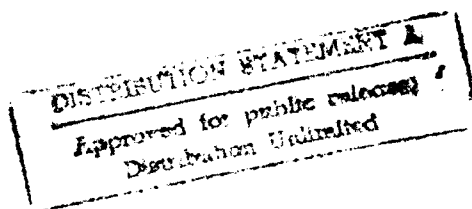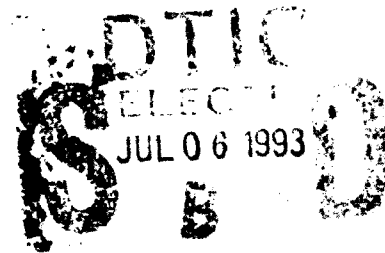National Défense
Defence nationale

EMP HARDENING INVESTIGATION
OF THE PRC-77 RADIO SET

by

J.S. Seregelyi, C. Gardner, J.A. Walsh and R. Apps

93-15159

DEFENCE RESEARCH ESTABLISHMENT OTTAWA
REPORT NO. 1167

Canada

February 1993
Ottawa

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Radiation Effects Section
Electronics Division

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ABSTRACT

The susceptibility of a PRC-77 Radio to a simulated nuclear electromagnetic pulse (EMP) was investigated. Detailed evaluation procedures and results are presented. It is shown that under normal operating conditions, with either the 72-cm or 2.9-m antenna, it is very unlikely that there will be any damage to the radio in the event of an EMP. It should be noted that this was one of the first evaluations performed in the Defence Research Electromagnetic Pulse Simulator (DREMPS) and the investigation was viewed primarily as a means of optimizing general analysis techniques.

RÉSUMÉ

Ce rapport analyse la susceptibilité du radio PRC-77 aux impulsions électromagnétiques (IEM) simulées. Une étude détaillée des procédures d'évaluation et des résultats est présentée. Il est démontré que sous des conditions normales d'opération, avec une antenne de 72 cm ou de 2.9 m, il est peu probable que le radio soit endommagé par les impulsions. Cette évaluation a été l'une des premières à utiliser le simulateur d'IEM de 10 m du CRDO et elle doit aussi être considérée comme un exercice pour optimiser les techniques d'analyse.

DTIC QUAL... 3

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EXECUTIVE SUMMARY

The purpose of this investigation was to determine the susceptibility of the PRC-77 Radio to the electromagnetic fields produced by a nuclear electromagnetic pulse (EMP). In addition, this was one of the first evaluations performed in the Defence Research Electromagnetic Pulse Simulator (DREMPS) and was viewed as a means of optimizing general analysis techniques. As a result, procedural simplifications in the radio analysis were considered acceptable in so far as no serious compromise was made in the validity or conclusions of the investigation.

The results of the radiated susceptibility investigation indicate that the radio, when equipped with either the 72-cm or the 2.9-m antenna, will survive exposure to an EMP with negligible changes to the operating system. In general, the work performed for this report has been an excellent opportunity to explore the dynamics of the field interaction both with the radio (and its antennae) and within the EMP simulator. The results have gone a long way in helping to understand the behaviour of these systems and, by using this knowledge, many of the minor difficulties encountered in this evaluation can easily be avoided or corrected in future testing.

TABLE OF CONTENTS

Radio Set PRC-77 EMP Hardening Investigation

1.0 INTRODUCTION

The purpose of this investigation was to determine the susceptibility of the PRC-77 Radio to the electromagnetic fields produced by a nuclear electromagnetic pulse (EMP). The characteristics of the EMP are to be defined by the RS05 requirement as specified in MIL-STD-461C, Part 4, and the RS05 test methods as specified in MIL-STD-462, Notice 5.

It should be noted that this was one of the first EMP evaluations performed in the Defence Research Electromagnetic Pulse Simulator (DREMPS) and there are no clients requesting specific results with respect to this unit. The investigation was viewed primarily as a means of optimizing the facility and establishing analysis techniques. As a result, procedural simplifications were considered acceptable in so far as no serious compromise was made in the validity or conclusions of the investigation.

The evaluation proceeded in two phases: the first occurred in the spring of 1991 and involved exposure of the radio in a 1-meter parallel-plate simulator. The latter was performed in November of 1992 and took place in the 10-meter parallel-plate simulator (DREMPS). The schedule was executed in this fashion simply because the radio and its antennae were physically too large to be fully exposed in the smaller simulator and the larger facility was not available earlier.

