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Electromagnetic Emissions from an Electro-Impulse Deicing System in a Composite Wing Equipped with Lightning Protection

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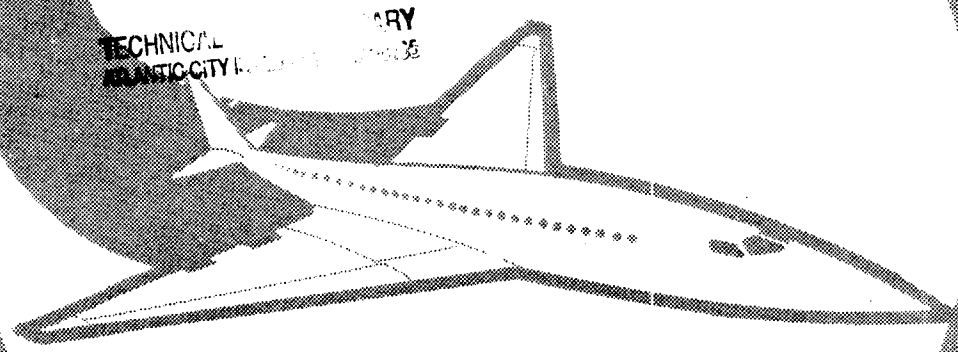

September 1991

DOT/FAA/CT-TN90/32

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technical note technical note

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Aviation Safety Division, FAA Technical Center

16. Abstract

Electromagnetic interference (EMI) accompanying the use of the Electro-Impulse Deicing (EIDI) system was investigated in 1988-89. Results indicated that EIDI emissions inside aluminum wings were almost totally shielded, but EIDI inside composite wings produced emissions exceeding permissible levels unless shielding and grounding was provided for all components.

However, lightning protection for composite wings requires a fine-mesh copper screen grid to be embedded in the composite. The questions arose concerning the shielding effect of this screen. Would it significantly reduce EMI from EIDI? Emissions tests were conducted on two similar composite wing leading edges with EIDI installed; one had a lightning protection grid. The results were negative; the embedded lightning protection wire added negligible shielding at all frequencies to the composite leading edge.

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PREFACE

The work reported herein was performed under a Federal Aviation Administration (FAA) Purchase Order to the Institute for Aviation Research at Wichita State University (WSU). Mr. Wade Davis of Beech Airplane Company did the actual testing at the Beech Electromagnetic Interference Facility.

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LIST OF ABBREVIATIONS

E-Field	Electrical Field
EIDI	Electro-Impulse Deicing
EMI	Electromagnetic interference
dB	Decibel
FAA	Federal Aviation Administration
GHz	Gigahertz, billions of cycles per second
H-Field	Magnetic field
Hz	Hertz, cycles per second
I.D.	Inside diameter
kHz	Kilohertz, thousands of cycles per second
Mhz	Megahertz, millions of cycles per second
O.D.	Outside diameter

EXECUTIVE SUMMARY

Electro-Impulse Deicing (EIDI) Systems produce a very high intensity electromagnetic induced mechanical force on an aircraft surface to dislodge ice. Discharge of 1000 volts and over 2,000 amps during a half-milli second time span creates the potential for electromagnetic interference. This had been studied in previous tests sponsored by FAA for both metal and composite wing leading edges. The results were generally that metal wings shield the emissions very well, but composite wings permit an unacceptable amount of electromagnetic radiation to be broadcast.

However, composite aircraft are required to have lightning protection, generally in the form of a fine mesh copper or aluminum wire grid buried in the composite material, which could provide some shielding of EIDI emissions. This is a report of tests of radiated EIDI emissions through two composite leading edges which are quite similar in every way except one: one has the lightning protective copper grid installed. That wing section came from a Beechcraft Starship.

Comparative tests were conducted. The results were essentially negative. The lightning protection grid did not make a significant difference in the emissions. Thus the question remains as to how the wire grid provides sufficient conductivity for potential lighting current paths, but remains almost transparent to electromagnetic emissions.

1. INTRODUCTION

Over the last seven years research in the U.S.A. has been carried out to develop and evaluate the Electro-Impulse Deicing (EIDI) system technology for application to civil aircraft ice protection. This research and development has encompassed theoretical studies, fabrication and installation techniques, icing wind tunnel and flight testing and laboratory tests for fatigue and electromagnetic interference (EMI). The EMI investigations were undertaken to ascertain the extent of EIDI EMI emissions and what effects these emissions might have on onboard avionics and other electronic control equipment.

Recent EMI tests both in Wichita, (reference 1) and Seattle (reference 2) have been conducted under FAA sponsorship. These revealed that EIDI systems tend to meet appropriate emission standards when installed in metal wings, but do not meet some standards when installed in composite wing sections. However, composite wings will typically be afforded some type of lightning protection, such as copper or aluminum wire mesh screens embedded in the composite layers. It is conceivable that this lightning protection may provide significant EMI shielding.

Tests reported here were performed at the Beech Aircraft Company EMI/EMC test facility during August 1989 under funding and guidance from the Federal Aviation Administration to the Institute for Aviation Research at Wichita State University.

2. ELECTROMAGNETIC EMISSIONS TESTS

2.1 TEST PLAN

The test plan was agreed to in a conference between Dr. Zumwalt, Mr. Charles Masters and Beechcraft test engineer Mr. Wade Davis. The changes were made to emphasize the direct comparison of the two wing models rather than explore for maximum emissions conditions. The revised plan was:

1. Measurements of both E (electric) and H (magnetic) fields for the vertical axis of the wing section only.

2. E-field measurements shall encompass frequency range of 150 kHz through 1 GHz.

3. H-field measurements shall cover the range of 10 kHz through 10 MHz.

4. Test methodology shall be RTCA-DO-160B Section 21, para. 21.3 (E-field), Categories A and Z (reference 3), broadband measurements only; and for (H-field) in accord with BS- 21320C, para. 5.7 (reference 4), narrowband mode. Figures A1 and A2 show emission standards limits for E-field and H- field respectively.

2.2 TEST SITE

The testing was performed at the electromagnetic interference (EMI) test facility of the Beech Aircraft Company in Wichita, KS. The EIDI power supply was installed in a shielded room adjoining the larger main shielded room in which the wing section was installed and measurements made.

Antennas used were a rod type for E-fields, shown in figure 1, and a ferrite rod loaded loop antenna for H-field measurements, shown in figure 2.

2.3 TEST MODELS

The two test models were both made of composite and were of very similar shapes. Only leading edges of the wing were used with the model closed at ends by metal ribs and at the rear by a composite spar. Both had two coils at the span station activated, one coil on the upper wing side and one on the lower, as shown in figures 3 and 5. Since the nose of the wing had a small radius, a pair of opposing coils was used for the ice removal system rather than wing a nose coil.

One of the models shown in figure 4, was used in the tests in references 1 and 2. It was made by the Learfan Company, and was a Kevlar composite. This had no lightning protection grid and is identified in the data in the appendix for the suffix N (for nonprotected).

The second was supplied by the Beech Aircraft Company and had been made for their Starship business aircraft. It was made from a graphite epoxy composite and had a copper wire grid buried with the outer layer of fabric. The wire grid had a 12 x 12 per inch mesh. This model is identified in the plots in the appendix by the suffix P (for protected).

Both models were 38 inches long with the active coil station 9 1/2 from one end (the quarter-position). The two coils, wired in series, were 30 turns of 0.025 x 0.125 inch copper ribbon wire. Coil outer diameter was 2.0 inches and inner diameter 0.50 inches. An unalloyed aluminum doubler of 2.25 inch diameter was bonded to the inner skin of the model, directly opposite each coil as shown in figure 6. The doubler thickness was 0.050 inches and the gap between doubler and coil was 0.07 inches.

2.4 TEST PROCEDURE

The model was placed in the large shielded room and connected to the EIDI power box by well shielded cables led through the wall between the two rooms. The antenna was placed one meter away from the model, directly opposite the coil on a line perpendicular to the leading edge. Models were both placed in the vertical position, i.e., as though the plane were flying straight up (see figures 1 and 2). This did not necessarily give the highest emission position, but gave a direct comparison between the two models with minimum effect from the supports.

The power box was set for 800 volts with 550 microfarad capacitance. A timer regulated the firing interval at 10 seconds to avoid overheating the coil. The receiver was programmed to scan the frequencies with a dwell time ("gate") of 300 milliseconds, an interval much longer than the discharge period (less than one millisecond), but not long enough to ensure a "hit" at every frequency. This necessarily introduces some randomness in the data. Figure A-3 shows three scans taken a few minutes apart. All conditions were nominally identical, but the coincidence of firing time and gate-opening at a given frequency makes quantitative differences.

3. RESULTS AND CONCLUSIONS

Results are shown in the plots of emissions (decibel microvolts per mega Hertz per meter) vs. frequency. These are in the appendix. The straight lines are permissible limits. Figures A-4 through A-7 give the ambient radiation level in the test location.

On each page of plots for figures A-8 and following, the protected and non-protected models are shown for the same conditions. In no case is the lightning protected wing transmitting significantly smaller emissions. In some cases (e.g., A-11) the reverse appears to be true, probably due to the randomness of the data taking mentioned in 2.4.

Although the copper wire grid embedded for lightning protection has a fine mesh (12 x 12 per inch) the wires are quite small, so the open area is still over 90%. This appears to have too little metal to effectively shield the radiation.

The conclusion of this test is that an embedded metal wire grid that is adequate for lightning protection is not adequate to shield EIDI electromagnetic emissions.

REFERENCES

1. Zumwalt, G.W., Friedberg, R.A. and Schwartz, J.A. "Electro-Impulse De-Icing Research: Fatigue and Electromagnetic Interference Tests." F.A.A. Report DOT/FAA/CT-88/27, March 1989.

2. Zieve, P., Huffer, B. and Ng, J. "Electromagnetic Emissions from a Modular Low Voltage Electro-Impulse De-Icing System.' FAA Report DOT/FAA/CT-88/31.

3. "Environmental Conditions and Test Procedures for Airbourne Equipment," RTCA/DO-160B, Section 21. para. 21.4, Categories A and Z, July 1984.

4. "Radiated Emission Test" (H-field), BS-21320C, para. 5.7, narrowband mode.

