284	126.1	<.0001
1	2	928	12.62	0.1056	277	119.51	<.0001
2	2		13.1467	0.1056	277	124.49	<.0001
1	2	930	12.95	0.1403	249	92.33	<.0001
2	2		14.0267	0.1403	249	100.01	<.0001

Table 74: Absolute Power on Tag Forward (dBm) Location 2 Comparisons

sce	fre	sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-1.3633	0.1008	220	-13.52	<.0001	Tukey-Kramer	<.0001
1	902	2	-1.58	0.09131	254	-17.3	<.0001	Tukey-Kramer	<.0001
1	904	2	-1.79	0.1144	266	-15.65	<.0001	Tukey-Kramer	<.0001
1	906	2	-1.5833	0.1174	264	-13.49	<.0001	Tukey-Kramer	<.0001
1	908	2	-0.98	0.1029	252	-9.53	<.0001	Tukey-Kramer	<.0001
1	910	2	-0.27	0.1256	247	-2.15	0.0326	Tukey-Kramer	1
1	912	2	0.06333	0.1073	251	0.59	0.5555	Tukey-Kramer	1
1	914	2	0.3867	0.1139	262	3.39	0.0008	Tukey-Kramer	0.5941
1	916	2	0.5467	0.1161	270	4.71	<.0001	Tukey-Kramer	0.0092
1	918	2	0.5533	0.1265	281	4.37	<.0001	Tukey-Kramer	0.0371
1	920	2	0.5567	0.1607	293	3.46	0.0006	Tukey-Kramer	0.5285
1	922	2	0.4367	0.1415	297	3.09	0.0022	Tukey-Kramer	0.8499
1	924	2	0.3333	0.1406	294	2.37	0.0184	Tukey-Kramer	0.9996
1	926	2	0.1	0.137	284	0.73	0.4662	Tukey-Kramer	1
1	928	2	-0.5267	0.1493	277	-3.53	0.0005	Tukey-Kramer	0.4692
1	930	2	-1.0767	0.1984	249	-5.43	<.0001	Tukey-Kramer	0.0003

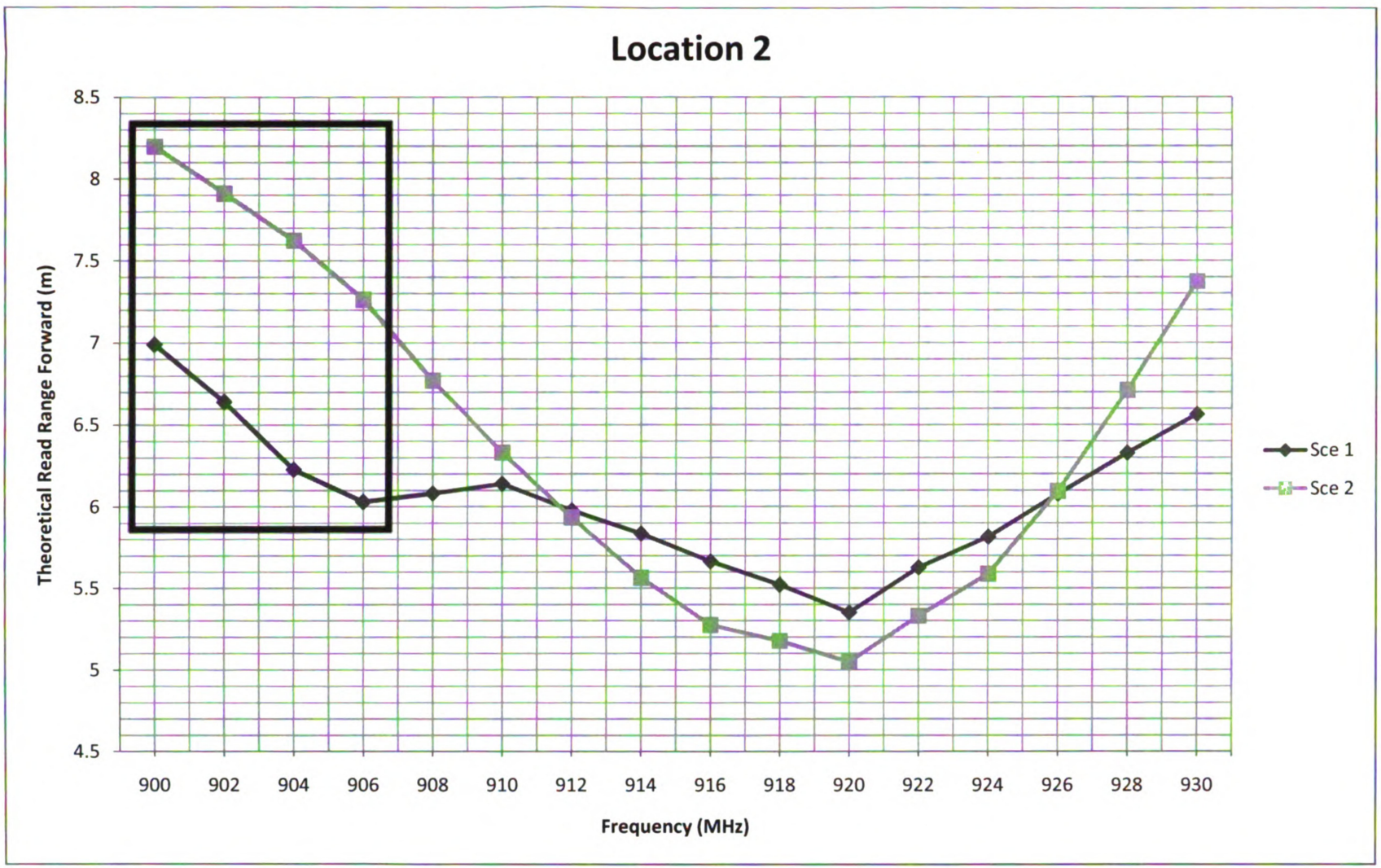

Figure 54: Location 2 - Theoretical Read Range Forward (m) vs. Frequency (MHz)

Table 75: Theoretical Read Range Forward (m) Location 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	2	900	6.99	0.05727	230	122.05	<.0001
2	2	900	8.1967	0.05727	230	143.12	<.0001
1	2	902	6.64	0.04414	256	150.42	<.0001
2	2	902	7.91	0.04414	256	179.19	<.0001
1	2	904	6.2267	0.04841	266	128.62	<.0001
2	2	904	7.6233	0.04841	266	157.47	<.0001
1	2	906	6.03	0.04618	271	130.58	<.0001
2	2	906	7.2633	0.04618	271	157.28	<.0001
1	2	908	6.08	0.04687	269	129.73	<.0001
2	2	908	6.77	0.04687	269	144.45	<.0001
1	2	910	6.14	0.05849	272	104.97	<.0001
2	2	910	6.33	0.05849	272	108.22	<.0001
1	2	912	5.9767	0.04547	274	131.45	<.0001
2	2	912	5.9333	0.04547	274	130.5	<.0001
1	2	914	5.8333	0.0438	284	133.17	<.0001
2	2	914	5.5633	0.0438	284	127	<.0001
1	2	916	5.6633	0.0447	290	126.7	<.0001
2	2	916	5.2733	0.0447	290	117.97	<.0001
1	2	918	5.52	0.03992	283	138.28	<.0001
2	2	918	5.1767	0.03992	283	129.68	<.0001
1	2	920	5.35	0.04942	274	108.25	<.0001
2	2	920	5.0467	0.04942	274	102.11	<.0001
1	2	922	5.6267	0.03724	260	151.1	<.0001
2	2	922	5.33	0.03724	260	143.13	<.0001
1	2	924	5.8133	0.03611	252	160.97	<.0001
2	2	924	5.5867	0.03611	252	154.7	<.0001
1	2	926	6.0767	0.03879	248	156.66	<.0001
2	2	926	6.0933	0.03879	248	157.08	<.0001
1	2	928	6.3267	0.04469	252	141.58	<.0001
2	2	928	6.71	0.04469	252	150.16	<.0001
1	2	930	6.5633	0.05986	234	109.65	<.0001
2	2	930	7.3733	0.05986	234	123.18	<.0001

Table 76: Theoretical Read Range Forward (m) Location 2 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-1.2067	0.08099	230	-14.9	<.0001	Tukey-Kramer	<.0001
1	902	2	-1.27	0.06243	256	-20.34	<.0001	Tukey-Kramer	<.0001
1	904	2	-1.3967	0.06846	266	-20.4	<.0001	Tukey-Kramer	<.0001
1	906	2	-1.2333	0.06531	271	-18.88	<.0001	Tukey-Kramer	<.0001
1	908	2	-0.69	0.06628	269	-10.41	<.0001	Tukey-Kramer	<.0001
1	910	2	-0.19	0.08272	272	-2.3	0.0224	Tukey-Kramer	0.9999
1	912	2	0.04333	0.0643	274	0.67	0.5009	Tukey-Kramer	1
1	914	2	0.27	0.06195	284	4.36	<.0001	Tukey-Kramer	0.0393
1	916	2	0.39	0.06322	290	6.17	<.0001	Tukey-Kramer	<.0001
1	918	2	0.3433	0.05645	283	6.08	<.0001	Tukey-Kramer	<.0001
1	920	2	0.3033	0.06989	274	4.34	<.0001	Tukey-Kramer	0.0422
1	922	2	0.2967	0.05266	260	5.63	<.0001	Tukey-Kramer	<.0001
1	924	2	0.2267	0.05107	252	4.44	<.0001	Tukey-Kramer	0.0288
1	926	2	-0.01667	0.05486	248	-0.3	0.7615	Tukey-Kramer	1
1	928	2	-0.3833	0.0632	252	-6.07	<.0001	Tukey-Kramer	<.0001
1	930	2	-0.81	0.08465	234	-9.57	<.0001	Tukey-Kramer	<.0001

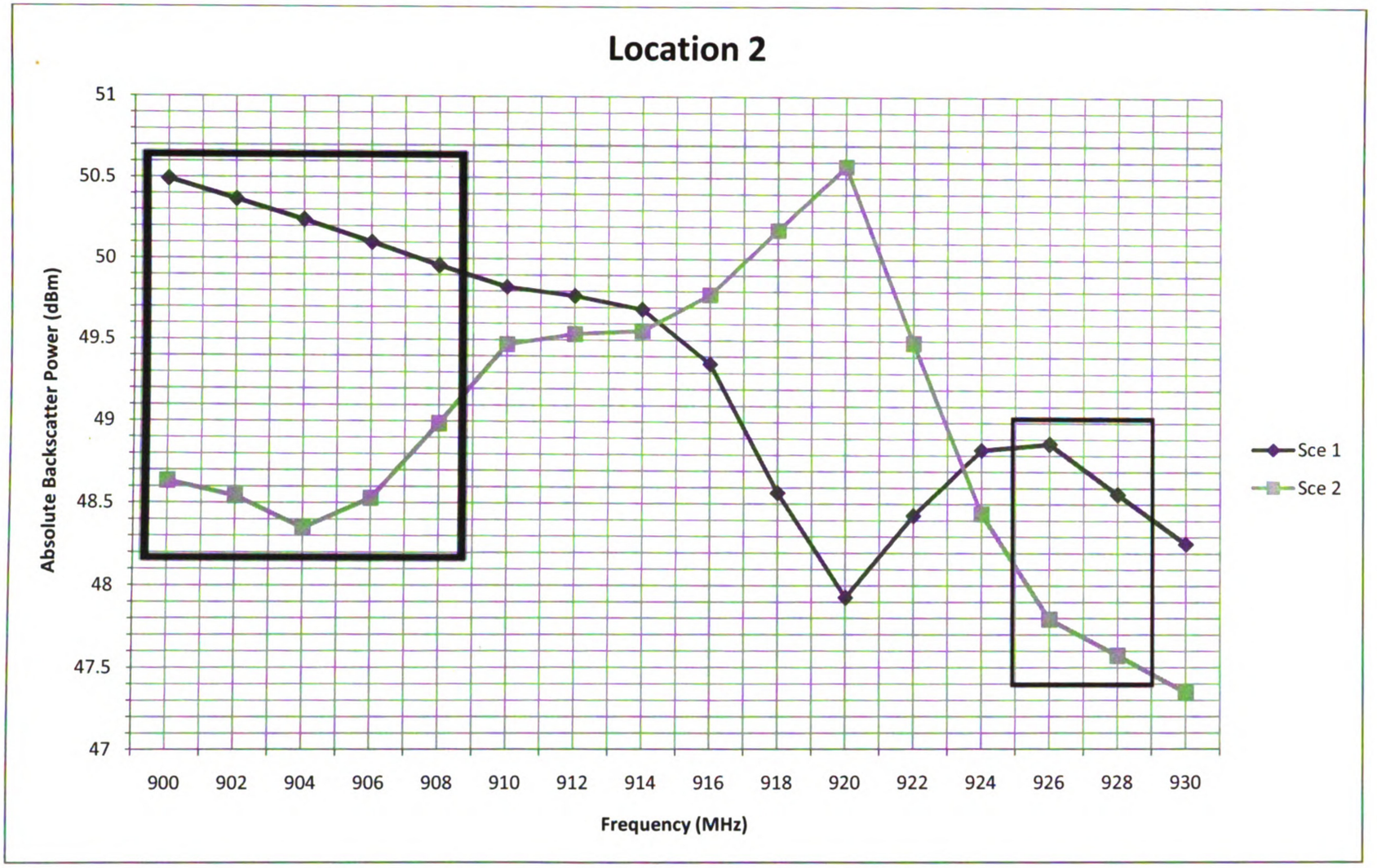

Figure 55: Location 2 - Absolute Backscatter Power (dBm) vs. Frequency (MHz)