Figure 1 Test Setup for E-field Measurements

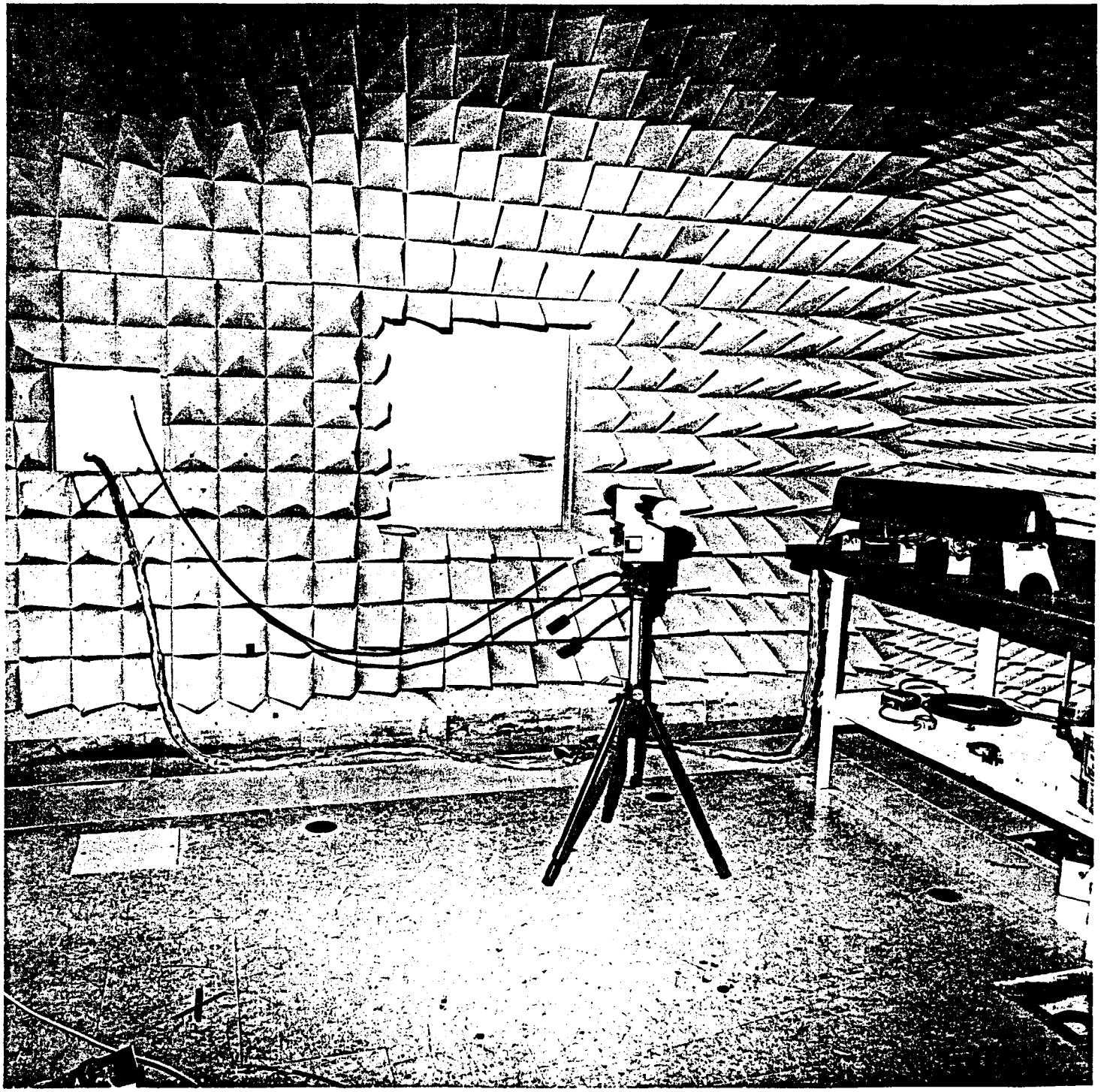

Figure 2 Test Setup for H-field Measurements

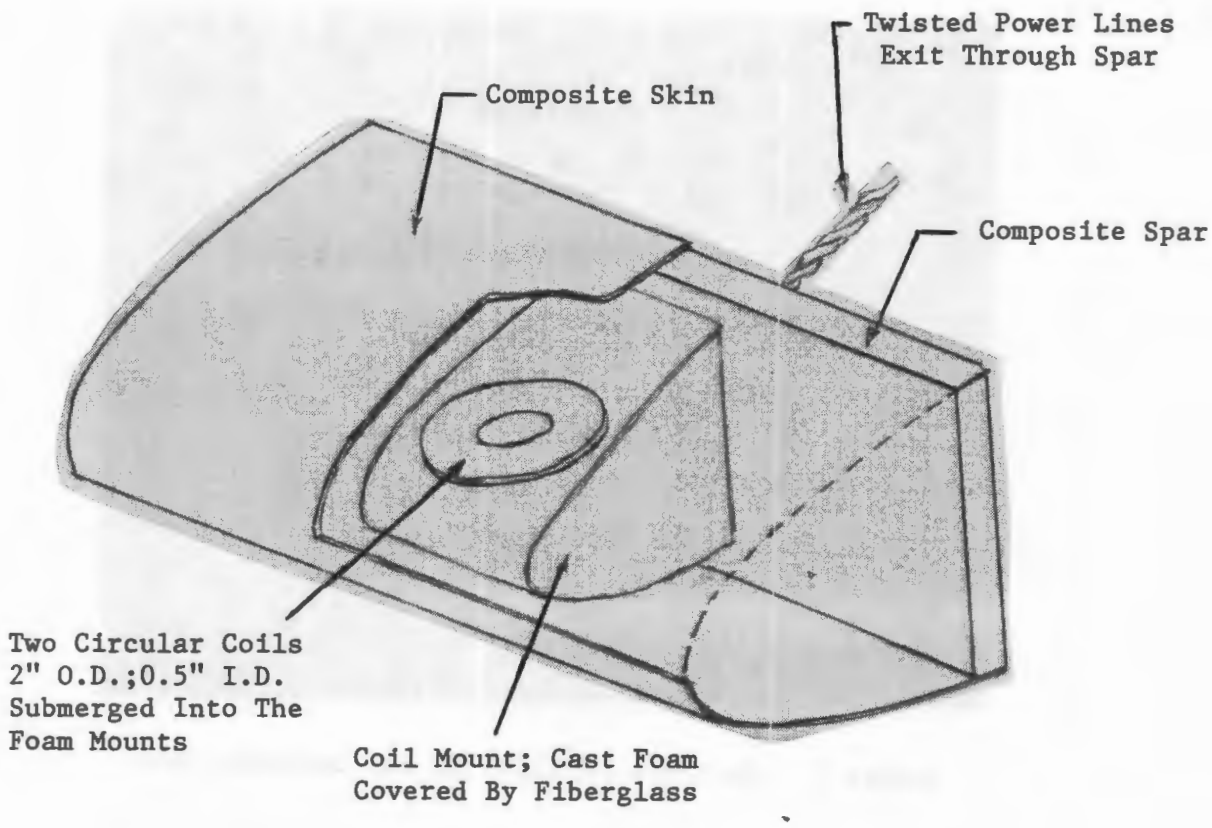

Figure 3 Coil Mounting Method

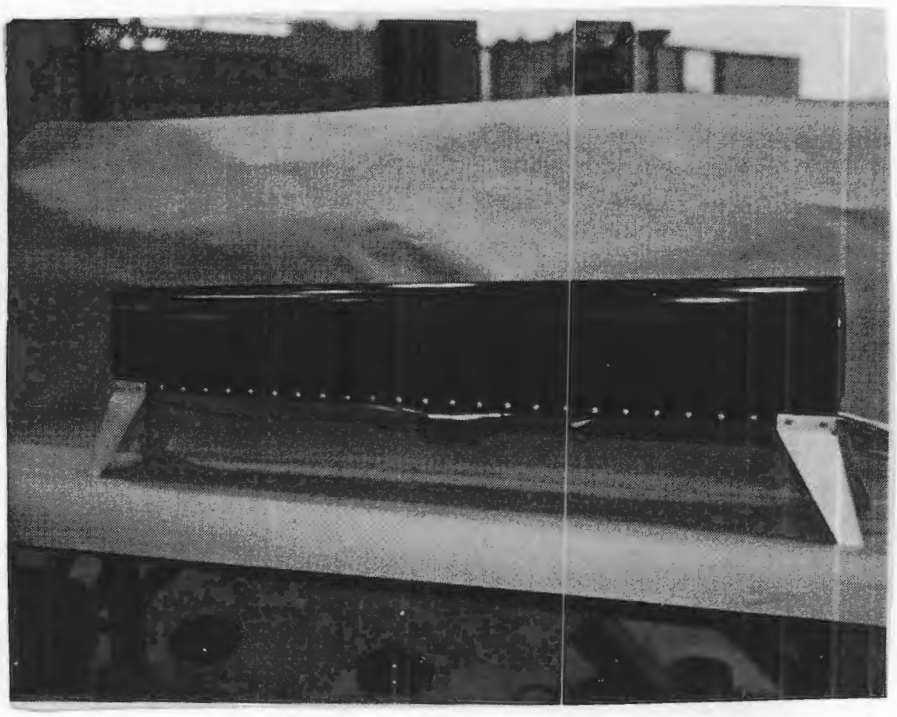

Figure 4 Composite Leading Edge Model (Non-Protected)

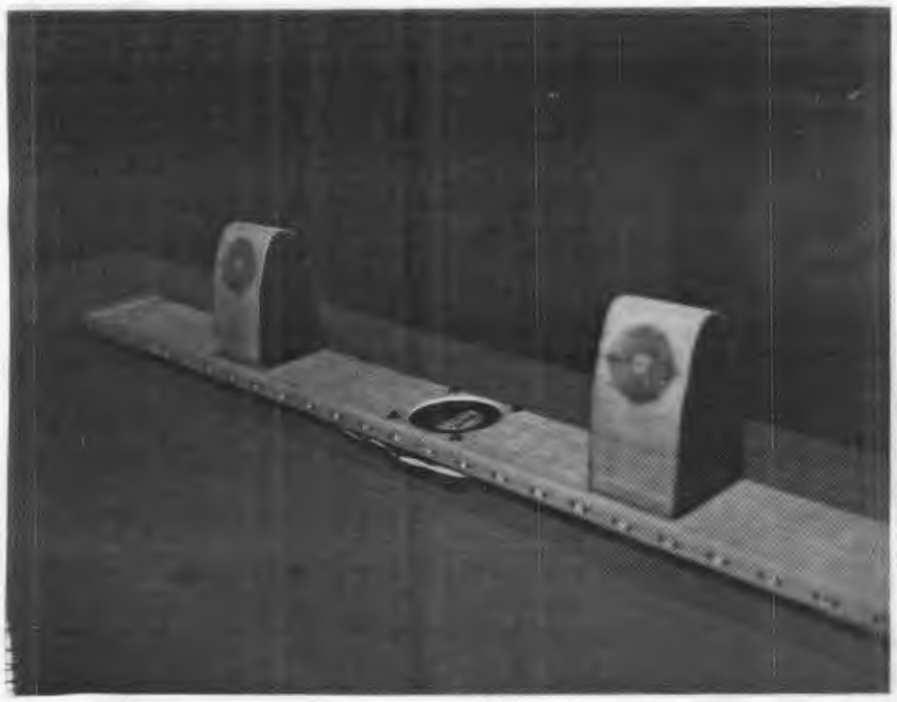

Figure 5 Spar and Coil Mounts for Composite Model

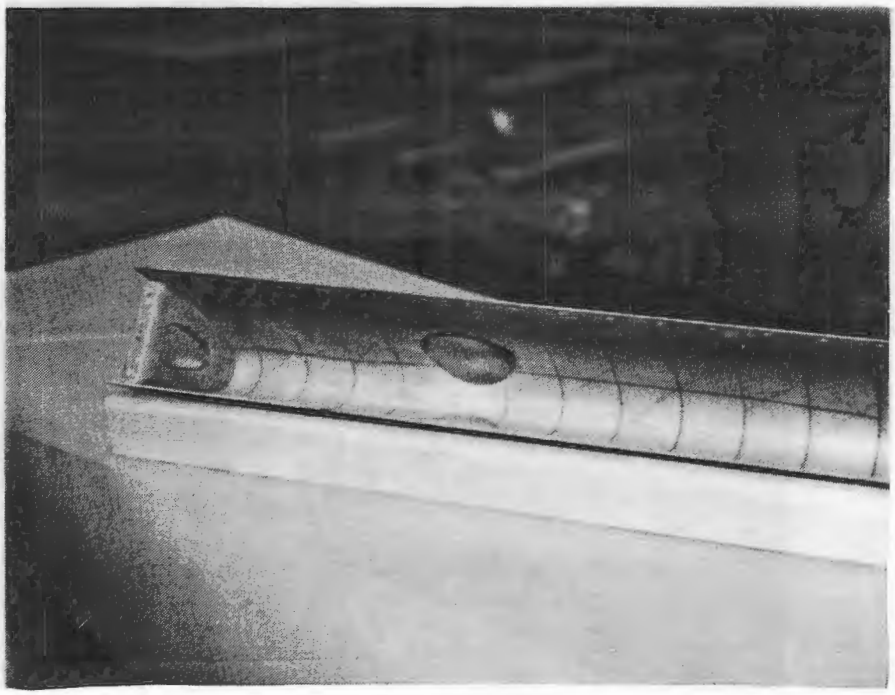

Figure 6 Inside View of Composite Model

APPENDIX

PLOTS OF EMISSIONS VERSUS FREQUENCY

Conditions for all plots:

Capacitors charged to 800 v. for 550 F
Gate (dwell) times are 300 milli-sec.

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A-3	Reapeatability Tests for E-field (conditions of figure A-8N)	A-3
A-4&5	Ambient Scan for E-field, bandwidths 5 & 100 kHz	A-4
A-6&7	Ambient Scan for E-field, bandwidths 0.5 & 5 MHz	A-5
A-8P&8N	E-field Comparisons for the Two Models, 100-1000 kHz	A-6
A-9P&9N	E-field Comparisons for the Two Models, 1-10 MHz	A-7
A-10P&10N	E-field Comparisons for the Two Models, 10-100 MHz	A-8
A-11P&11N	E-field Comparisons for the Two Models, 100-1000 MHz	A-9
A-12P&12N	H-field Comparisons for the Two Models, 10-100 kHz	A-10
A-13P&13N	H-field Comparisons for the Two Models, 100-1000 kHz	A-11
A-14P&14N	H-field Comparisons for the Two Models, 1-10 MHz	A-12

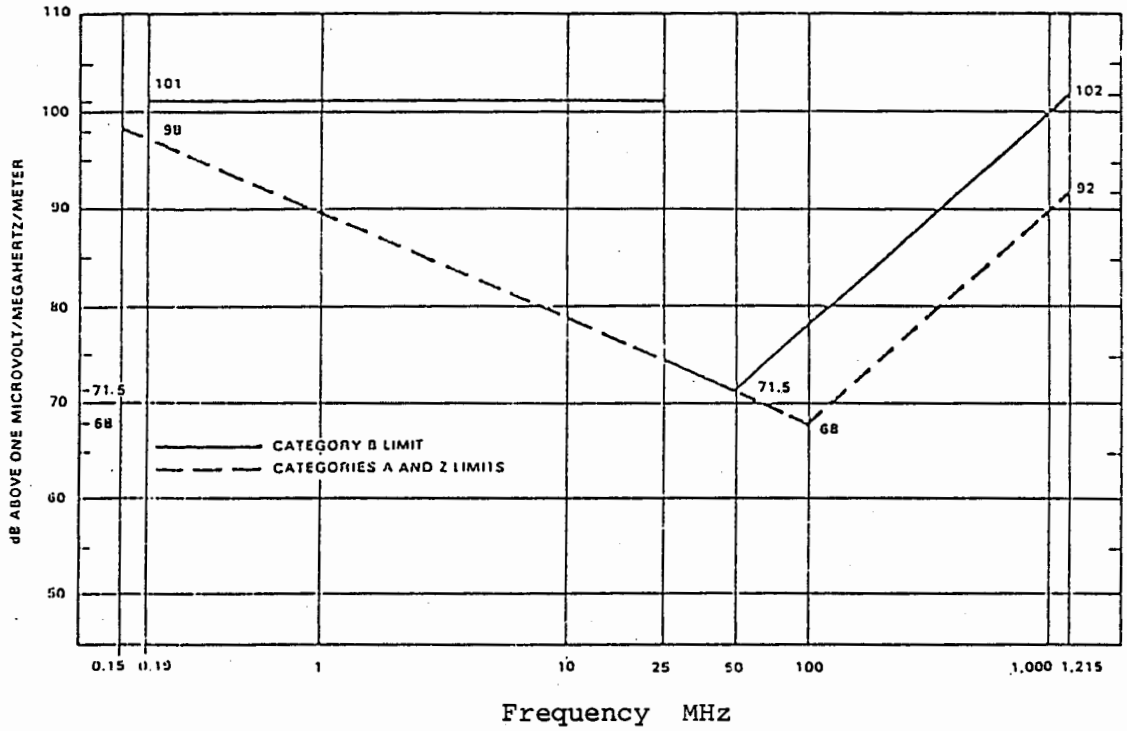


Figure A-1
Broadband E-Field Radiated
Emissions Limits

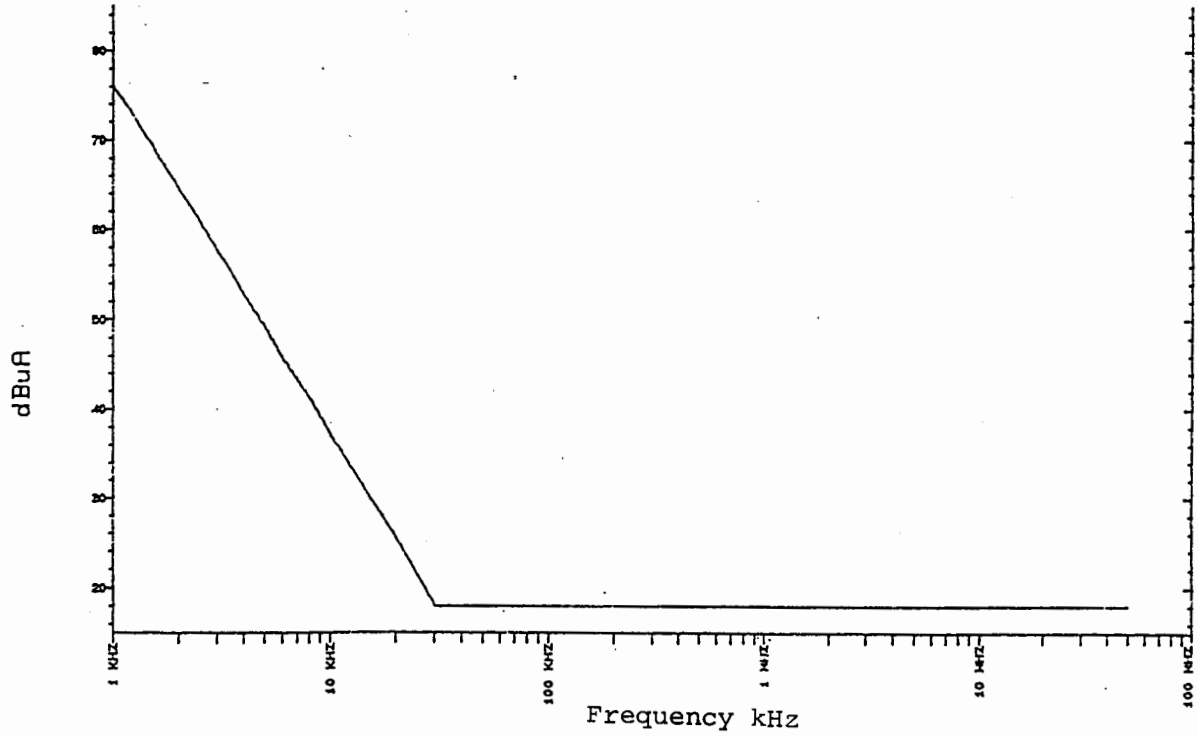


Figure A-2
Narrowband H-Field Radiated
Emissions Limits

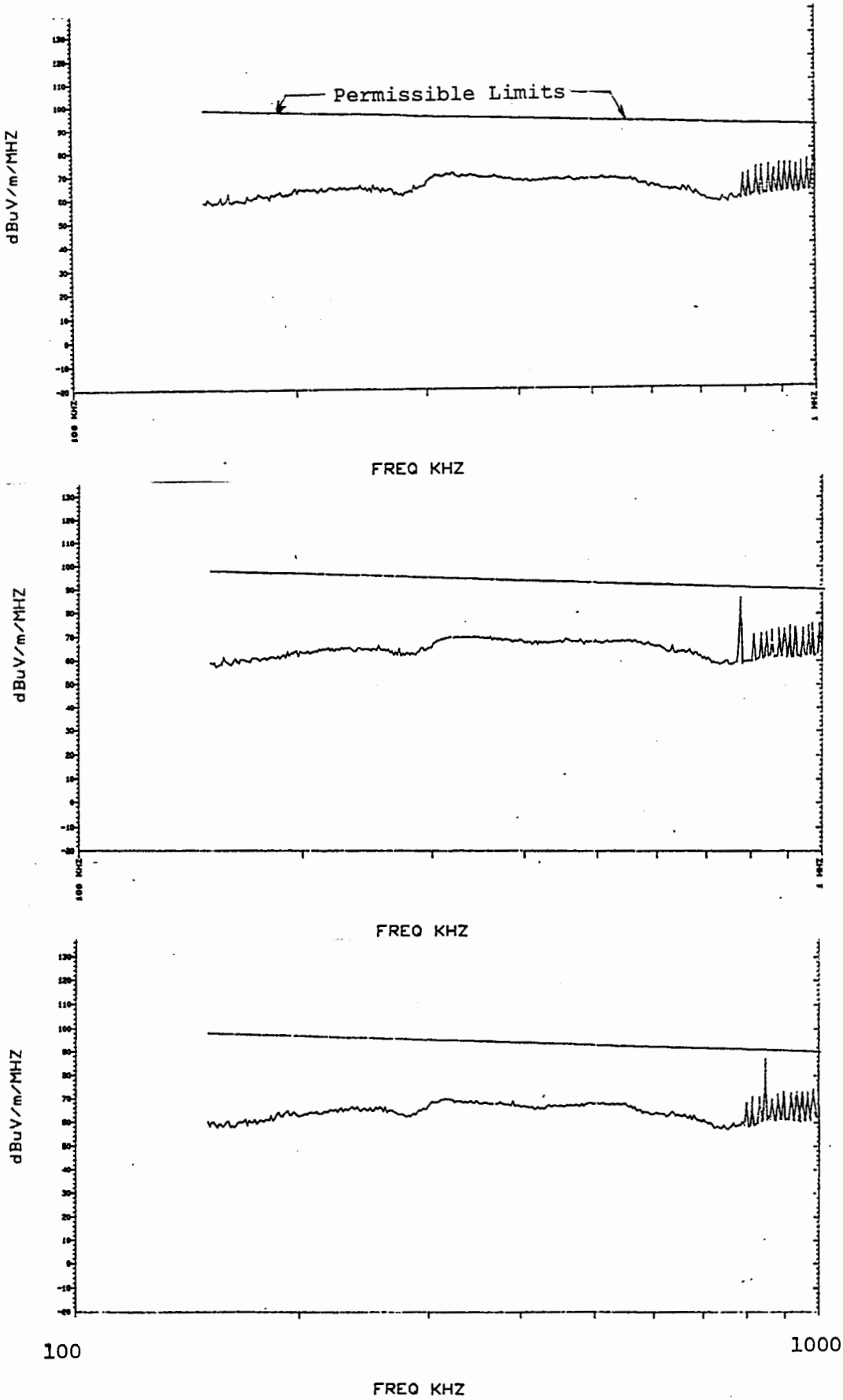


Figure A-3
Repeatability Tests for E-Field Emissions
BW 5 kHz Step: 1 kHz

Figure A-4
Ambient Scan for E-Field
BW 5 kHz Step: 1 kHz

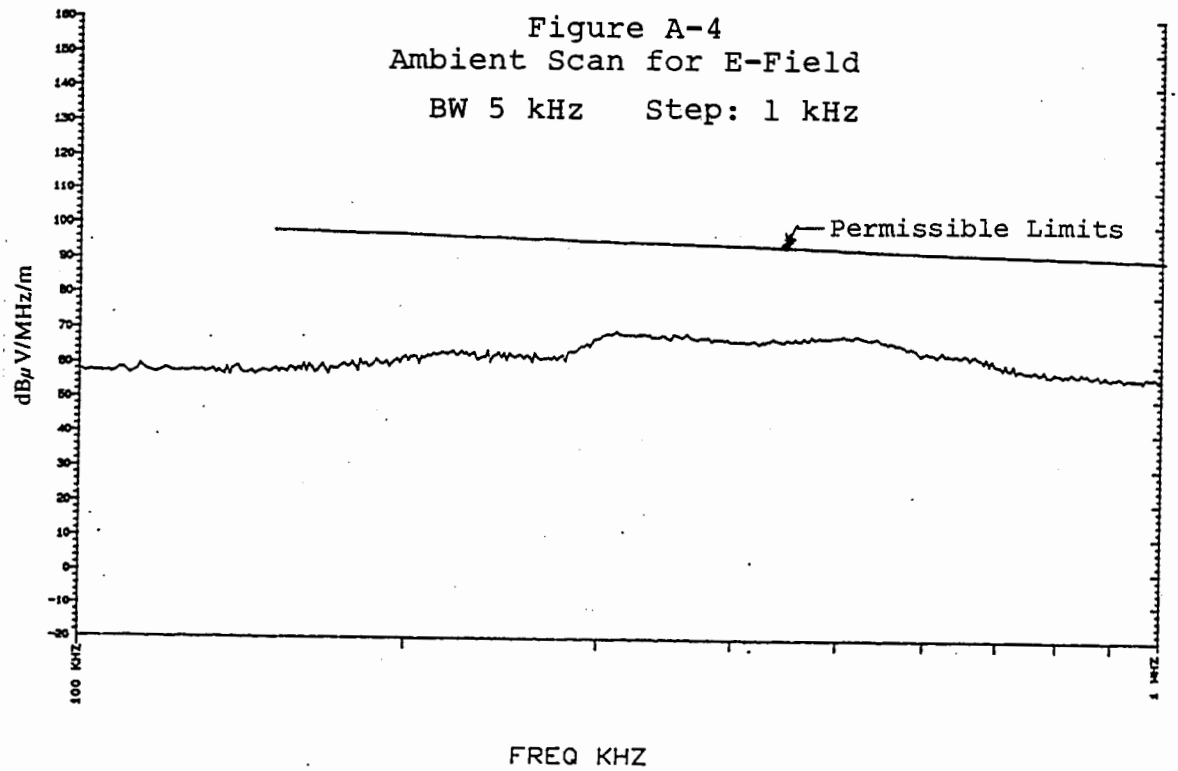
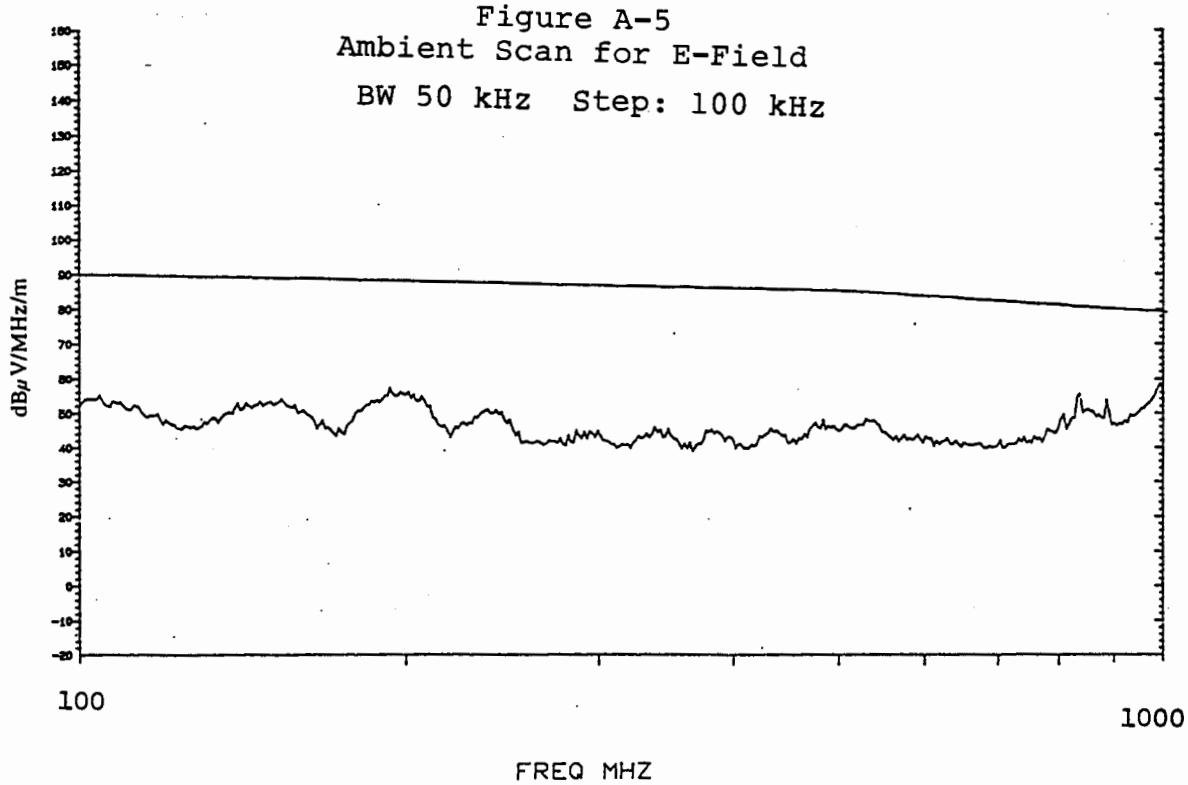