Table 77: Absolute Backscatter Power (dBm) Location 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	2	900	50.49	0.1075	215	469.51	<.0001
2	2		48.635	0.1075	215	452.26	<.0001
1	2	902	50.365	0.08893	248	566.32	<.0001
2	2		48.5417	0.08893	248	545.82	<.0001
1	2	904	50.2383	0.1069	263	470.1	<.0001
2	2		48.3467	0.1069	263	452.4	<.0001
1	2	906	50.1	0.108	263	464.01	<.0001
2	2		48.53	0.108	263	449.47	<.0001
1	2	908	49.9567	0.09665	248	516.87	<.0001
2	2		48.985	0.09665	248	506.81	<.0001
1	2	910	49.825	0.1201	237	414.72	<.0001
2	2		49.4717	0.1201	237	411.78	<.0001
1	2	912	49.77	0.09783	242	508.72	<.0001
2	2		49.5367	0.09783	242	506.33	<.0001
1	2	914	49.6883	0.1226	254	405.43	<.0001
2	2		49.5567	0.1226	254	404.36	<.0001
1	2	916	49.355	0.129	251	382.5	<.0001
2	2		49.78	0.129	251	385.8	<.0001
1	2	918	48.5683	0.1203	246	403.79	<.0001
2	2		50.18	0.1203	246	417.19	<.0001
1	2	920	47.9267	0.1382	258	346.68	<.0001
2	2		50.5733	0.1382	258	365.83	<.0001
1	2	922	48.4283	0.09647	271	502.02	<.0001
2	2		49.4867	0.09647	271	513	<.0001
1	2	924	48.8317	0.0857	282	569.79	<.0001
2	2		48.4417	0.0857	282	565.24	<.0001
1	2	926	48.87	0.08378	287	583.31	<.0001
2	2		47.7947	0.08378	287	570.48	<.0001
1	2	928	48.5617	0.09099	293	533.71	<.0001
2	2		47.5733	0.09099	293	522.84	<.0001
1	2	930	48.2583	0.1227	266	393.32	<.0001
2	2		47.345	0.1227	266	385.88	<.0001

Table 78: Absolute Backscatter Power (dBm) Location 2 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	1.855	0.1521	215	12.2	<.0001	Tukey-Kramer	<.0001
1	902	2	1.8233	0.1258	248	14.5	<.0001	Tukey-Kramer	<.0001
1	904	2	1.8917	0.1511	263	12.52	<.0001	Tukey-Kramer	<.0001
1	906	2	1.57	0.1527	263	10.28	<.0001	Tukey-Kramer	<.0001
1	908	2	0.9717	0.1367	248	7.11	<.0001	Tukey-Kramer	<.0001
1	910	2	0.3533	0.1699	237	2.08	0.0386	Tukey-Kramer	1
1	912	2	0.2333	0.1384	242	1.69	0.093	Tukey-Kramer	1
1	914	2	0.1317	0.1733	254	0.76	0.4482	Tukey-Kramer	1
1	916	2	-0.425	0.1825	251	-2.33	0.0207	Tukey-Kramer	0.9998
1	918	2	-1.6117	0.1701	246	-9.47	<.0001	Tukey-Kramer	<.0001
1	920	2	-2.6467	0.1955	258	-13.54	<.0001	Tukey-Kramer	<.0001
1	922	2	-1.0583	0.1364	271	-7.76	<.0001	Tukey-Kramer	<.0001
1	924	2	0.39	0.1212	282	3.22	0.0014	Tukey-Kramer	0.7525
1	926	2	1.0753	0.1185	287	9.08	<.0001	Tukey-Kramer	<.0001
1	928	2	0.9883	0.1287	293	7.68	<.0001	Tukey-Kramer	<.0001
1	930	2	0.9133	0.1735	266	5.26	<.0001	Tukey-Kramer	0.0006

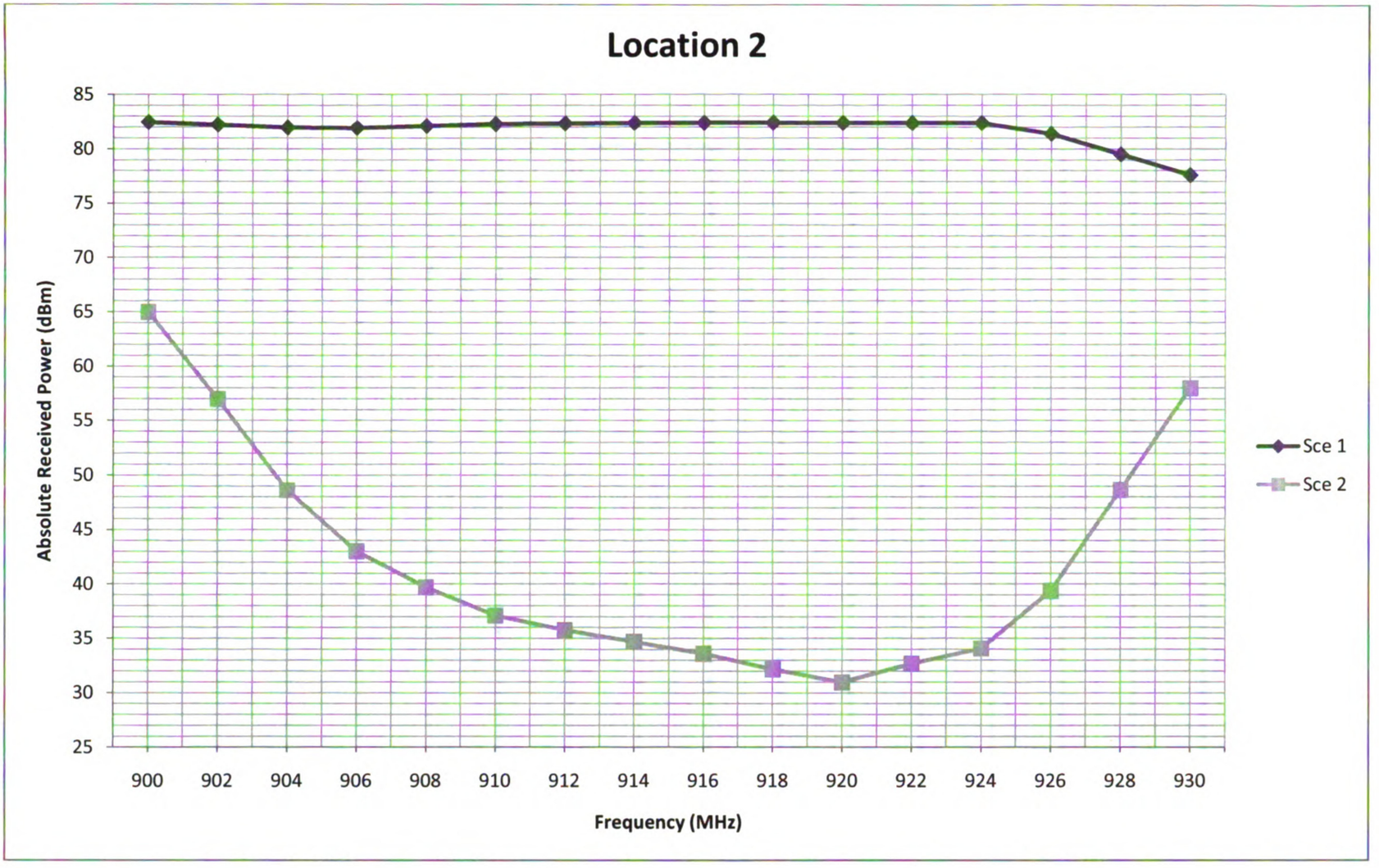

Figure 56: Location 2 - Absolute Received Power (dBm) vs. Frequency (MHz)

Table 79: Absolute Received Power (dBm) Location 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	2	900	82.44	1.3084	2157	63.01	<.0001
2	2		64.9667	1.3084	2157	49.66	<.0001
1	2	902	82.1967	1.3084	2157	62.82	<.0001
2	2		56.9667	1.3084	2157	43.54	<.0001
1	2	904	81.9333	1.3084	2157	62.62	<.0001
2	2		48.6	1.3084	2157	37.15	<.0001
1	2	906	81.8967	1.3084	2157	62.6	<.0001
2	2		43	1.3084	2157	32.87	<.0001
1	2	908	82.09	1.3084	2157	62.74	<.0001
2	2		39.7	1.3084	2157	30.34	<.0001
1	2	910	82.26	1.3084	2157	62.87	<.0001
2	2		37.1	1.3084	2157	28.36	<.0001
1	2	912	82.3233	1.3084	2157	62.92	<.0001
2	2		35.7667	1.3084	2157	27.34	<.0001
1	2	914	82.37	1.3084	2157	62.96	<.0001
2	2		34.7	1.3084	2157	26.52	<.0001
1	2	916	82.3867	1.3084	2157	62.97	<.0001
2	2		33.6	1.3084	2157	25.68	<.0001
1	2	918	82.38	1.3084	2157	62.96	<.0001
2	2		32.1667	1.3084	2157	24.59	<.0001
1	2	920	82.36	1.3084	2157	62.95	<.0001
2	2		30.9667	1.3084	2157	23.67	<.0001
1	2	922	82.37	1.3084	2157	62.96	<.0001
2	2		32.6667	1.3084	2157	24.97	<.0001
1	2	924	82.3633	1.3084	2157	62.95	<.0001
2	2		34.0667	1.3084	2157	26.04	<.0001
1	2	926	81.3667	1.3084	2157	62.19	<.0001
2	2		39.3667	1.3084	2157	30.09	<.0001
1	2	928	79.4733	1.3084	2157	60.74	<.0001
2	2		48.6333	1.3084	2157	37.17	<.0001
1	2	930	77.5633	1.3084	2157	59.28	<.0001
2	2		57.9667	1.3084	2157	44.3	<.0001

Table 80: Absolute Received Power (dBm) Location 2 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	17.4733	1.8503	2157	9.44	<.0001	Tukey-Kramer	<.0001
1	902	2	25.23	1.8503	2157	13.64	<.0001	Tukey-Kramer	<.0001
1	904	2	33.3333	1.8503	2157	18.02	<.0001	Tukey-Kramer	<.0001
1	906	2	38.8967	1.8503	2157	21.02	<.0001	Tukey-Kramer	<.0001
1	908	2	42.39	1.8503	2157	22.91	<.0001	Tukey-Kramer	<.0001
1	910	2	45.16	1.8503	2157	24.41	<.0001	Tukey-Kramer	<.0001
1	912	2	46.5567	1.8503	2157	25.16	<.0001	Tukey-Kramer	<.0001
1	914	2	47.67	1.8503	2157	25.76	<.0001	Tukey-Kramer	<.0001
1	916	2	48.7867	1.8503	2157	26.37	<.0001	Tukey-Kramer	<.0001
1	918	2	50.2133	1.8503	2157	27.14	<.0001	Tukey-Kramer	<.0001
1	920	2	51.3933	1.8503	2157	27.78	<.0001	Tukey-Kramer	<.0001
1	922	2	49.7033	1.8503	2157	26.86	<.0001	Tukey-Kramer	<.0001
1	924	2	48.2967	1.8503	2157	26.1	<.0001	Tukey-Kramer	<.0001
1	926	2	42	1.8503	2157	22.7	<.0001	Tukey-Kramer	<.0001
1	928	2	30.84	1.8503	2157	16.67	<.0001	Tukey-Kramer	<.0001
1	930	2	19.5967	1.8503	2157	10.59	<.0001	Tukey-Kramer	<.0001

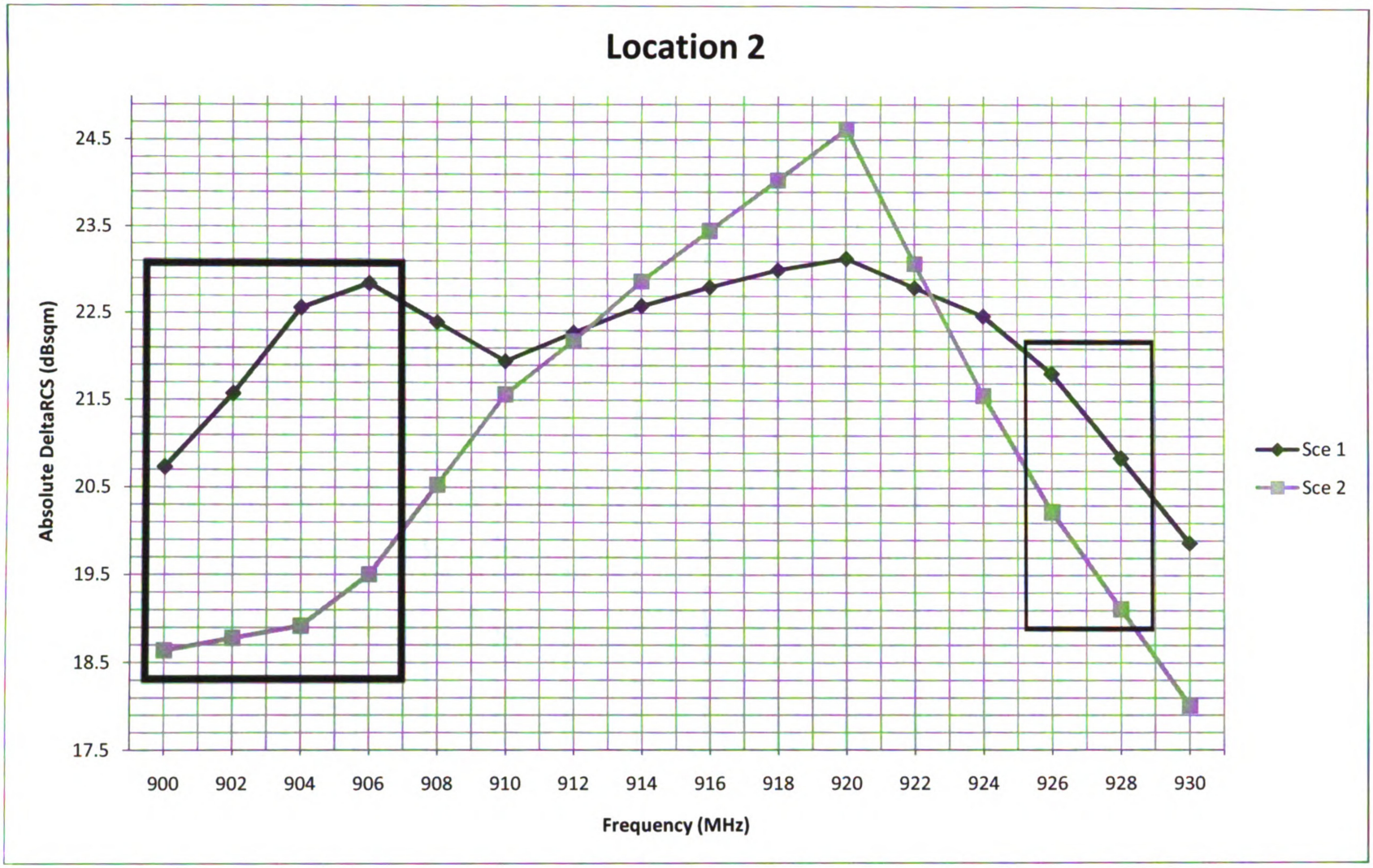

Figure 57: Location 2 - Absolute Delta RCS (dBsqm) vs. Frequency (MHz)