Figure A-5
Ambient Scan for E-Field
BW 50 kHz Step: 100 kHz



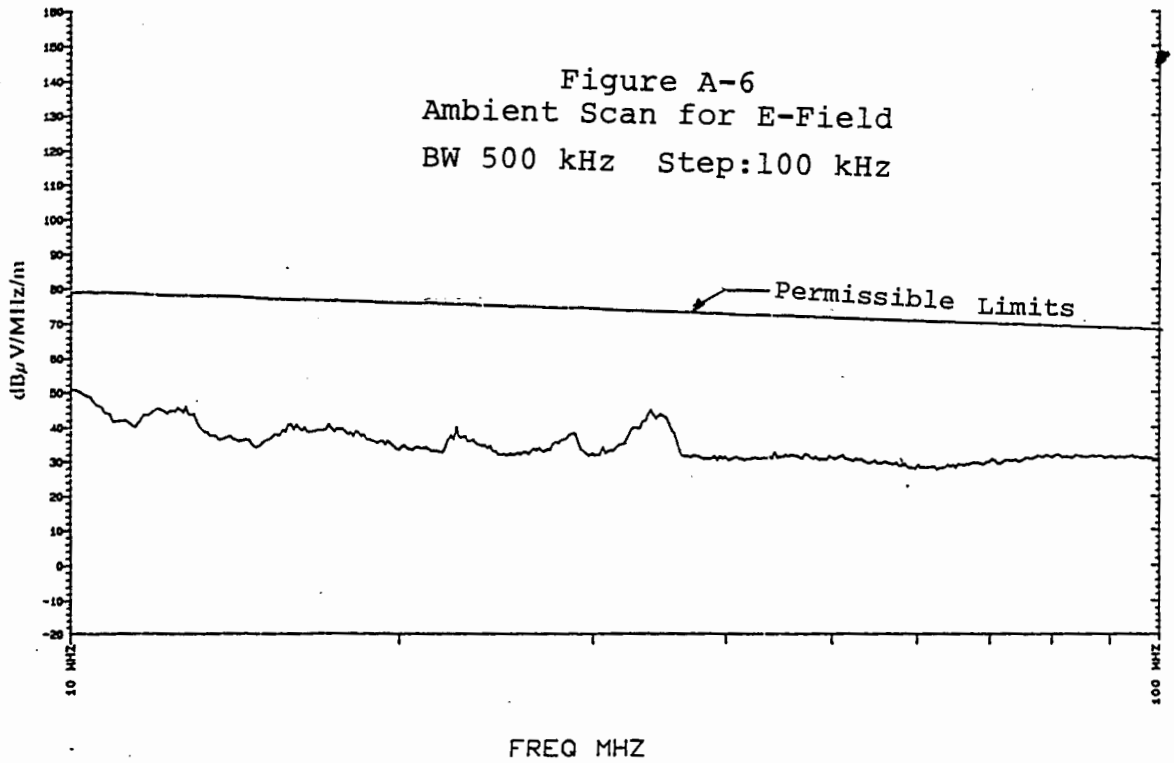


Figure A-6
Ambient Scan for E-Field
BW 500 kHz Step:100 kHz

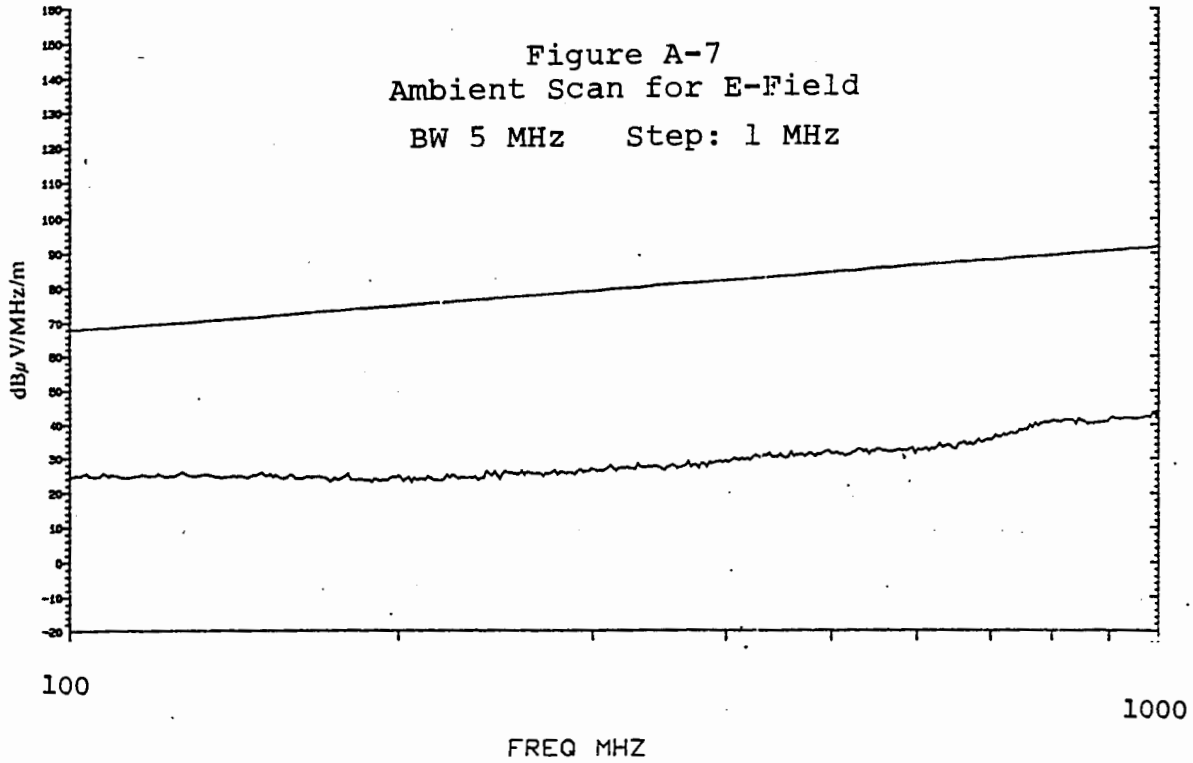


Figure A-7
Ambient Scan for E-Field
BW 5 MHz Step: 1 MHz

Figure A-8P
E-Field Emissions for
Lightning Protected Wing

BW 5 kHz Step: 1 kHz