Table 81: Absolute Delta RCS (dBsqm) Location 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	2	900	20.73	0.06879	241	301.35	<.0001
2	2		18.6367	0.06879	241	270.92	<.0001
1	2	902	21.5733	0.05175	284	416.84	<.0001
2	2		18.78	0.05175	284	362.87	<.0001
1	2	904	22.56	0.05928	300	380.57	<.0001
2	2		18.92	0.05928	300	319.16	<.0001
1	2	906	22.8433	0.06073	298	376.14	<.0001
2	2		19.5033	0.06073	298	321.15	<.0001
1	2	908	22.3967	0.05707	275	392.44	<.0001
2	2		20.53	0.05707	275	359.73	<.0001
1	2	910	21.9467	0.08024	250	273.53	<.0001
2	2		21.5667	0.08024	250	268.79	<.0001
1	2	912	22.2767	0.06471	243	344.23	<.0001
2	2		22.1833	0.06471	243	342.79	<.0001
1	2	914	22.5833	0.08271	267	273.04	<.0001
2	2		22.87	0.08271	267	276.5	<.0001
1	2	916	22.8033	0.08333	271	273.64	<.0001
2	2		23.4533	0.08333	271	281.44	<.0001
1	2	918	23	0.07213	246	318.88	<.0001
2	2		24.0333	0.07213	246	333.21	<.0001
1	2	920	23.13	0.07515	249	307.78	<.0001
2	2		24.6167	0.07515	249	327.56	<.0001
1	2	922	22.8	0.05087	278	448.17	<.0001
2	2		23.0767	0.05087	278	453.61	<.0001
1	2	924	22.4733	0.05668	282	396.46	<.0001
2	2		21.56	0.05668	282	380.35	<.0001
1	2	926	21.8133	0.05673	250	384.52	<.0001
2	2		20.2267	0.05673	250	356.55	<.0001
1	2	928	20.8467	0.05403	219	385.85	<.0001
2	2		19.1167	0.05403	219	353.83	<.0001
1	2	930	19.8733	0.07357	200	270.13	<.0001
2	2		18.0133	0.07357	200	244.84	<.0001

Table 82: Absolute Delta RCS (dBsqm) Location 2 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	2.0933	0.09728	241	21.52	<.0001	Tukey-Kramer	<.0001
1	902	2	2.7933	0.07319	284	38.16	<.0001	Tukey-Kramer	<.0001
1	904	2	3.64	0.08383	300	43.42	<.0001	Tukey-Kramer	<.0001
1	906	2	3.34	0.08589	298	38.89	<.0001	Tukey-Kramer	<.0001
1	908	2	1.8667	0.08071	275	23.13	<.0001	Tukey-Kramer	<.0001
1	910	2	0.38	0.1135	250	3.35	0.0009	Tukey-Kramer	0.6364
1	912	2	0.09333	0.09152	243	1.02	0.3088	Tukey-Kramer	1
1	914	2	-0.2867	0.117	267	-2.45	0.0149	Tukey-Kramer	0.9988
1	916	2	-0.65	0.1178	271	-5.52	<.0001	Tukey-Kramer	0.0002
1	918	2	-1.0333	0.102	246	-10.13	<.0001	Tukey-Kramer	<.0001
1	920	2	-1.4867	0.1063	249	-13.99	<.0001	Tukey-Kramer	<.0001
1	922	2	-0.2767	0.07195	278	-3.85	0.0001	Tukey-Kramer	0.2191
1	924	2	0.9133	0.08016	282	11.39	<.0001	Tukey-Kramer	<.0001
1	926	2	1.5867	0.08023	250	19.78	<.0001	Tukey-Kramer	<.0001
1	928	2	1.73	0.07641	219	22.64	<.0001	Tukey-Kramer	<.0001
1	930	2	1.86	0.104	200	17.88	<.0001	Tukey-Kramer	<.0001

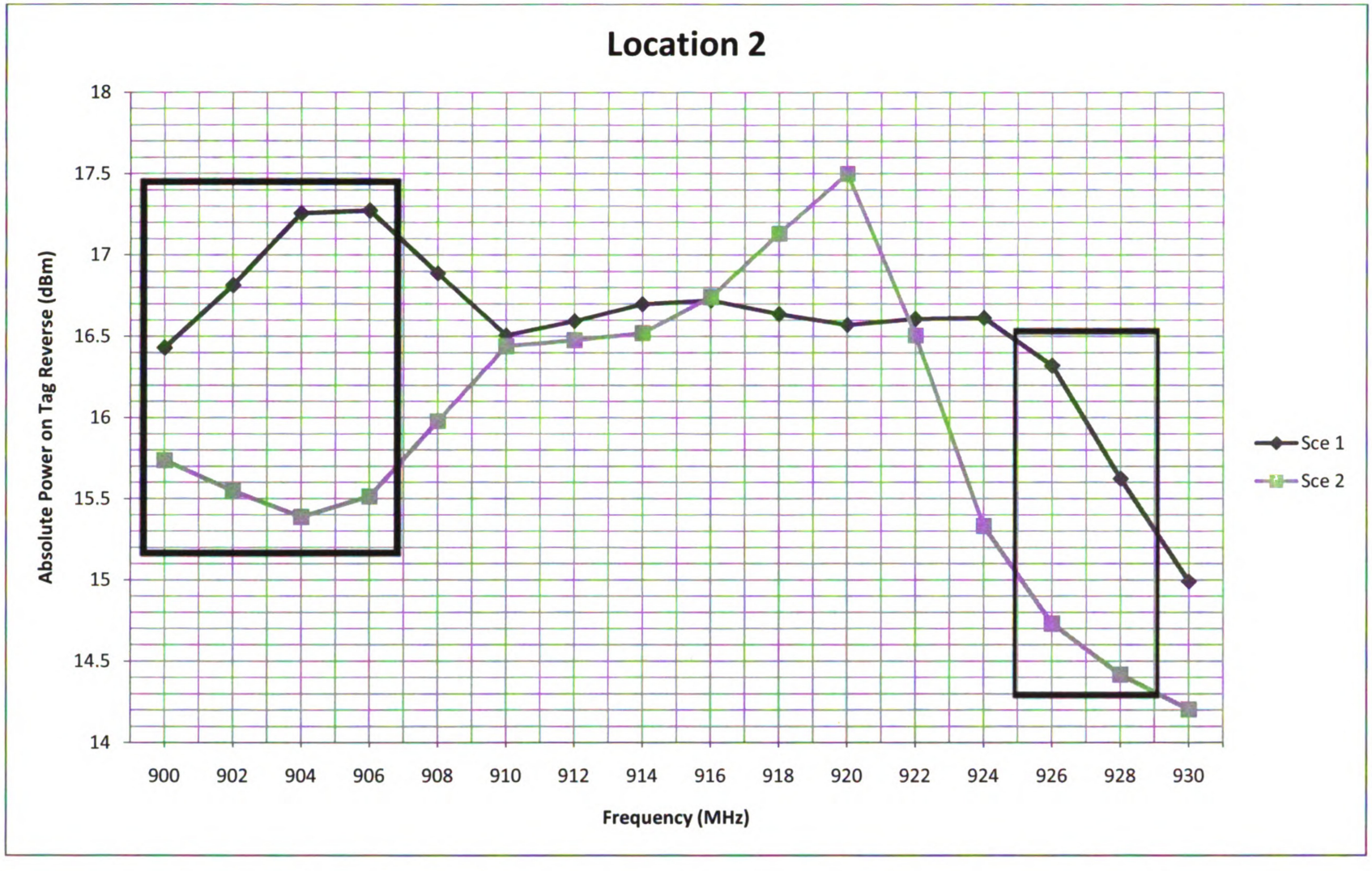

Figure 58: Location 2 - Absolute Power on Tag Reverse (dBm) vs. Frequency (MHz)

Table 83: Absolute Power on Tag Reverse (dBm) Location 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	2	900	16.43	0.1007	226	163.14	<.0001
2	2		15.7367	0.1007	226	156.26	<.0001
1	2	902	16.8133	0.08459	262	198.77	<.0001
2	2		15.5467	0.08459	262	183.79	<.0001
1	2	904	17.2567	0.1024	276	168.49	<.0001
2	2		15.3867	0.1024	276	150.23	<.0001
1	2	906	17.2733	0.1052	274	164.17	<.0001
2	2		15.5133	0.1052	274	147.45	<.0001
1	2	908	16.8867	0.09129	257	184.99	<.0001
2	2		15.9767	0.09129	257	175.02	<.0001
1	2	910	16.5067	0.1161	247	142.24	<.0001
2	2		16.44	0.1161	247	141.66	<.0001
1	2	912	16.5933	0.09585	250	173.12	<.0001
2	2		16.4767	0.09585	250	171.9	<.0001
1	2	914	16.6967	0.1161	266	143.84	<.0001
2	2		16.52	0.1161	266	142.32	<.0001
1	2	916	16.72	0.1181	267	141.6	<.0001
2	2		16.74	0.1181	267	141.77	<.0001
1	2	918	16.6367	0.1069	258	155.7	<.0001
2	2		17.13	0.1069	258	160.32	<.0001
1	2	920	16.57	0.1356	254	122.19	<.0001
2	2		17.5	0.1356	254	129.05	<.0001
1	2	922	16.6067	0.1028	254	161.55	<.0001
2	2		16.5067	0.1028	254	160.58	<.0001
1	2	924	16.6133	0.09421	258	176.35	<.0001
2	2		15.33	0.09421	258	162.72	<.0001
1	2	926	16.32	0.09469	264	172.35	<.0001
2	2		14.73	0.09469	264	155.56	<.0001
1	2	928	15.6233	0.09708	276	160.93	<.0001
2	2		14.4167	0.09708	276	148.5	<.0001
1	2	930	14.99	0.1285	254	116.63	<.0001
2	2		14.2033	0.1285	254	110.51	<.0001

Table 84: Absolute Power on Tag Reverse (dBm) Location 2 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.6933	0.1424	226	4.87	<.0001	Tukey-Kramer	0.0045
1	902	2	1.2667	0.1196	262	10.59	<.0001	Tukey-Kramer	<.0001
1	904	2	1.87	0.1448	276	12.91	<.0001	Tukey-Kramer	<.0001
1	906	2	1.76	0.1488	274	11.83	<.0001	Tukey-Kramer	<.0001
1	908	2	0.91	0.1291	257	7.05	<.0001	Tukey-Kramer	<.0001
1	910	2	0.06667	0.1641	247	0.41	0.6849	Tukey-Kramer	1
1	912	2	0.1167	0.1356	250	0.86	0.3902	Tukey-Kramer	1
1	914	2	0.1767	0.1642	266	1.08	0.2828	Tukey-Kramer	1
1	916	2	-0.02	0.167	267	-0.12	0.9048	Tukey-Kramer	1
1	918	2	-0.4933	0.1511	258	-3.26	0.0012	Tukey-Kramer	0.7126
1	920	2	-0.93	0.1918	254	-4.85	<.0001	Tukey-Kramer	0.0049
1	922	2	0.1	0.1454	254	0.69	0.4922	Tukey-Kramer	1
1	924	2	1.2833	0.1332	258	9.63	<.0001	Tukey-Kramer	<.0001
1	926	2	1.59	0.1339	264	11.87	<.0001	Tukey-Kramer	<.0001
1	928	2	1.2067	0.1373	276	8.79	<.0001	Tukey-Kramer	<.0001
1	930	2	0.7867	0.1818	254	4.33	<.0001	Tukey-Kramer	0.0442

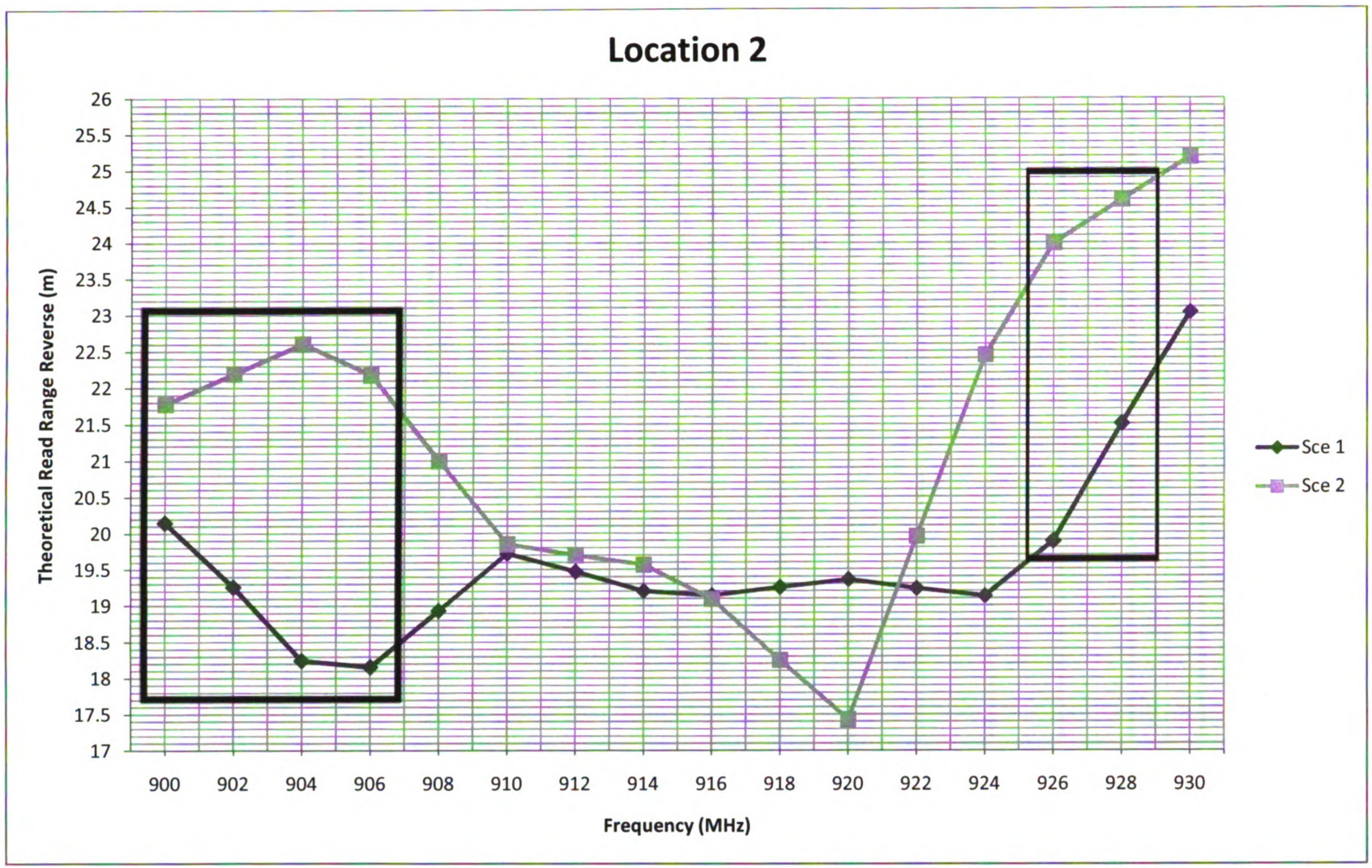

Figure 59: Theoretical Read Range Reverse (m) vs. Frequency (MHz)