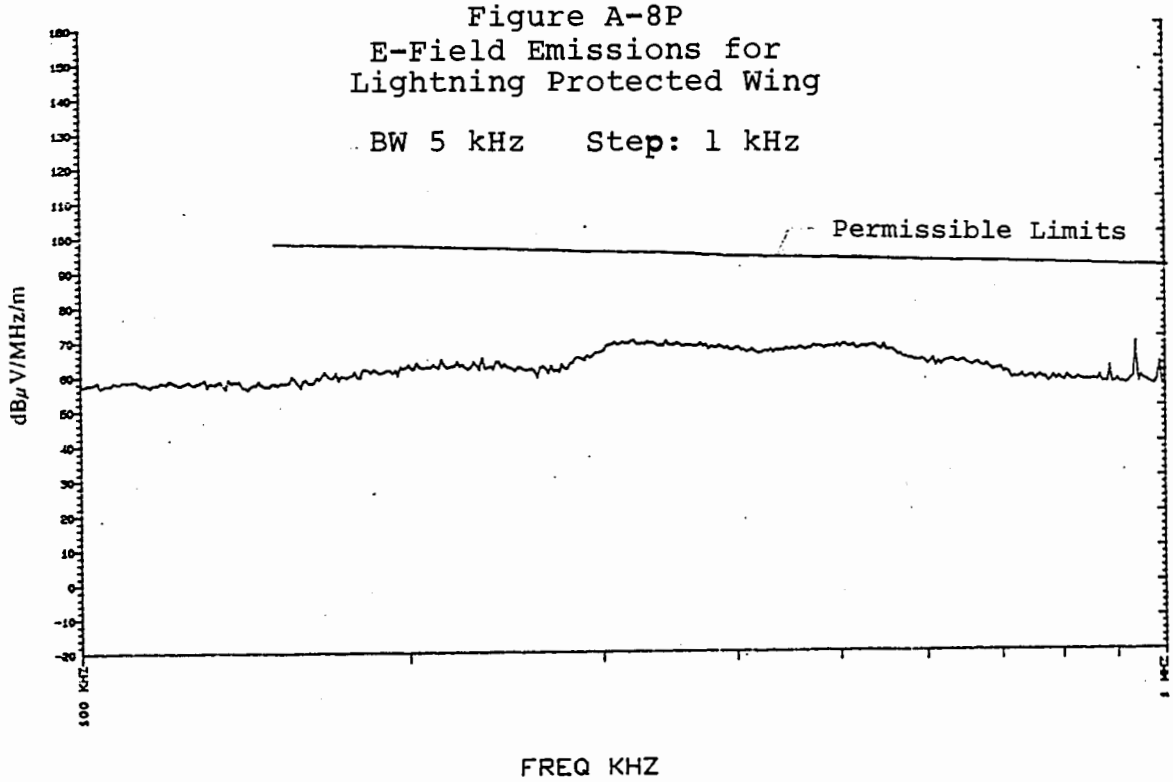


Figure A-8N
E-Field Emissions for
Non-Protected Wing

BW 5 kHz Step: 1 kHz

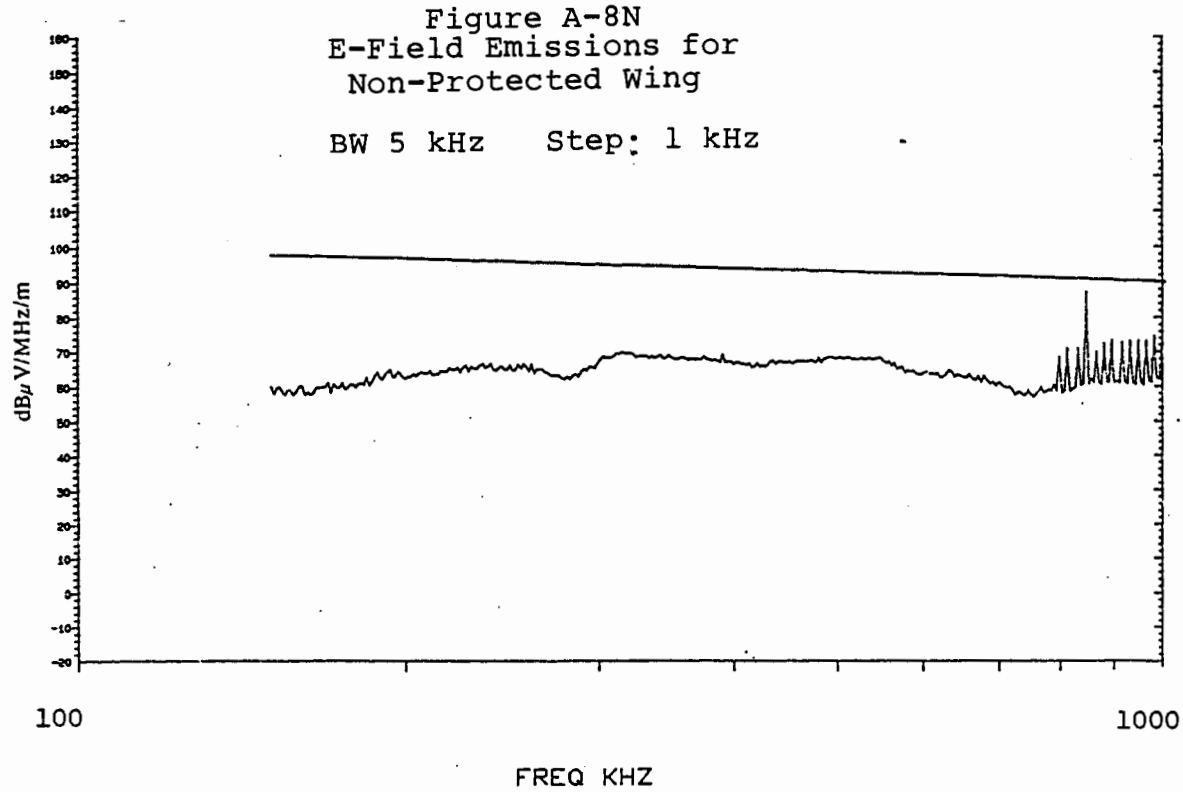


Figure A-9P
E-Field Emissions for Lightning
Protected Wing

BW 50 kHz Step 10 kHz

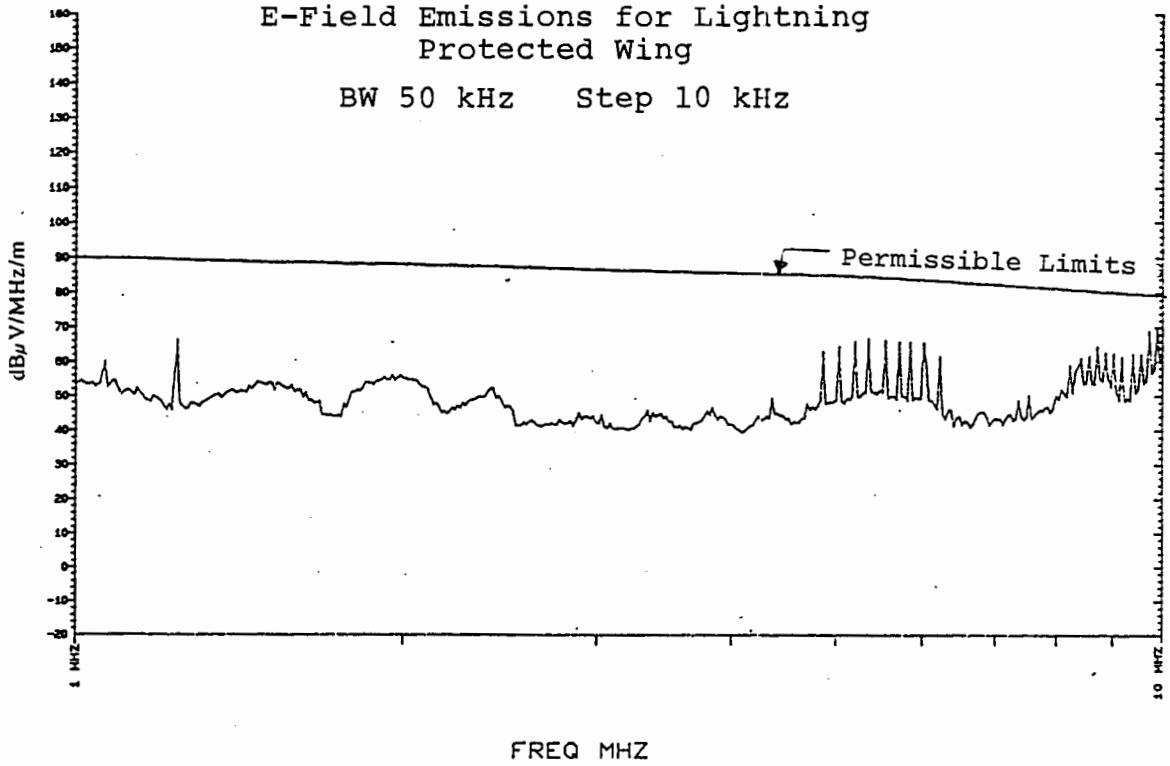
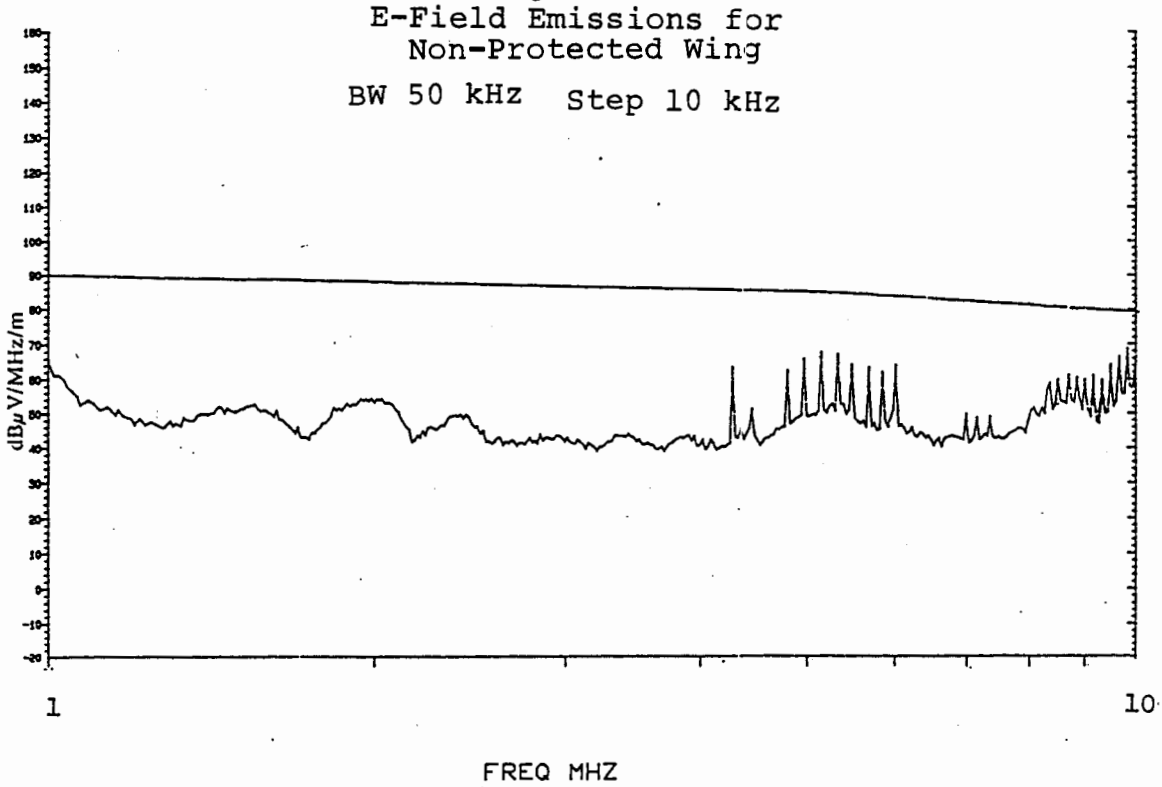