Table 85:



Table 85: Theoretical Read Range Reverse (m) Location 2 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	2	900	20.1467	0.2375	227	84.82	<.0001
2	2		21.7767	0.2375	227	91.68	<.0001
1	2	902	19.2567	0.2029	264	94.91	<.0001
2	2		22.1933	0.2029	264	109.38	<.0001
1	2	904	18.2433	0.2605	278	70.03	<.0001
2	2		22.6033	0.2605	278	86.77	<.0001
1	2	906	18.1533	0.2628	276	69.09	<.0001
2	2		22.1733	0.2628	276	84.39	<.0001
1	2	908	18.93	0.2238	257	84.59	<.0001
2	2		20.9933	0.2238	257	93.81	<.0001
1	2	910	19.72	0.2846	243	69.29	<.0001
2	2		19.85	0.2846	243	69.75	<.0001
1	2	912	19.4667	0.2423	247	80.35	<.0001
2	2		19.6933	0.2423	247	81.29	<.0001
1	2	914	19.2	0.3164	261	60.68	<.0001
2	2		19.5633	0.3164	261	61.83	<.0001
1	2	916	19.1367	0.3331	257	57.45	<.0001
2	2		19.0833	0.3331	257	57.29	<.0001
1	2	918	19.2467	0.2761	257	69.71	<.0001
2	2		18.2467	0.2761	257	66.08	<.0001
1	2	920	19.3533	0.3315	275	58.37	<.0001
2	2		17.4267	0.3315	275	52.56	<.0001
1	2	922	19.23	0.2409	281	79.82	<.0001
2	2		19.9467	0.2409	281	82.79	<.0001
1	2	924	19.1267	0.2227	281	85.89	<.0001
2	2		22.44	0.2227	281	100.77	<.0001
1	2	926	19.88	0.2202	278	90.27	<.0001
2	2		23.9867	0.2202	278	108.92	<.0001
1	2	928	21.4967	0.2607	275	82.45	<.0001
2	2		24.59	0.2607	275	94.32	<.0001
1	2	930	23.0267	0.3552	246	64.83	<.0001
2	2		25.18	0.3552	246	70.89	<.0001

Table 86: Theoretical Read Range Reverse (m) Location 2 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-1.63	0.3359	227	-4.85	<.0001	Tukey-Kramer	0.0048
1	902	2	-2.9367	0.2869	264	-10.23	<.0001	Tukey-Kramer	<.0001
1	904	2	-4.36	0.3684	278	-11.83	<.0001	Tukey-Kramer	<.0001
1	906	2	-4.02	0.3716	276	-10.82	<.0001	Tukey-Kramer	<.0001
1	908	2	-2.0633	0.3165	257	-6.52	<.0001	Tukey-Kramer	<.0001
1	910	2	-0.13	0.4025	243	-0.32	0.747	Tukey-Kramer	1
1	912	2	-0.2267	0.3426	247	-0.66	0.5089	Tukey-Kramer	1
1	914	2	-0.3633	0.4475	261	-0.81	0.4176	Tukey-Kramer	1
1	916	2	0.05333	0.471	257	0.11	0.9099	Tukey-Kramer	1
1	918	2	1	0.3905	257	2.56	0.011	Tukey-Kramer	0.9961
1	920	2	1.9267	0.4689	275	4.11	<.0001	Tukey-Kramer	0.097
1	922	2	-0.7167	0.3407	281	-2.1	0.0363	Tukey-Kramer	1
1	924	2	-3.3133	0.3149	281	-10.52	<.0001	Tukey-Kramer	<.0001
1	926	2	-4.1067	0.3114	278	-13.19	<.0001	Tukey-Kramer	<.0001
1	928	2	-3.0933	0.3687	275	-8.39	<.0001	Tukey-Kramer	<.0001
1	930	2	-2.1533	0.5023	246	-4.29	<.0001	Tukey-Kramer	0.0517

Appendix H: Location 3 – Michigan State University Engineering Building Basement Tables and Figures

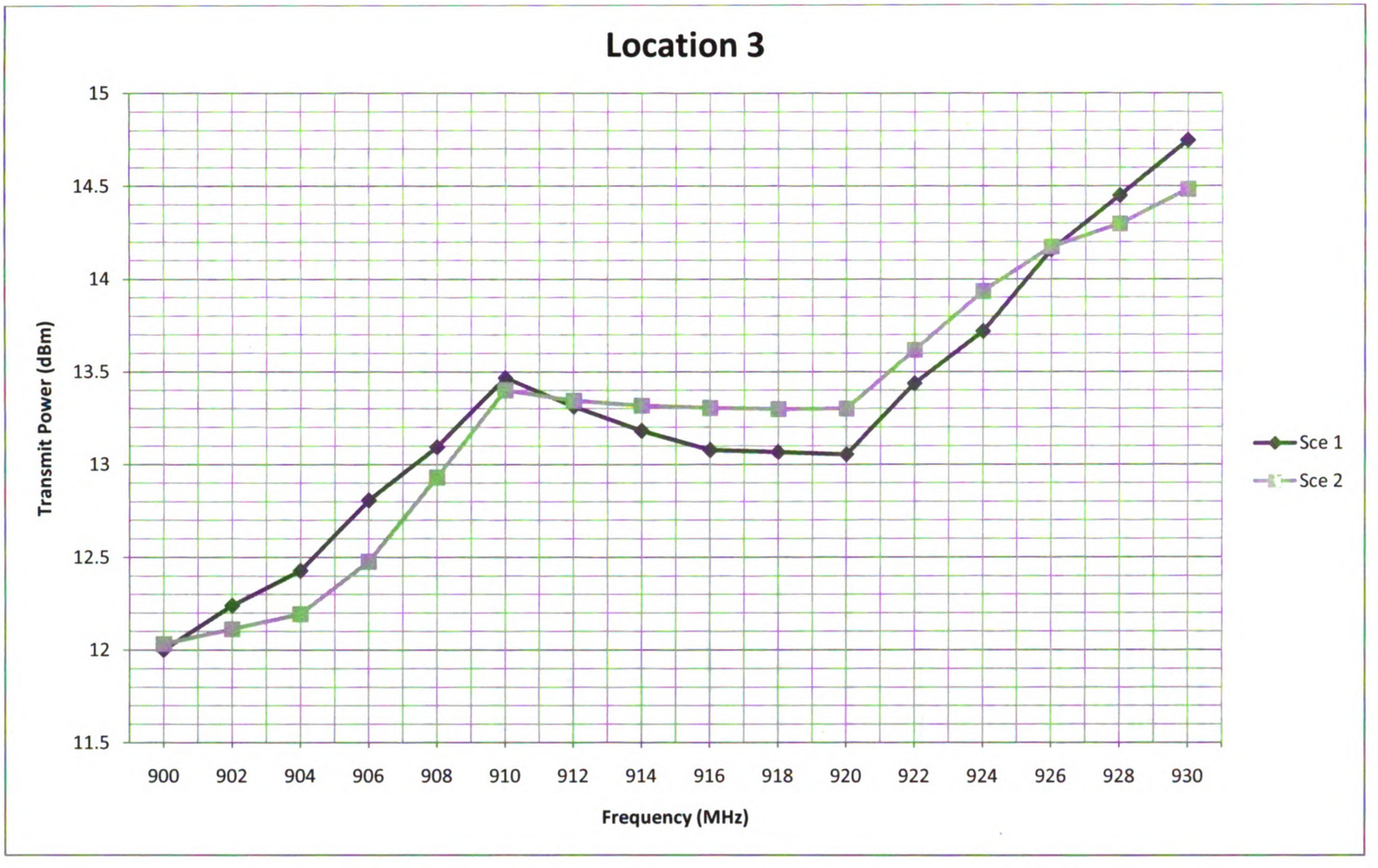

Figure 60: Location 3 - Transmit Power (dBm) vs. Frequency (MHz)

Table 87: Transmit Power (dBm) Location 3 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	3	900	12	0.07243	215	165.68	<.0001
2	3		12.0333	0.07243	215	166.14	<.0001
1	3	902	12.24	0.06779	249	180.56	<.0001
2	3		12.1133	0.06779	249	178.7	<.0001
1	3	904	12.4267	0.08463	261	146.84	<.0001
2	3		12.1933	0.08463	261	144.08	<.0001
1	3	906	12.8067	0.08354	258	153.3	<.0001
2	3		12.4767	0.08354	258	149.35	<.0001
1	3	908	13.0933	0.0734	247	178.38	<.0001
2	3		12.93	0.0734	247	176.16	<.0001
1	3	910	13.4667	0.08972	246	150.09	<.0001
2	3		13.4	0.08972	246	149.35	<.0001
1	3	912	13.31	0.0711	254	187.2	<.0001
2	3		13.3433	0.0711	254	187.66	<.0001
1	3	914	13.18	0.08047	266	163.8	<.0001
2	3		13.3167	0.08047	266	165.49	<.0001
1	3	916	13.0767	0.08486	273	154.1	<.0001
2	3		13.3033	0.08486	273	156.77	<.0001
1	3	918	13.0667	0.09041	284	144.53	<.0001
2	3		13.2967	0.09041	284	147.08	<.0001
1	3	920	13.0533	0.1165	295	112.08	<.0001
2	3		13.3	0.1165	295	114.19	<.0001
1	3	922	13.4367	0.09568	299	140.44	<.0001
2	3		13.6167	0.09568	299	142.32	<.0001
1	3	924	13.7167	0.09556	295	143.54	<.0001
2	3		13.9333	0.09556	295	145.81	<.0001
1	3	926	14.1567	0.09565	285	148	<.0001
2	3		14.1733	0.09565	285	148.18	<.0001
1	3	928	14.45	0.103	278	140.25	<.0001
2	3		14.2967	0.103	278	138.76	<.0001
1	3	930	14.7467	0.1393	252	105.88	<.0001
2	3		14.4833	0.1393	252	103.99	<.0001

Table 88: Transmit Power (dBm) Location 3 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-0.03333	0.1024	215	-0.33	0.7452	Tukey-Kramer	1
1	902	2	0.1267	0.09587	249	1.32	0.1876	Tukey-Kramer	1
1	904	2	0.2333	0.1197	261	1.95	0.0523	Tukey-Kramer	1
1	906	2	0.33	0.1181	258	2.79	0.0056	Tukey-Kramer	0.971
1	908	2	0.1633	0.1038	247	1.57	0.1169	Tukey-Kramer	1
1	910	2	0.06667	0.1269	246	0.53	0.5998	Tukey-Kramer	1
1	912	2	-0.03333	0.1006	254	-0.33	0.7405	Tukey-Kramer	1
1	914	2	-0.1367	0.1138	266	-1.2	0.2308	Tukey-Kramer	1
1	916	2	-0.2267	0.12	273	-1.89	0.06	Tukey-Kramer	1
1	918	2	-0.23	0.1279	284	-1.8	0.0731	Tukey-Kramer	1
1	920	2	-0.2467	0.1647	295	-1.5	0.1353	Tukey-Kramer	1
1	922	2	-0.18	0.1353	299	-1.33	0.1844	Tukey-Kramer	1
1	924	2	-0.2167	0.1351	295	-1.6	0.1099	Tukey-Kramer	1
1	926	2	-0.01667	0.1353	285	-0.12	0.902	Tukey-Kramer	1
1	928	2	0.1533	0.1457	278	1.05	0.2936	Tukey-Kramer	1
1	930	2	0.2633	0.197	252	1.34	0.1824	Tukey-Kramer	1

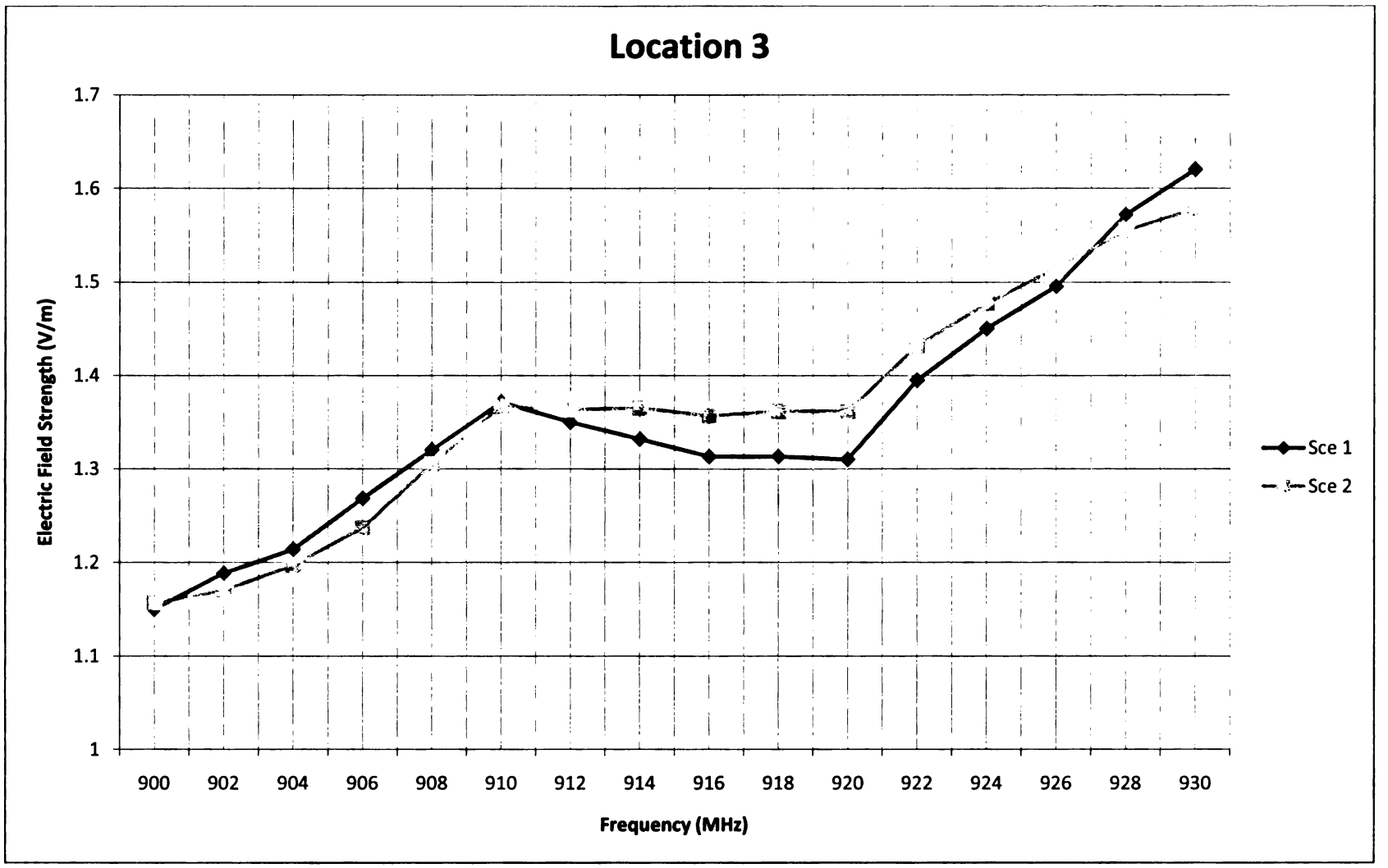

Figure 61: Location 3 - Electric Field Strength (V/m) vs. Frequency (MHz)