Figure A-9N
E-Field Emissions for
Non-Protected Wing

BW 50 kHz Step 10 kHz



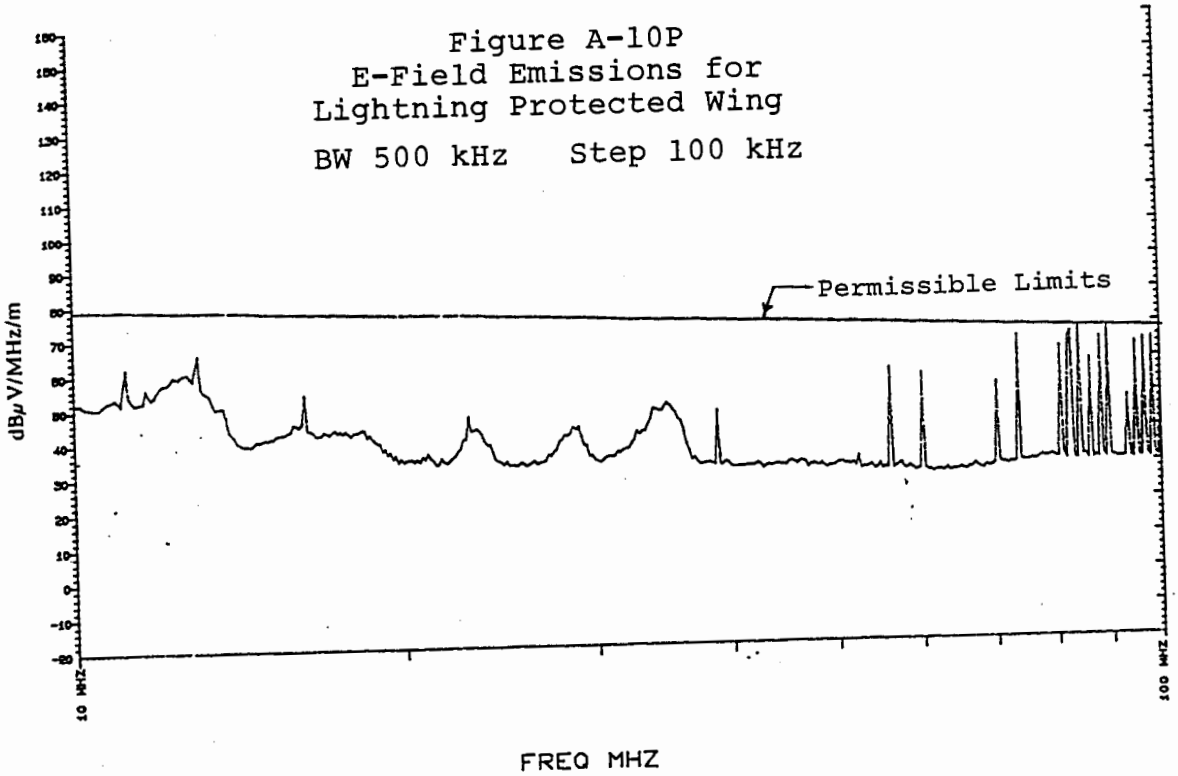


Figure A-10P
E-Field Emissions for
Lightning Protected Wing
BW 500 kHz Step 100 kHz
Permissible Limits
dBμV/MHz/m
10 MHZ
100 MHZ
FREQ MHZ

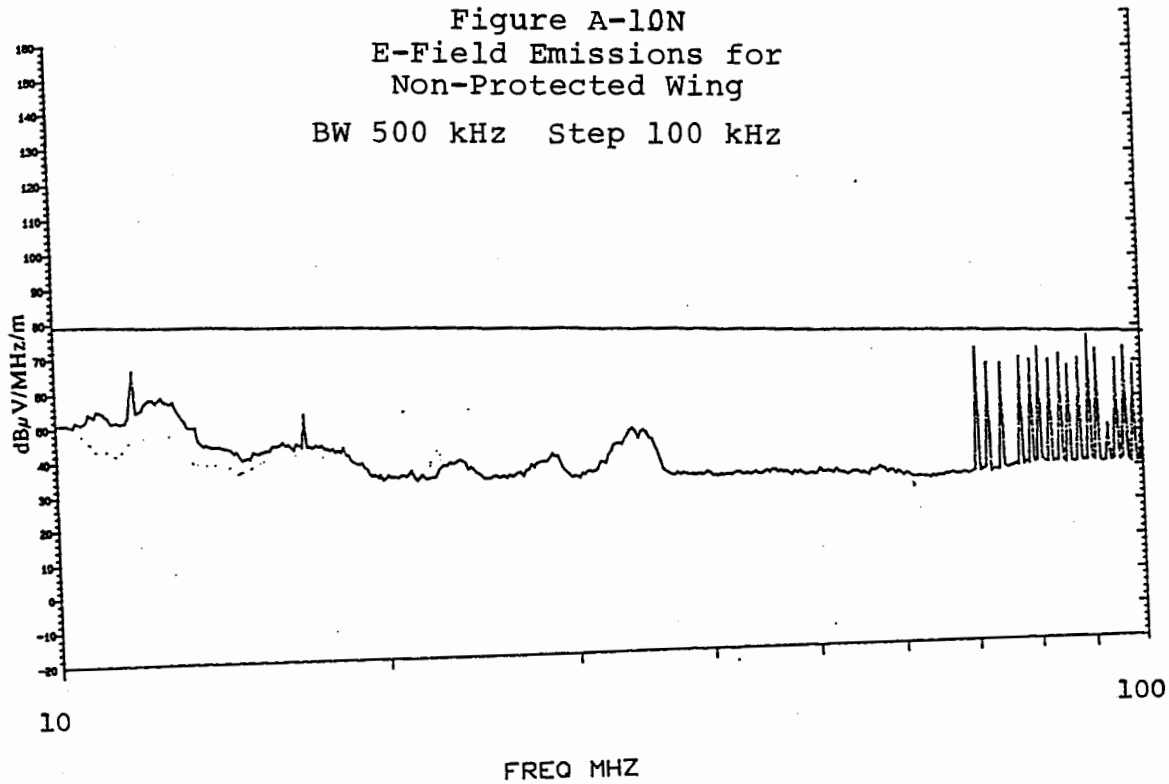


Figure A-10N
E-Field Emissions for
Non-Protected Wing
BW 500 kHz Step 100 kHz
dBμV/MHz/m
10
100
FREQ MHZ