Table 89: Electric Field Strength (V/m) Location 3 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	3	900	1.15	0.01532	165	75.06	<.0001
2	3		1.1567	0.01532	165	75.49	<.0001
1	3	902	1.1883	0.02764	184	43	<.0001
2	3		1.17	0.02764	184	42.33	<.0001
1	3	904	1.2137	0.01965	224	61.77	<.0001
2	3		1.1967	0.01965	224	60.91	<.0001
1	3	906	1.2683	0.0163	247	77.8	<.0001
2	3		1.2367	0.0163	247	75.85	<.0001
1	3	908	1.32	0.01309	249	100.85	<.0001
2	3		1.305	0.01309	249	99.71	<.0001
1	3	910	1.371	0.01521	256	90.13	<.0001
2	3		1.3667	0.01521	256	89.84	<.0001
1	3	912	1.35	0.01333	273	101.28	<.0001
2	3		1.3633	0.01333	273	102.28	<.0001
1	3	914	1.3317	0.01541	290	86.44	<.0001
2	3		1.365	0.01541	290	88.6	<.0001
1	3	916	1.3133	0.0168	301	78.19	<.0001
2	3		1.3567	0.0168	301	80.77	<.0001
1	3	918	1.3133	0.01951	316	67.32	<.0001
2	3		1.3617	0.01951	316	69.79	<.0001
1	3	920	1.31	0.02568	332	51.02	<.0001
2	3		1.3617	0.02568	332	53.03	<.0001
1	3	922	1.3947	0.02235	336	62.41	<.0001
2	3		1.4317	0.02235	336	64.07	<.0001
1	3	924	1.45	0.02353	328	61.62	<.0001
2	3		1.4767	0.02353	328	62.76	<.0001
1	3	926	1.4953	0.02341	311	63.87	<.0001
2	3		1.515	0.02341	311	64.71	<.0001
1	3	928	1.572	0.02256	295	69.69	<.0001
2	3		1.555	0.02256	295	68.94	<.0001
1	3	930	1.6203	0.03025	258	53.57	<.0001
2	3		1.5783	0.03025	258	52.18	<.0001

Table 90: Electric Field Strength (V/m) Location 3 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-0.00667	0.02167	165	-0.31	0.7587	Tukey-Kramer	1
1	902	2	0.01833	0.03909	184	0.47	0.6396	Tukey-Kramer	1
1	904	2	0.017	0.02779	224	0.61	0.5413	Tukey-Kramer	1
1	906	2	0.03167	0.02306	247	1.37	0.1709	Tukey-Kramer	1
1	908	2	0.015	0.01851	249	0.81	0.4185	Tukey-Kramer	1
1	910	2	0.004333	0.02151	256	0.2	0.8405	Tukey-Kramer	1
1	912	2	-0.01333	0.01885	273	-0.71	0.48	Tukey-Kramer	1
1	914	2	-0.03333	0.02179	290	-1.53	0.1271	Tukey-Kramer	1
1	916	2	-0.04333	0.02375	301	-1.82	0.0691	Tukey-Kramer	1
1	918	2	-0.04833	0.02759	316	-1.75	0.0808	Tukey-Kramer	1
1	920	2	-0.05167	0.03631	332	-1.42	0.1558	Tukey-Kramer	1
1	922	2	-0.037	0.0316	336	-1.17	0.2425	Tukey-Kramer	1
1	924	2	-0.02667	0.03328	328	-0.8	0.4235	Tukey-Kramer	1
1	926	2	-0.01967	0.03311	311	-0.59	0.5529	Tukey-Kramer	1
1	928	2	0.017	0.0319	295	0.53	0.5945	Tukey-Kramer	1
1	930	2	0.042	0.04278	258	0.98	0.3271	Tukey-Kramer	1

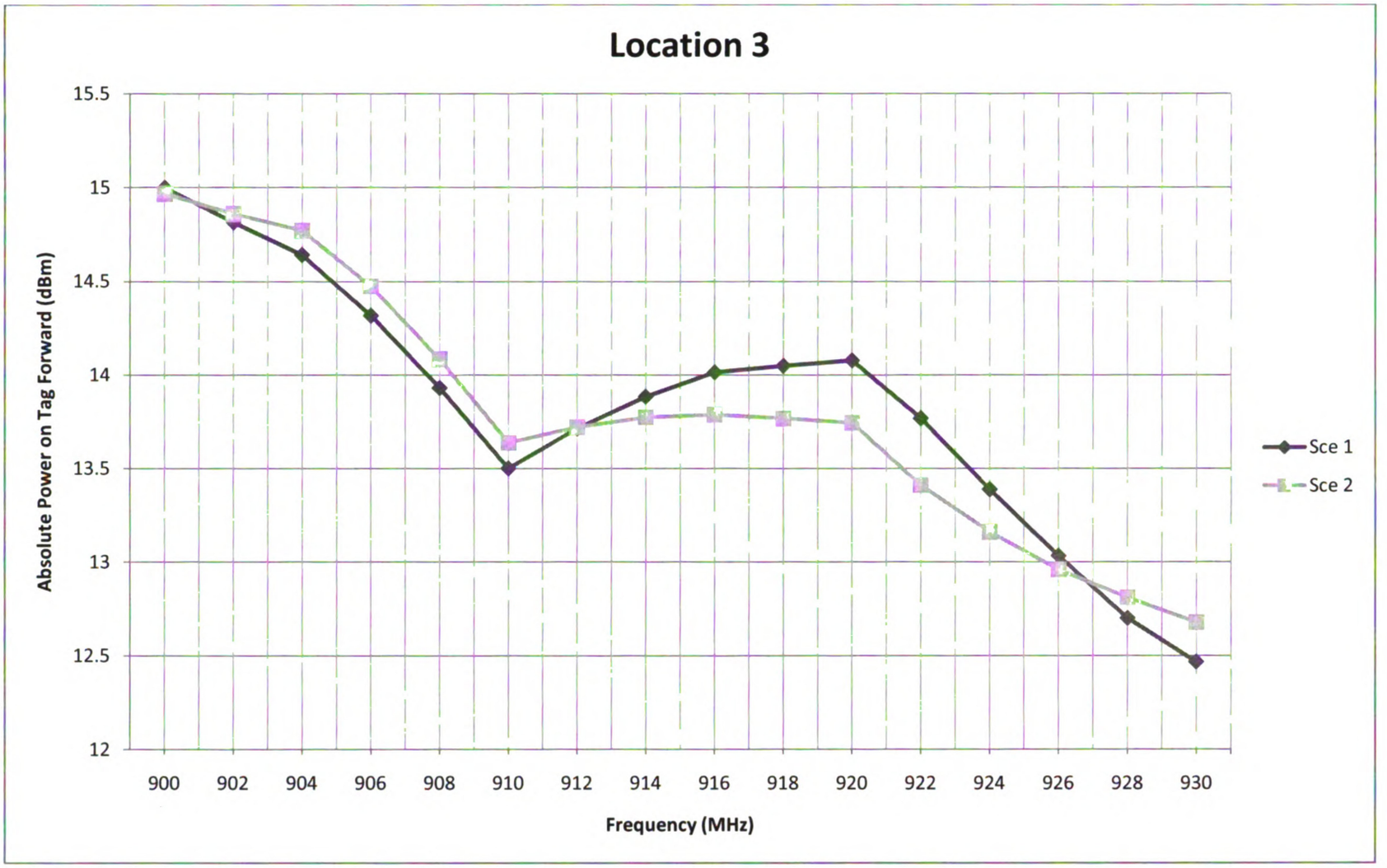

Figure 62: Location 3 - Absolute Power on Tag Forward (dBm) vs. Frequency (MHz)

Table 91: Absolute Power on Tag Forward (dBm) Location 3 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	3	900	15	0.07129	220	210.42	<.0001
2	3		14.9667	0.07129	220	209.95	<.0001
1	3	902	14.8133	0.06457	254	229.42	<.0001
2	3		14.86	0.06457	254	230.14	<.0001
1	3	904	14.64	0.08087	266	181.03	<.0001
2	3		14.77	0.08087	266	182.63	<.0001
1	3	906	14.3167	0.083	264	172.49	<.0001
2	3		14.4733	0.083	264	174.38	<.0001
1	3	908	13.93	0.07273	252	191.52	<.0001
2	3		14.0833	0.07273	252	193.63	<.0001
1	3	910	13.5	0.08883	247	151.97	<.0001
2	3		13.6367	0.08883	247	153.51	<.0001
1	3	912	13.7133	0.07585	251	180.79	<.0001
2	3		13.72	0.07585	251	180.88	<.0001
1	3	914	13.8833	0.08056	262	172.34	<.0001
2	3		13.7733	0.08056	262	170.97	<.0001
1	3	916	14.0133	0.08209	270	170.71	<.0001
2	3		13.7867	0.08209	270	167.95	<.0001
1	3	918	14.0467	0.08946	281	157.02	<.0001
2	3		13.7667	0.08946	281	153.89	<.0001
1	3	920	14.0767	0.1137	293	123.85	<.0001
2	3		13.7433	0.1137	293	120.92	<.0001
1	3	922	13.7667	0.1001	297	137.6	<.0001
2	3		13.41	0.1001	297	134.03	<.0001
1	3	924	13.3867	0.0994	294	134.67	<.0001
2	3		13.16	0.0994	294	132.39	<.0001
1	3	926	13.0333	0.09691	284	134.49	<.0001
2	3		12.96	0.09691	284	133.74	<.0001
1	3	928	12.7	0.1056	277	120.26	<.0001
2	3		12.81	0.1056	277	121.3	<.0001
1	3	930	12.4667	0.1403	249	88.88	<.0001
2	3		12.6767	0.1403	249	90.38	<.0001

Table 92: Absolute Power on Tag Forward (dBm) Location 3 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.03333	0.1008	220	0.33	0.7412	Tukey-Kramer	1
1	902	2	-0.04667	0.09131	254	-0.51	0.6098	Tukey-Kramer	1
1	904	2	-0.13	0.1144	266	-1.14	0.2567	Tukey-Kramer	1
1	906	2	-0.1567	0.1174	264	-1.33	0.1831	Tukey-Kramer	1
1	908	2	-0.1533	0.1029	252	-1.49	0.1373	Tukey-Kramer	1
1	910	2	-0.1367	0.1256	247	-1.09	0.2777	Tukey-Kramer	1
1	912	2	-0.00667	0.1073	251	-0.06	0.9505	Tukey-Kramer	1
1	914	2	0.11	0.1139	262	0.97	0.3352	Tukey-Kramer	1
1	916	2	0.2267	0.1161	270	1.95	0.0519	Tukey-Kramer	1
1	918	2	0.28	0.1265	281	2.21	0.0277	Tukey-Kramer	1
1	920	2	0.3333	0.1607	293	2.07	0.039	Tukey-Kramer	1
1	922	2	0.3567	0.1415	297	2.52	0.0122	Tukey-Kramer	0.9974
1	924	2	0.2267	0.1406	294	1.61	0.1079	Tukey-Kramer	1
1	926	2	0.07333	0.137	284	0.54	0.593	Tukey-Kramer	1
1	928	2	-0.11	0.1493	277	-0.74	0.462	Tukey-Kramer	1
1	930	2	-0.21	0.1984	249	-1.06	0.2908	Tukey-Kramer	1

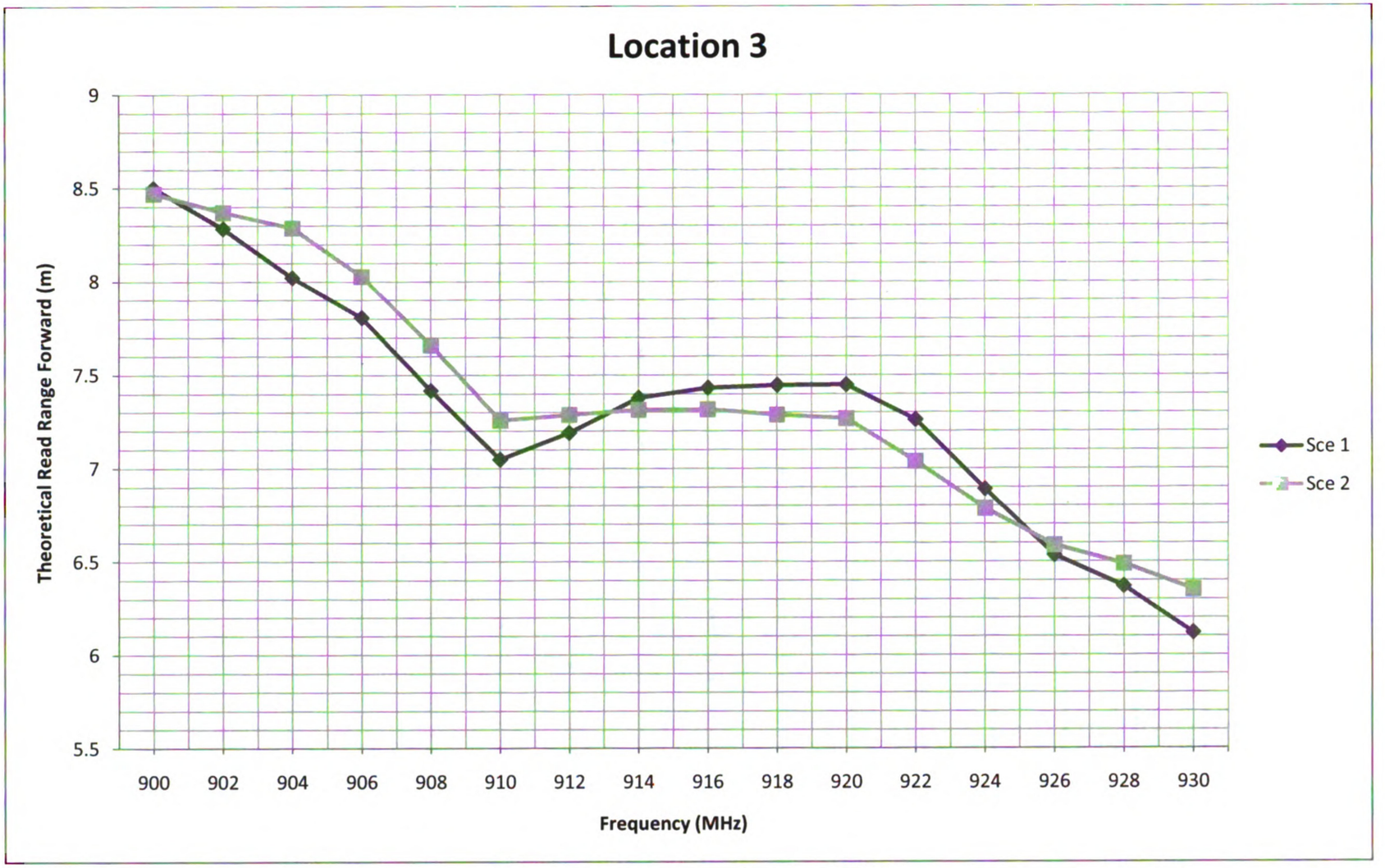

Figure 63: Location 3 - Theoretical Read Range Forward (m) vs. Frequency (MHz)

Table 93: Theoretical Read Range Forward (m) Location 3 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	3	900	8.5	0.05727	230	148.42	<.0001
2	3		8.47	0.05727	230	147.9	<.0001
1	3	902	8.2833	0.04414	256	187.65	<.0001
2	3		8.37	0.04414	256	189.61	<.0001
1	3	904	8.02	0.04841	266	165.67	<.0001
2	3		8.2867	0.04841	266	171.17	<.0001
1	3	906	7.8067	0.04618	271	169.05	<.0001
2	3		8.0267	0.04618	271	173.81	<.0001
1	3	908	7.4167	0.04687	269	158.25	<.0001
2	3		7.66	0.04687	269	163.44	<.0001
1	3	910	7.0467	0.05849	272	120.47	<.0001
2	3		7.2567	0.05849	272	124.06	<.0001
1	3	912	7.19	0.04547	274	158.14	<.0001
2	3		7.2867	0.04547	274	160.26	<.0001
1	3	914	7.3767	0.0438	284	168.4	<.0001
2	3		7.3133	0.0438	284	166.95	<.0001
1	3	916	7.43	0.0447	290	166.22	<.0001
2	3		7.3167	0.0447	290	163.68	<.0001
1	3	918	7.4433	0.03992	283	186.46	<.0001
2	3		7.2867	0.03992	283	182.54	<.0001
1	3	920	7.4467	0.04942	274	150.67	<.0001
2	3		7.2667	0.04942	274	147.03	<.0001
1	3	922	7.26	0.03724	260	194.96	<.0001
2	3		7.0367	0.03724	260	188.96	<.0001
1	3	924	6.8867	0.03611	252	190.69	<.0001
2	3		6.7833	0.03611	252	187.83	<.0001
1	3	926	6.5333	0.03879	248	168.43	<.0001
2	3		6.5867	0.03879	248	169.8	<.0001
1	3	928	6.3667	0.04469	252	142.47	<.0001
2	3		6.4867	0.04469	252	145.16	<.0001
1	3	930	6.1167	0.05986	234	102.19	<.0001
2	3		6.35	0.05986	234	106.08	<.0001

Table 94: Theoretical Read Range Forward (m) Location 3 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.03	0.08099	230	0.37	0.7114	Tukey-Kramer	1
1	902	2	-0.08667	0.06243	256	-1.39	0.1663	Tukey-Kramer	1
1	904	2	-0.2667	0.06846	266	-3.9	0.0001	Tukey-Kramer	0.1901
1	906	2	-0.22	0.06531	271	-3.37	0.0009	Tukey-Kramer	0.6179
1	908	2	-0.2433	0.06628	269	-3.67	0.0003	Tukey-Kramer	0.3431
1	910	2	-0.21	0.08272	272	-2.54	0.0117	Tukey-Kramer	0.9969
1	912	2	-0.09667	0.0643	274	-1.5	0.1339	Tukey-Kramer	1
1	914	2	0.06333	0.06195	284	1.02	0.3075	Tukey-Kramer	1
1	916	2	0.1133	0.06322	290	1.79	0.074	Tukey-Kramer	1
1	918	2	0.1567	0.05645	283	2.78	0.0059	Tukey-Kramer	0.9745
1	920	2	0.18	0.06989	274	2.58	0.0105	Tukey-Kramer	0.9955
1	922	2	0.2233	0.05266	260	4.24	<.0001	Tukey-Kramer	0.0611
1	924	2	0.1033	0.05107	252	2.02	0.0441	Tukey-Kramer	1
1	926	2	-0.05333	0.05486	248	-0.97	0.3319	Tukey-Kramer	1
1	928	2	-0.12	0.0632	252	-1.9	0.0587	Tukey-Kramer	1
1	930	2	-0.2333	0.08465	234	-2.76	0.0063	Tukey-Kramer	0.9779

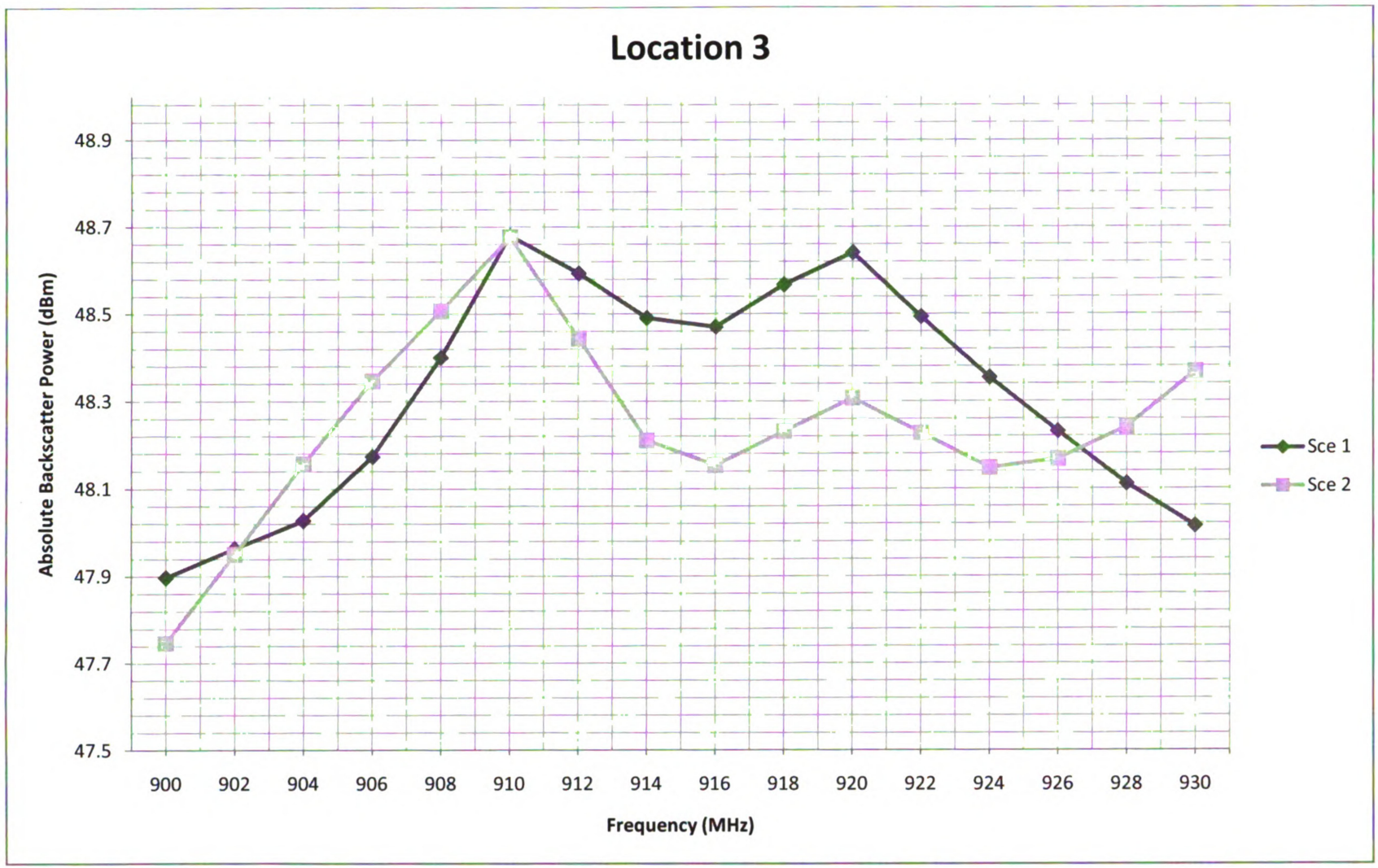

Figure 64: Location 3 - Absolute Backscatter Power (dBm) vs. Frequency (MHz)

Table 95: Absolute Backscatter Power (dBm) Location 3 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	3	900	47.8967	0.1075	215	445.39	<.0001
2	3		47.7467	0.1075	215	444	<.0001
1	3	902	47.9633	0.08893	248	539.32	<.0001
2	3		47.95	0.08893	248	539.17	<.0001
1	3	904	48.0267	0.1069	263	449.4	<.0001
2	3		48.1567	0.1069	263	450.62	<.0001
1	3	906	48.1733	0.108	263	446.16	<.0001
2	3		48.3467	0.108	263	447.77	<.0001
1	3	908	48.4	0.09665	248	500.76	<.0001
2	3		48.5067	0.09665	248	501.86	<.0001
1	3	910	48.68	0.1201	237	405.19	<.0001
2	3		48.6767	0.1201	237	405.16	<.0001
1	3	912	48.5933	0.09783	242	496.69	<.0001
2	3		48.4433	0.09783	242	495.16	<.0001
1	3	914	48.49	0.1226	254	395.65	<.0001
2	3		48.21	0.1226	254	393.37	<.0001
1	3	916	48.47	0.129	251	375.64	<.0001
2	3		48.1533	0.129	251	373.19	<.0001
1	3	918	48.5667	0.1203	246	403.78	<.0001
2	3		48.23	0.1203	246	400.98	<.0001
1	3	920	48.64	0.1382	258	351.84	<.0001
2	3		48.3067	0.1382	258	349.43	<.0001
1	3	922	48.4933	0.09647	271	502.7	<.0001
2	3		48.2267	0.09647	271	499.93	<.0001
1	3	924	48.3533	0.0857	282	564.21	<.0001
2	3		48.1467	0.0857	282	561.8	<.0001
1	3	926	48.23	0.08378	287	575.67	<.0001
2	3		48.1667	0.08378	287	574.92	<.0001
1	3	928	48.11	0.09099	293	528.74	<.0001
2	3		48.24	0.09099	293	530.17	<.0001
1	3	930	48.0133	0.1227	266	391.33	<.0001
2	3		48.3667	0.1227	266	394.21	<.0001

Table 96: Absolute Backscatter Power (dBm) Location 3 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.15	0.1521	215	0.99	0.3251	Tukey-Kramer	1
1	902	2	0.01333	0.1258	248	0.11	0.9157	Tukey-Kramer	1
1	904	2	-0.13	0.1511	263	-0.86	0.3905	Tukey-Kramer	1
1	906	2	-0.1733	0.1527	263	-1.14	0.2573	Tukey-Kramer	1
1	908	2	-0.1067	0.1367	248	-0.78	0.4359	Tukey-Kramer	1
1	910	2	0.003333	0.1699	237	0.02	0.9844	Tukey-Kramer	1
1	912	2	0.15	0.1384	242	1.08	0.2794	Tukey-Kramer	1
1	914	2	0.28	0.1733	254	1.62	0.1074	Tukey-Kramer	1
1	916	2	0.3167	0.1825	251	1.74	0.0839	Tukey-Kramer	1
1	918	2	0.3367	0.1701	246	1.98	0.0489	Tukey-Kramer	1
1	920	2	0.3333	0.1955	258	1.7	0.0894	Tukey-Kramer	1
1	922	2	0.2667	0.1364	271	1.95	0.0516	Tukey-Kramer	1
1	924	2	0.2067	0.1212	282	1.71	0.0893	Tukey-Kramer	1
1	926	2	0.06333	0.1185	287	0.53	0.5934	Tukey-Kramer	1
1	928	2	-0.13	0.1287	293	-1.01	0.3132	Tukey-Kramer	1
1	930	2	-0.3533	0.1735	266	-2.04	0.0427	Tukey-Kramer	1