Figure A-11P
E-Field Emissions for
Lightning Protected Wing
BW 5 MHz Step 1 MHz

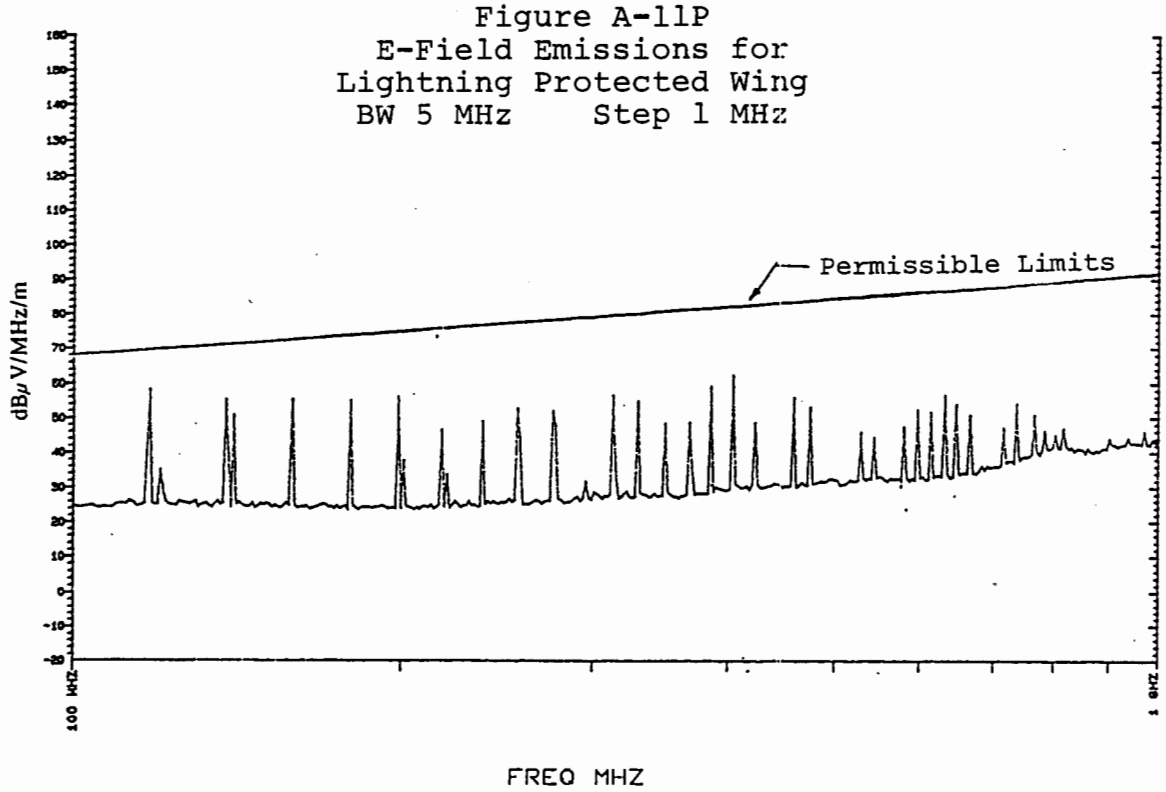
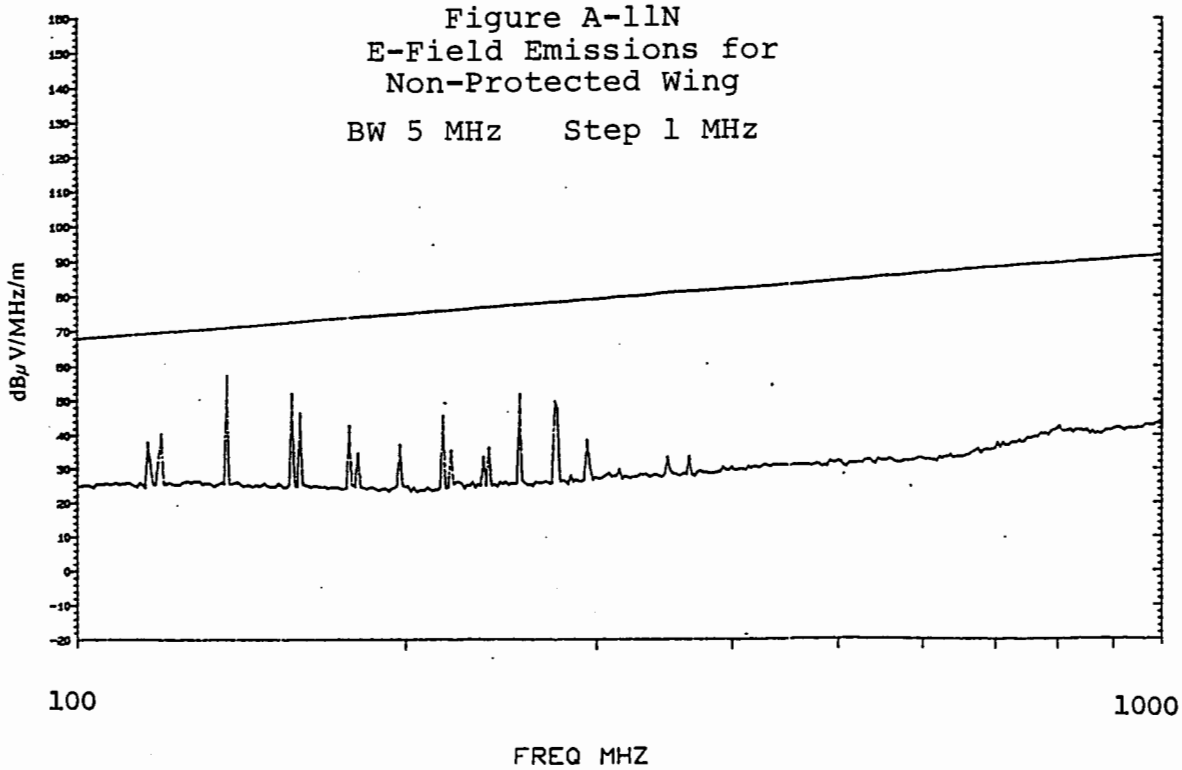


Figure A-11N
E-Field Emissions for
Non-Protected Wing
BW 5 MHz Step 1 MHz



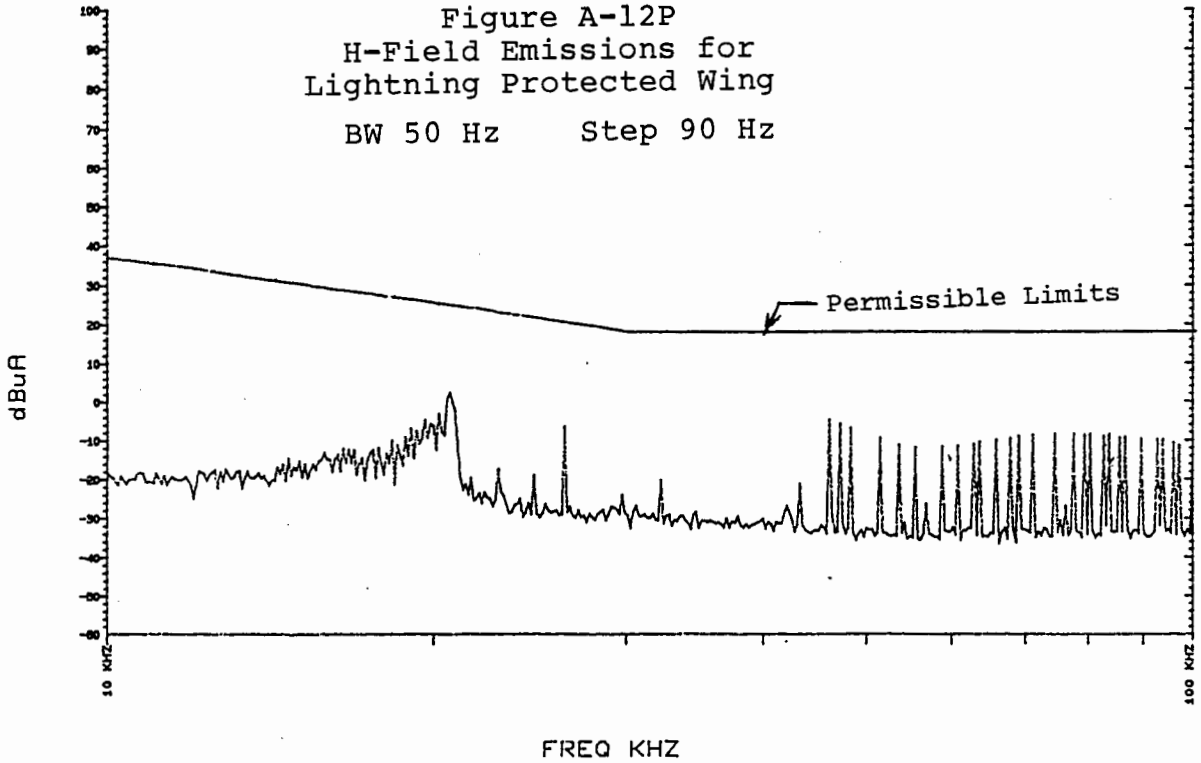


Figure A-12P
H-Field Emissions for
Lightning Protected Wing
BW 50 Hz Step 90 Hz
Permissible Limits
dBuA
10 KHZ
100 KHZ
FREQ KHZ

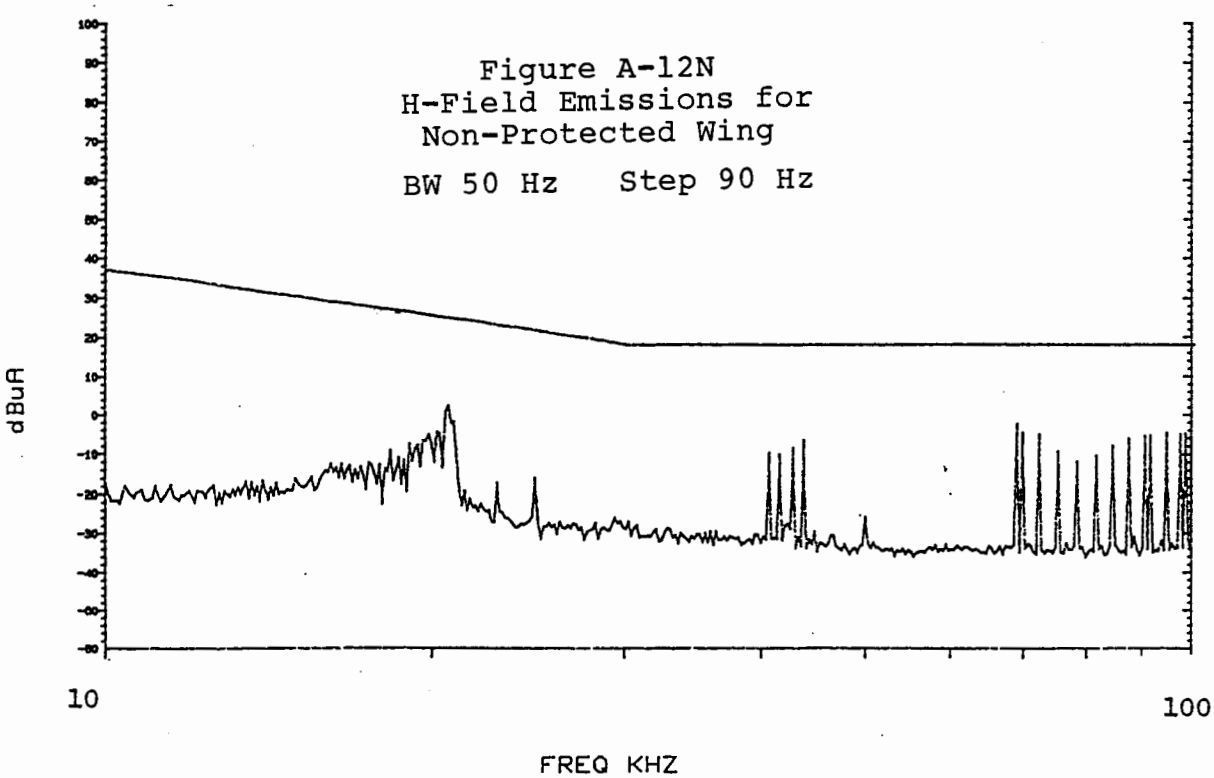


Figure A-12N
H-Field Emissions for
Non-Protected Wing
BW 50 Hz Step 90 Hz
dBuA
10
100
FREQ KHZ

Figure A-13P
H-Field Emissions for
Lightning Protected Wing

BW 500 Hz Step 900 Hz

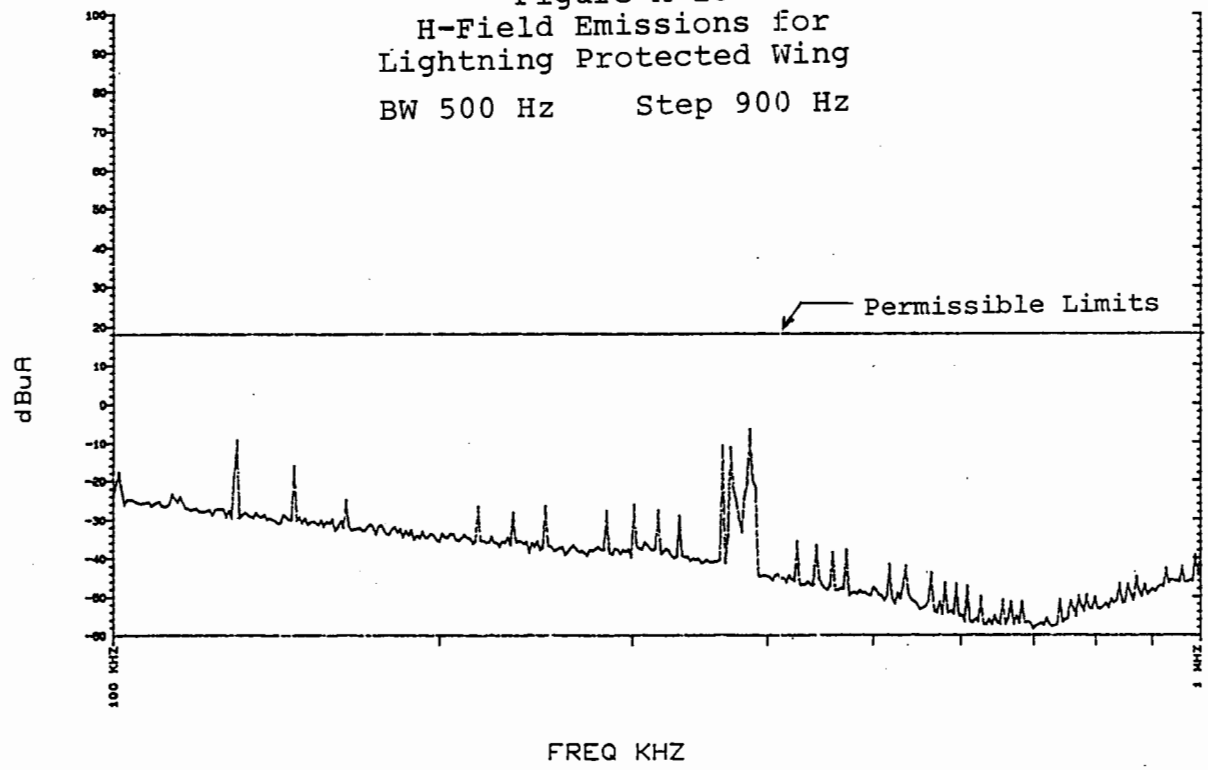
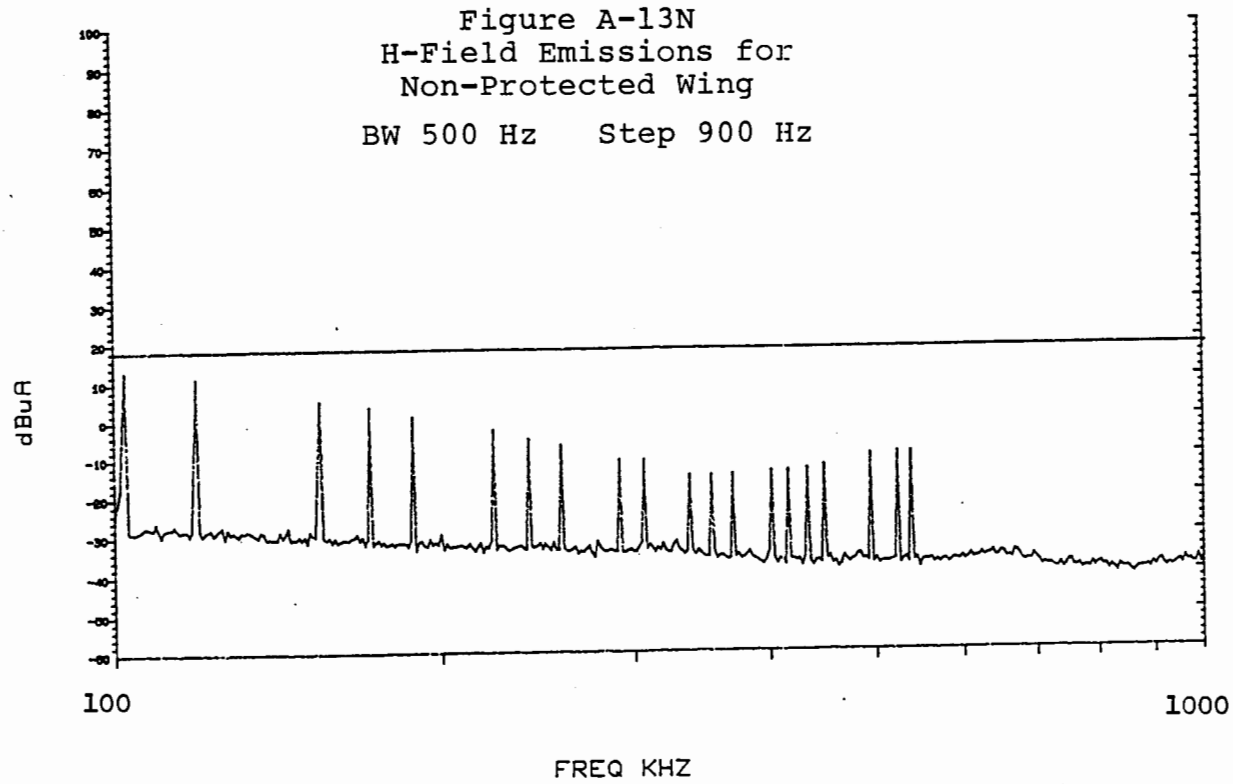


Figure A-13N
H-Field Emissions for
Non-Protected Wing

BW 500 Hz Step 900 Hz



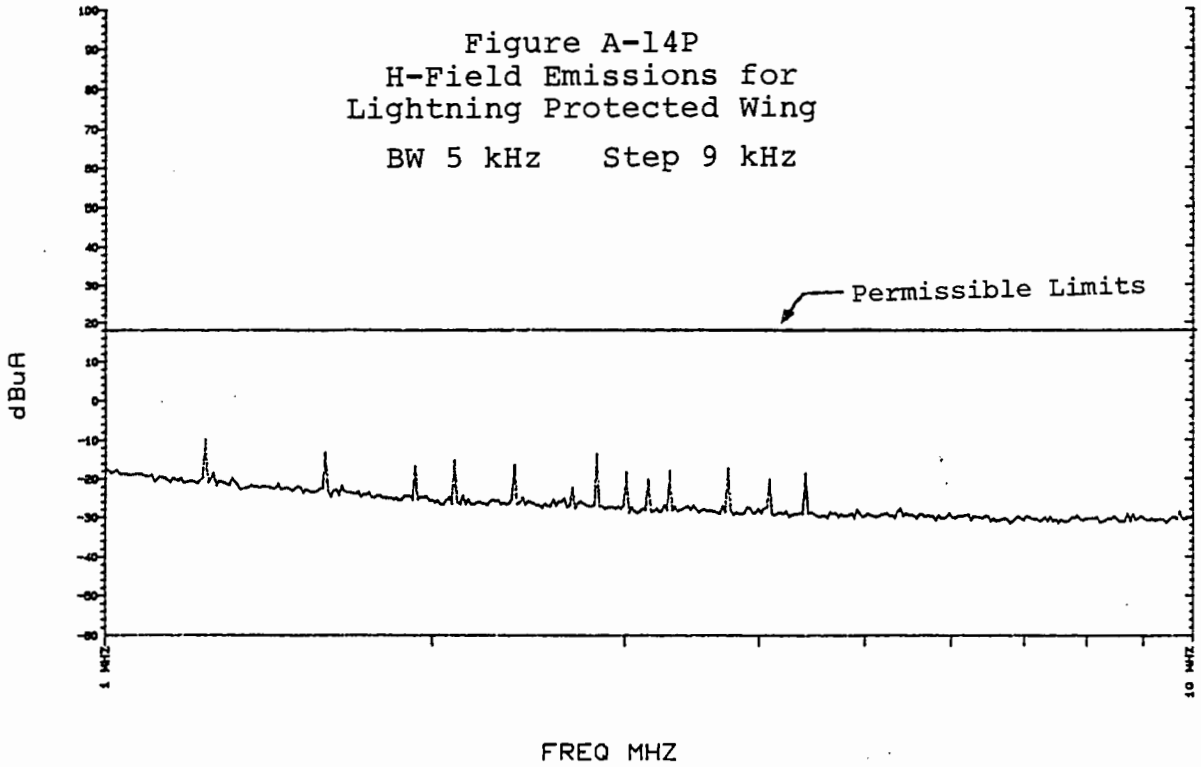


Figure A-14P
H-Field Emissions for
Lightning Protected Wing
BW 5 kHz Step 9 kHz
Permissible Limits
dBuA
FREQ MHZ

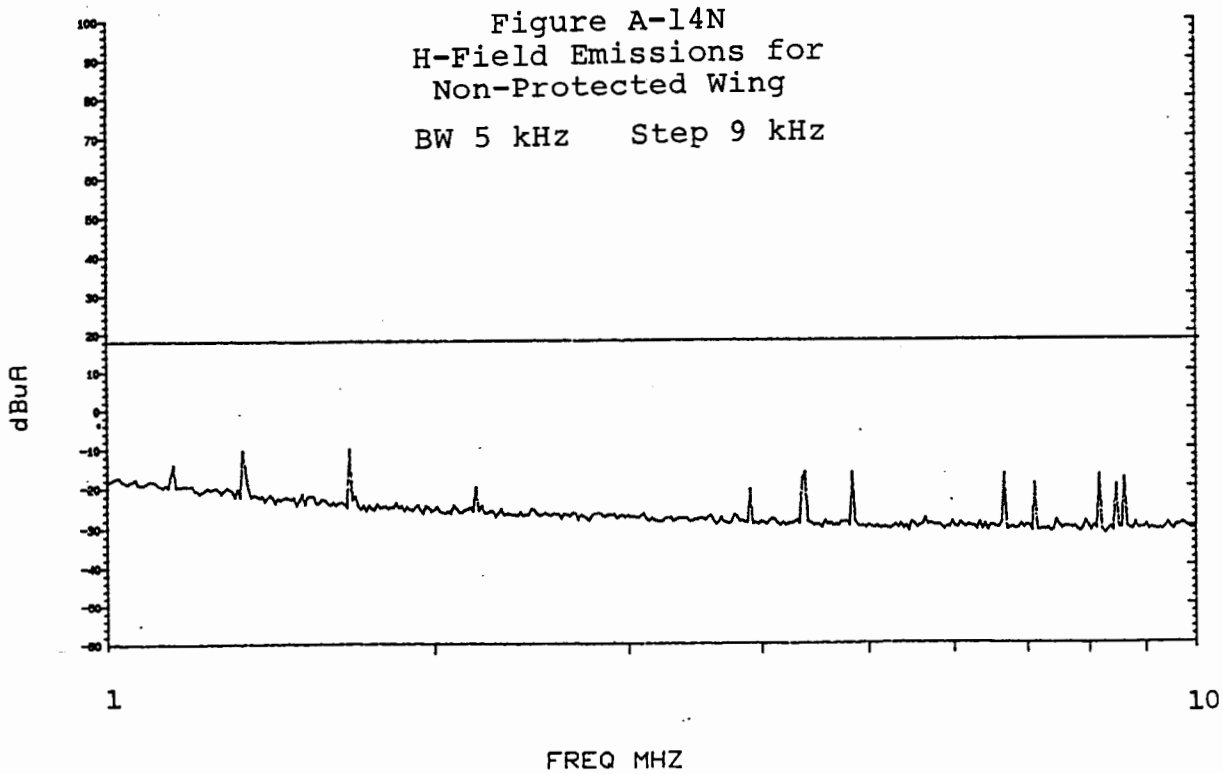


Figure A-14N
H-Field Emissions for
Non-Protected Wing
BW 5 kHz Step 9 kHz
dBuA
1
10
FREQ MHZ