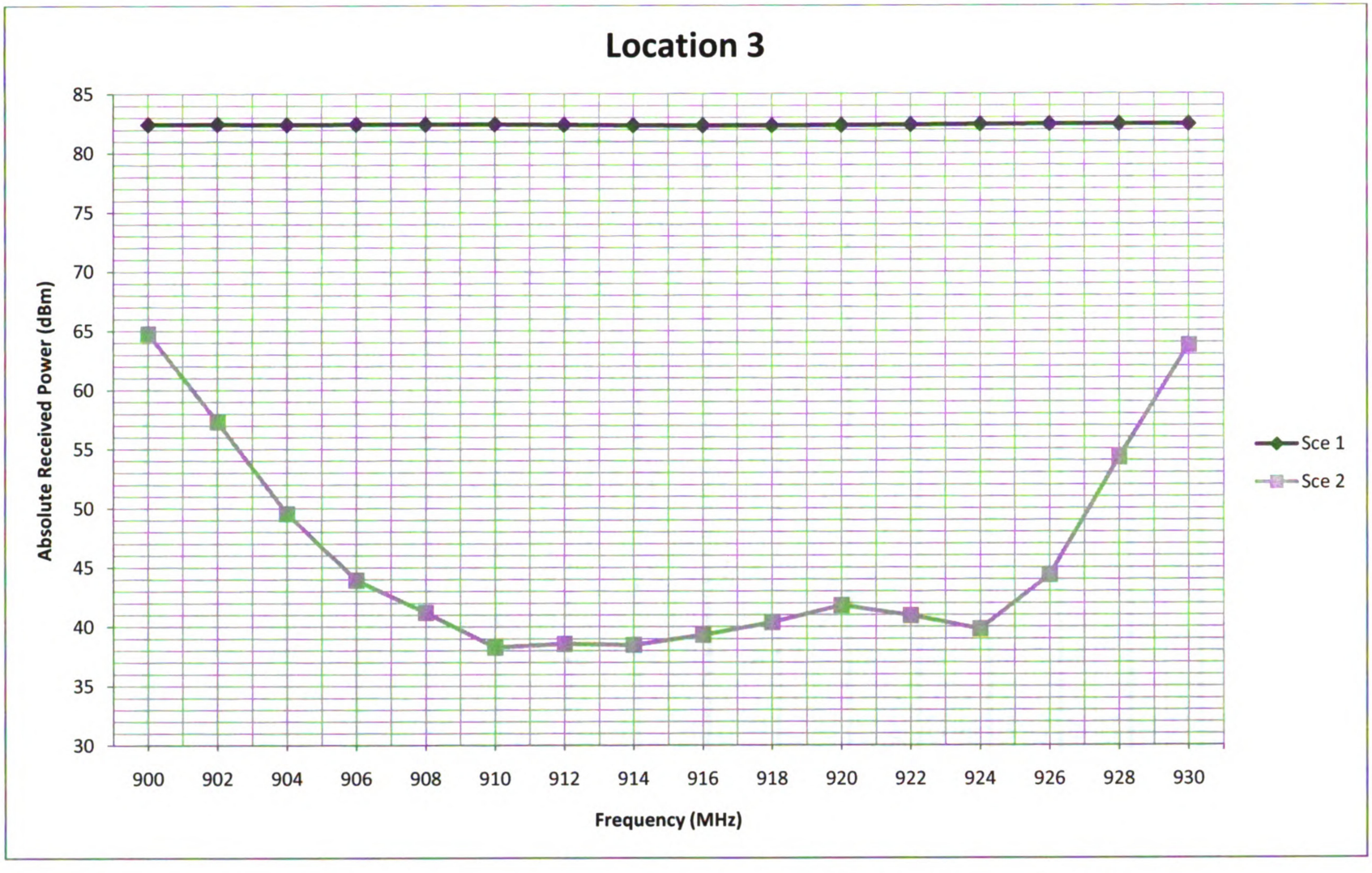

Figure 65: Location 3 - Absolute Received Power (dBm) vs. Frequency (MHz)

Table 97: Absolute Received Power (dBm) Location 3 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	3	900	82.4267	1.3084	2157	63	<.0001
2	3		64.7667	1.3084	2157	49.5	<.0001
1	3	902	82.4267	1.3084	2157	63	<.0001
2	3		57.3	1.3084	2157	43.8	<.0001
1	3	904	82.42	1.3084	2157	63	<.0001
2	3		49.5333	1.3084	2157	37.86	<.0001
1	3	906	82.4233	1.3084	2157	63	<.0001
2	3		43.9333	1.3084	2157	33.58	<.0001
1	3	908	82.4233	1.3084	2157	63	<.0001
2	3		41.2	1.3084	2157	31.49	<.0001
1	3	910	82.4333	1.3084	2157	63.01	<.0001
2	3		38.2667	1.3084	2157	29.25	<.0001
1	3	912	82.3833	1.3084	2157	62.97	<.0001
2	3		38.5667	1.3084	2157	29.48	<.0001
1	3	914	82.3467	1.3084	2157	62.94	<.0001
2	3		38.4667	1.3084	2157	29.4	<.0001
1	3	916	82.32	1.3084	2157	62.92	<.0001
2	3		39.3	1.3084	2157	30.04	<.0001
1	3	918	82.3267	1.3084	2157	62.92	<.0001
2	3		40.3667	1.3084	2157	30.85	<.0001
1	3	920	82.3367	1.3084	2157	62.93	<.0001
2	3		41.8	1.3084	2157	31.95	<.0001
1	3	922	82.37	1.3084	2157	62.96	<.0001
2	3		40.9333	1.3084	2157	31.29	<.0001
1	3	924	82.41	1.3084	2157	62.99	<.0001
2	3		39.8	1.3084	2157	30.42	<.0001
1	3	926	82.44	1.3084	2157	63.01	<.0001
2	3		44.3333	1.3084	2157	33.88	<.0001
1	3	928	82.4367	1.3084	2157	63.01	<.0001
2	3		54.2667	1.3084	2157	41.48	<.0001
1	3	930	82.44	1.3084	2157	63.01	<.0001
2	3		63.7667	1.3084	2157	48.74	<.0001

Table 98: Absolute Received Power (dBm) Location 3 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	17.66	1.8503	2157	9.54	<.0001	Tukey-Kramer	<.0001
1	902	2	25.1267	1.8503	2157	13.58	<.0001	Tukey-Kramer	<.0001
1	904	2	32.8867	1.8503	2157	17.77	<.0001	Tukey-Kramer	<.0001
1	906	2	38.49	1.8503	2157	20.8	<.0001	Tukey-Kramer	<.0001
1	908	2	41.2233	1.8503	2157	22.28	<.0001	Tukey-Kramer	<.0001
1	910	2	44.1667	1.8503	2157	23.87	<.0001	Tukey-Kramer	<.0001
1	912	2	43.8167	1.8503	2157	23.68	<.0001	Tukey-Kramer	<.0001
1	914	2	43.88	1.8503	2157	23.72	<.0001	Tukey-Kramer	<.0001
1	916	2	43.02	1.8503	2157	23.25	<.0001	Tukey-Kramer	<.0001
1	918	2	41.96	1.8503	2157	22.68	<.0001	Tukey-Kramer	<.0001
1	920	2	40.5367	1.8503	2157	21.91	<.0001	Tukey-Kramer	<.0001
1	922	2	41.4367	1.8503	2157	22.39	<.0001	Tukey-Kramer	<.0001
1	924	2	42.61	1.8503	2157	23.03	<.0001	Tukey-Kramer	<.0001
1	926	2	38.1067	1.8503	2157	20.59	<.0001	Tukey-Kramer	<.0001
1	928	2	28.17	1.8503	2157	15.22	<.0001	Tukey-Kramer	<.0001
1	930	2	18.6733	1.8503	2157	10.09	<.0001	Tukey-Kramer	<.0001

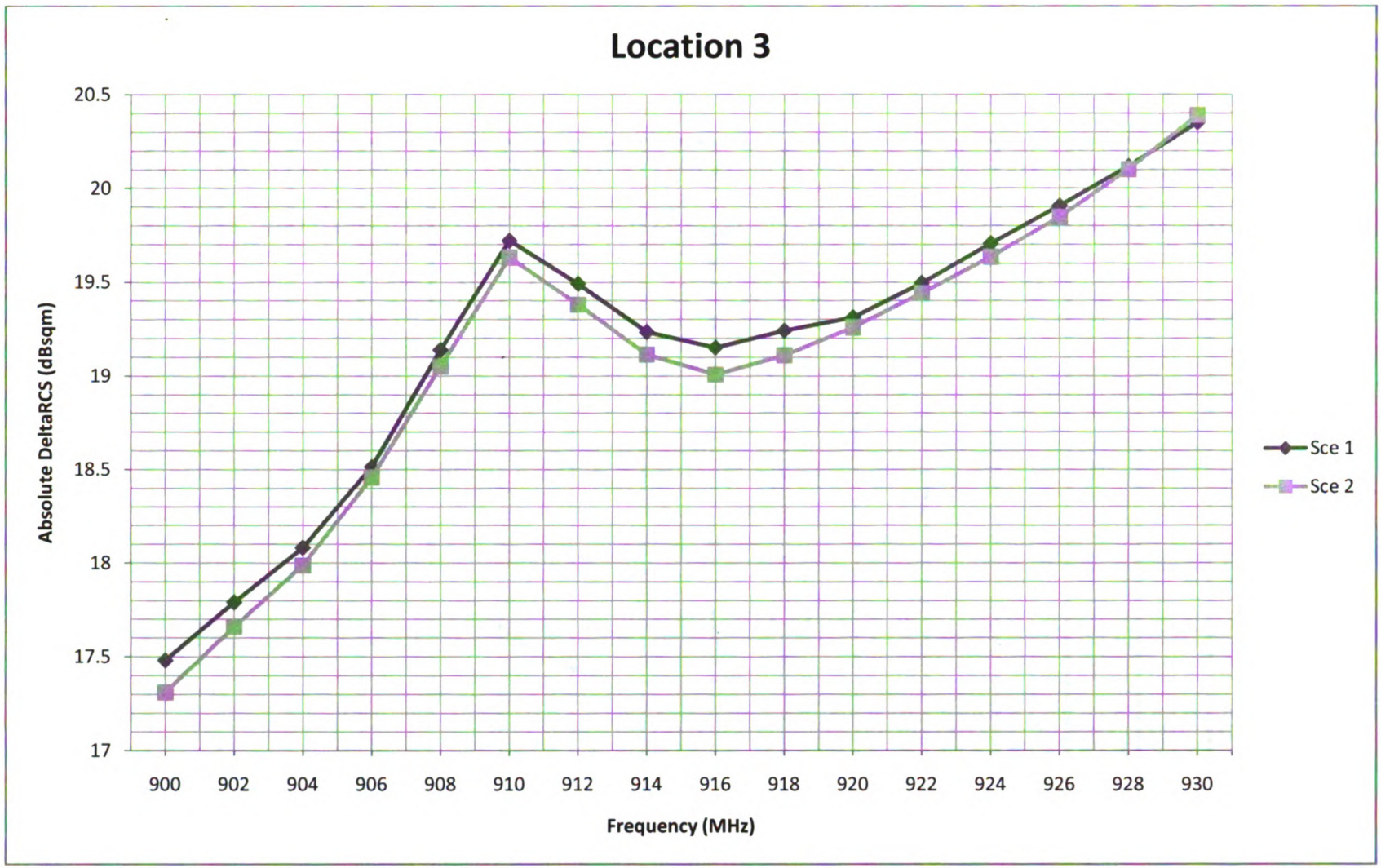

Figure 66: Location 3 - Absolute Delta RCS (dBsqm) vs. Frequency (MHz)

Table 99: Absolute Delta RCS (dBsqm) Location 3 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	3	900	17.48	0.06879	241	254.1	<.0001
2	3		17.31	0.06879	241	251.63	<.0001
1	3	902	17.79	0.05175	284	343.74	<.0001
2	3		17.66	0.05175	284	341.23	<.0001
1	3	904	18.08	0.05928	300	304.99	<.0001
2	3		17.9867	0.05928	300	303.42	<.0001
1	3	906	18.5133	0.06073	298	304.85	<.0001
2	3		18.4567	0.06073	298	303.91	<.0001
1	3	908	19.1367	0.05707	275	335.32	<.0001
2	3		19.05	0.05707	275	333.8	<.0001
1	3	910	19.72	0.08024	250	245.78	<.0001
2	3		19.63	0.08024	250	244.66	<.0001
1	3	912	19.49	0.06471	243	301.17	<.0001
2	3		19.38	0.06471	243	299.47	<.0001
1	3	914	19.2333	0.08271	267	232.53	<.0001
2	3		19.1133	0.08271	267	231.08	<.0001
1	3	916	19.15	0.08333	271	229.8	<.0001
2	3		19.0067	0.08333	271	228.08	<.0001
1	3	918	19.24	0.07213	246	266.75	<.0001
2	3		19.11	0.07213	246	264.95	<.0001
1	3	920	19.31	0.07515	249	256.95	<.0001
2	3		19.2567	0.07515	249	256.24	<.0001
1	3	922	19.4933	0.05087	278	383.18	<.0001
2	3		19.44	0.05087	278	382.13	<.0001
1	3	924	19.7033	0.05668	282	347.6	<.0001
2	3		19.6333	0.05668	282	346.36	<.0001
1	3	926	19.9067	0.05673	250	350.91	<.0001
2	3		19.8467	0.05673	250	349.86	<.0001
1	3	928	20.1167	0.05403	219	372.34	<.0001
2	3		20.1	0.05403	219	372.03	<.0001
1	3	930	20.35	0.07357	200	276.6	<.0001
2	3		20.39	0.07357	200	277.15	<.0001

Table 100: Absolute Delta RCS (dBsqm) Location 3 Comparisons

sce	fre	sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.17	0.09728	241	1.75	0.0818	Tukey-Kramer	1
1	902	2	0.13	0.07319	284	1.78	0.0768	Tukey-Kramer	1
1	904	2	0.09333	0.08383	300	1.11	0.2665	Tukey-Kramer	1
1	906	2	0.05667	0.08589	298	0.66	0.5099	Tukey-Kramer	1
1	908	2	0.08667	0.08071	275	1.07	0.2839	Tukey-Kramer	1
1	910	2	0.09	0.1135	250	0.79	0.4284	Tukey-Kramer	1
1	912	2	0.11	0.09152	243	1.2	0.2306	Tukey-Kramer	1
1	914	2	0.12	0.117	267	1.03	0.3059	Tukey-Kramer	1
1	916	2	0.1433	0.1178	271	1.22	0.225	Tukey-Kramer	1
1	918	2	0.13	0.102	246	1.27	0.2037	Tukey-Kramer	1
1	920	2	0.05333	0.1063	249	0.5	0.6162	Tukey-Kramer	1
1	922	2	0.05333	0.07195	278	0.74	0.4591	Tukey-Kramer	1
1	924	2	0.07	0.08016	282	0.87	0.3833	Tukey-Kramer	1
1	926	2	0.06	0.08023	250	0.75	0.4552	Tukey-Kramer	1
1	928	2	0.01667	0.07641	219	0.22	0.8275	Tukey-Kramer	1
1	930	2	-0.04	0.104	200	-0.38	0.7011	Tukey-Kramer	1

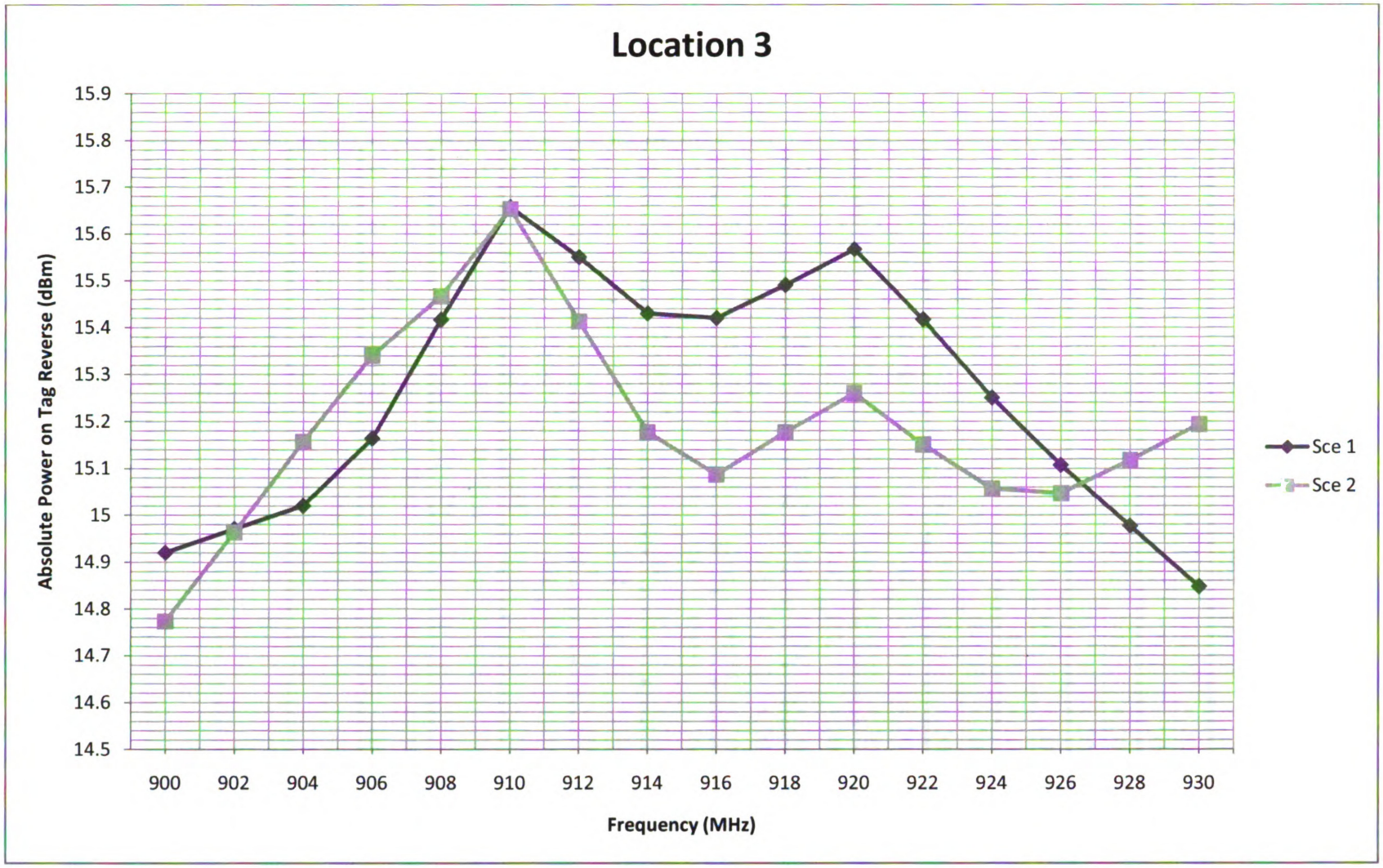

Figure 67: Location 3 - Absolute Power on Tag Reverse (dBm) vs. Frequency (MHz)

Table 101: Absolute Power on Tag Reverse (dBm) Location 3 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	3	900	14.92	0.1007	226	148.15	<.0001
2	3		14.7733	0.1007	226	146.69	<.0001
1	3	902	14.97	0.08459	262	176.97	<.0001
2	3		14.9633	0.08459	262	176.9	<.0001
1	3	904	15.02	0.1024	276	146.65	<.0001
2	3		15.1567	0.1024	276	147.98	<.0001
1	3	906	15.1633	0.1052	274	144.12	<.0001
2	3		15.34	0.1052	274	145.8	<.0001
1	3	908	15.4167	0.09129	257	168.88	<.0001
2	3		15.4667	0.09129	257	169.43	<.0001
1	3	910	15.6567	0.1161	247	134.91	<.0001
2	3		15.6533	0.1161	247	134.88	<.0001
1	3	912	15.55	0.09585	250	162.23	<.0001
2	3		15.4133	0.09585	250	160.81	<.0001
1	3	914	15.43	0.1161	266	132.93	<.0001
2	3		15.1767	0.1161	266	130.74	<.0001
1	3	916	15.42	0.1181	267	130.59	<.0001
2	3		15.0867	0.1181	267	127.77	<.0001
1	3	918	15.49	0.1069	258	144.97	<.0001
2	3		15.1767	0.1069	258	142.04	<.0001
1	3	920	15.5667	0.1356	254	114.79	<.0001
2	3		15.26	0.1356	254	112.53	<.0001
1	3	922	15.4167	0.1028	254	149.98	<.0001
2	3		15.15	0.1028	254	147.38	<.0001
1	3	924	15.25	0.09421	258	161.87	<.0001
2	3		15.0567	0.09421	258	159.82	<.0001
1	3	926	15.1067	0.09469	264	159.53	<.0001
2	3		15.0467	0.09469	264	158.9	<.0001
1	3	928	14.9767	0.09708	276	154.27	<.0001
2	3		15.1167	0.09708	276	155.72	<.0001
1	3	930	14.8467	0.1285	254	115.52	<.0001
2	3		15.1933	0.1285	254	118.21	<.0001

Table 102: Absolute Power on Tag Reverse (dBm) Location 3 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	0.1467	0.1424	226	1.03	0.3042	Tukey-Kramer	1
1	902	2	0.006667	0.1196	262	0.06	0.9556	Tukey-Kramer	1
1	904	2	-0.1367	0.1448	276	-0.94	0.3462	Tukey-Kramer	1
1	906	2	-0.1767	0.1488	274	-1.19	0.2361	Tukey-Kramer	1
1	908	2	-0.05	0.1291	257	-0.39	0.6988	Tukey-Kramer	1
1	910	2	0.003333	0.1641	247	0.02	0.9838	Tukey-Kramer	1
1	912	2	0.1367	0.1356	250	1.01	0.3143	Tukey-Kramer	1
1	914	2	0.2533	0.1642	266	1.54	0.124	Tukey-Kramer	1
1	916	2	0.3333	0.167	267	2	0.0469	Tukey-Kramer	1
1	918	2	0.3133	0.1511	258	2.07	0.0391	Tukey-Kramer	1
1	920	2	0.3067	0.1918	254	1.6	0.1111	Tukey-Kramer	1
1	922	2	0.2667	0.1454	254	1.83	0.0678	Tukey-Kramer	1
1	924	2	0.1933	0.1332	258	1.45	0.148	Tukey-Kramer	1
1	926	2	0.06	0.1339	264	0.45	0.6545	Tukey-Kramer	1
1	928	2	-0.14	0.1373	276	-1.02	0.3087	Tukey-Kramer	1
1	930	2	-0.3467	0.1818	254	-1.91	0.0576	Tukey-Kramer	1

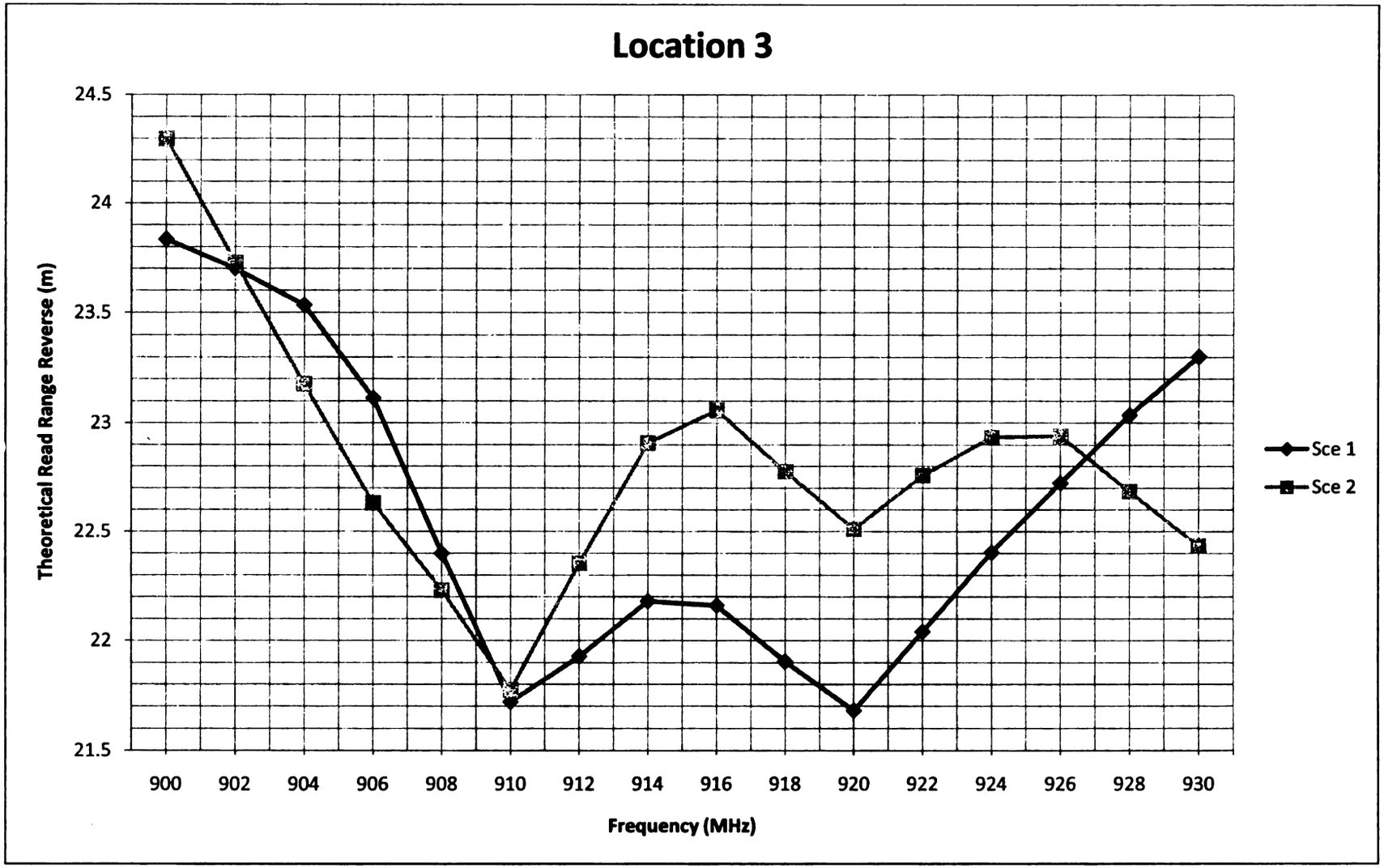

Figure 68: Location 3 - Theoretical Read Range Reverse (m) vs. Frequency (MHz)

Table 103: Theoretical Read Range Reverse (m) Location 3 Estimations

sce	loc	fre	Estimate	StdErr	DF	tValue	Probt
1	3	900	23.8333	0.2375	227	100.34	<.0001
2	3		24.2967	0.2375	227	102.29	<.0001
1	3	902	23.7	0.2029	264	116.8	<.0001
2	3		23.7267	0.2029	264	116.94	<.0001
1	3	904	23.5333	0.2605	278	90.34	<.0001
2	3		23.1767	0.2605	278	88.97	<.0001
1	3	906	23.1133	0.2628	276	87.97	<.0001
2	3		22.63	0.2628	276	86.13	<.0001
1	3	908	22.4	0.2238	257	100.09	<.0001
2	3		22.23	0.2238	257	99.33	<.0001
1	3	910	21.72	0.2846	243	76.32	<.0001
2	3		21.7733	0.2846	243	76.51	<.0001
1	3	912	21.9267	0.2423	247	90.51	<.0001
2	3		22.3533	0.2423	247	92.27	<.0001
1	3	914	22.18	0.3164	261	70.1	<.0001
2	3		22.9067	0.3164	261	72.39	<.0001
1	3	916	22.16	0.3331	257	66.53	<.0001
2	3		23.0567	0.3331	257	69.22	<.0001
1	3	918	21.9033	0.2761	257	79.33	<.0001
2	3		22.7767	0.2761	257	82.49	<.0001
1	3	920	21.68	0.3315	275	65.39	<.0001
2	3		22.51	0.3315	275	67.89	<.0001
1	3	922	22.04	0.2409	281	91.48	<.0001
2	3		22.7567	0.2409	281	94.46	<.0001
1	3	924	22.4033	0.2227	281	100.61	<.0001
2	3		22.9333	0.2227	281	102.99	<.0001
1	3	926	22.7233	0.2202	278	103.19	<.0001
2	3		22.94	0.2202	278	104.17	<.0001
1	3	928	23.0367	0.2607	275	88.36	<.0001
2	3		22.6833	0.2607	275	87.01	<.0001
1	3	930	23.3	0.3552	246	65.6	<.0001
2	3		22.4333	0.3552	246	63.16	<.0001

Table 104: Theoretical Read Range Reverse (m) Location 3 Comparisons

sce	fre	_sce	Estimate	StdErr	DF	tValue	Probt	Adjust	AdjP
1	900	2	-0.4633	0.3359	227	-1.38	0.1691	Tukey-Kramer	1
1	902	2	-0.02667	0.2869	264	-0.09	0.926	Tukey-Kramer	1
1	904	2	0.3567	0.3684	278	0.97	0.3338	Tukey-Kramer	1
1	906	2	0.4833	0.3716	276	1.3	0.1944	Tukey-Kramer	1
1	908	2	0.17	0.3165	257	0.54	0.5916	Tukey-Kramer	1
1	910	2	-0.05333	0.4025	243	-0.13	0.8947	Tukey-Kramer	1
1	912	2	-0.4267	0.3426	247	-1.25	0.2142	Tukey-Kramer	1
1	914	2	-0.7267	0.4475	261	-1.62	0.1056	Tukey-Kramer	1
1	916	2	-0.8967	0.471	257	-1.9	0.0581	Tukey-Kramer	1
1	918	2	-0.8733	0.3905	257	-2.24	0.0262	Tukey-Kramer	0.9999
1	920	2	-0.83	0.4689	275	-1.77	0.0778	Tukey-Kramer	1
1	922	2	-0.7167	0.3407	281	-2.1	0.0363	Tukey-Kramer	1
1	924	2	-0.53	0.3149	281	-1.68	0.0935	Tukey-Kramer	1
1	926	2	-0.2167	0.3114	278	-0.7	0.4872	Tukey-Kramer	1
1	928	2	0.3533	0.3687	275	0.96	0.3387	Tukey-Kramer	1
1	930	2	0.8667	0.5023	246	1.73	0.0857	Tukey-Kramer	1

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