2.0 UNIT DESCRIPTION

Radio set RT-841/PRC-77 is a portable, battery-powered transmitter/receiver tunable in 50-kHz increments over a frequency range of 30.00 to 75.95 MHz to provide 920 channels. The frequency range is covered in two bands: the low band is 30.0 to 52.95 MHz; the high band is 53.00 to 75.95 MHz. The front panel tuning controls and the BAND switch are used for tuning the radio to the desired frequency[1]. For schematics and detailed working principles of the radio consult Ref. 2 & 3. The unit has the following dimensions:

Component	Overall Dimensions (cm)			Weight (kg)
	Height	Width	Depth	
Radio Set RT-841/PRC-77 serial no. 122 stock no. 5820-00-930-3725	28	28	10	6
Antenna, AT-892/PRC-25	72	---	---	.23
Antenna, AT-271B/PRC	290	---	---	.35
Handset, H-189/GR	20	5	7.5	1.8

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[1] See Figure 1 for a radio part list and detailed view of the control features. Figure 2 is an indication of how the radio is typically worn.

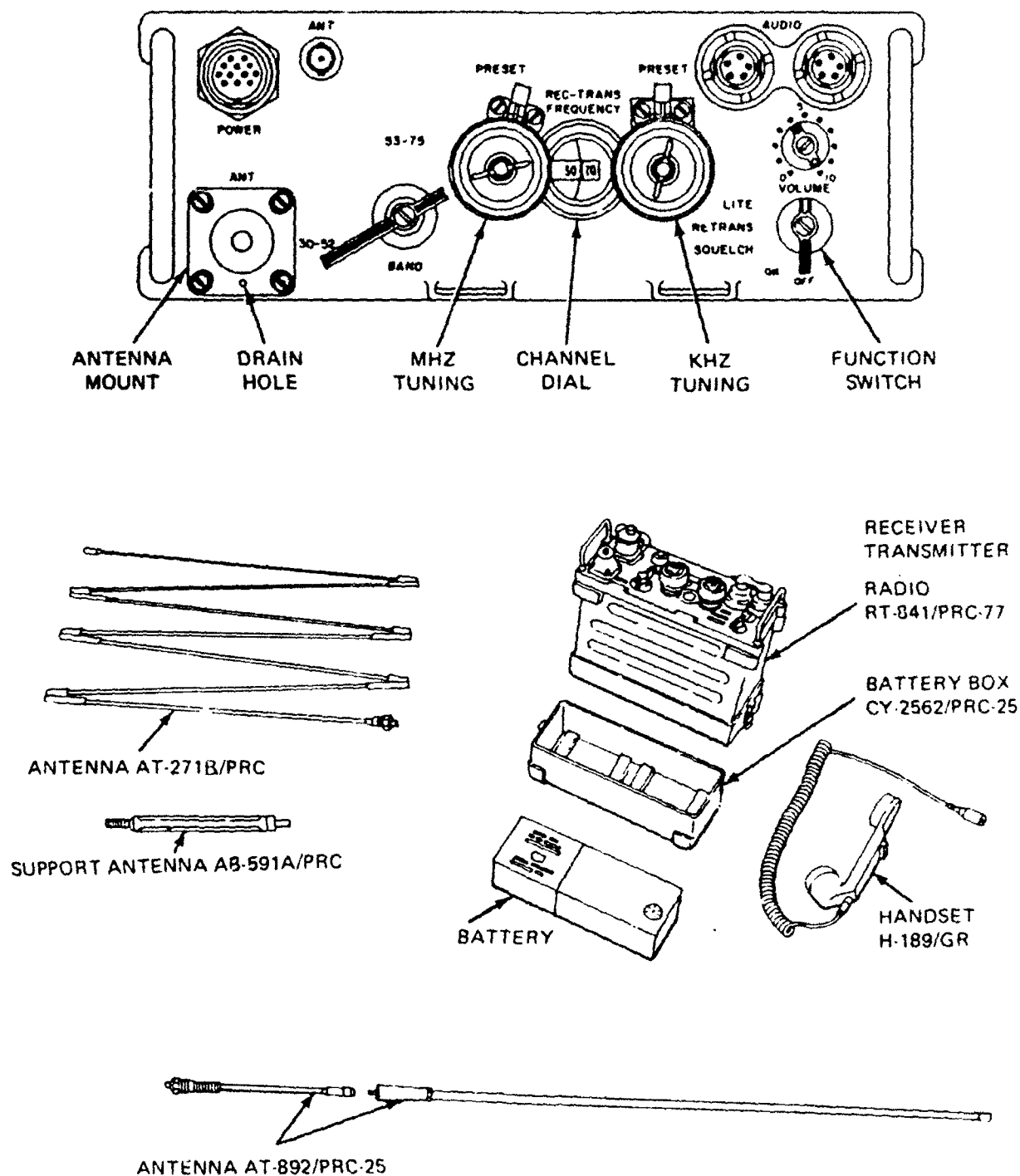Figure 1: Control panel detail and parts list for the PRC-77 radio. Only the PRC-25 antenna is tested with the RS05 method.
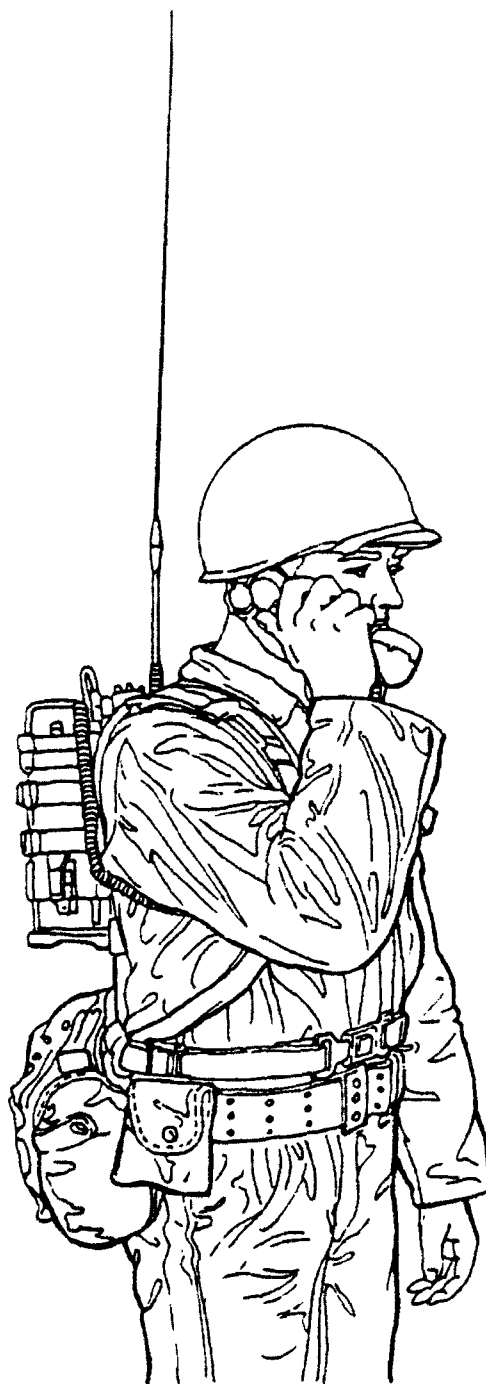
Figure 2: PRC-77 radio as typically worn in the field. Ideally the EMP testing should be performed with the antenna and handset in a similar configuration. Also, the soldier's body and the fact that the radio is approx. 1.5 meters above the ground should also be simulated.

It should be noted that the PRC-77 has been in service for several years and a number of design modifications have been implemented. Apparently, all these changes have not been made to each unit and, therefore, the investigation may be influenced by the status of the radio. The serial number of the unit used in this evaluation is recorded above so that its repair history may be consulted.

3.0 DESCRIPTION OF FACILITIES

The radio evaluation was carried out in the Defence Research Establishment Ottawa (DREO) EMP Laboratory. The facilities used for radiated susceptibility (RS05) include:

- a 1-meter, parallel-plate EMP simulator (Fig .3)
- the DREO, 50-kV, EMP generator
- the DREO 10-meter, parallel-plate EMP simulator DREMPS (Fig .4)
- a Maxwell, 600-kV EMP generator
- shielded enclosures
- various electric and magnetic field sensors
- data acquisition and signal processing equipment and software.

4.0 RADIATED SUSCEPTIBILITY SET-UP AND PROCEDURE

It was postulated that the major threat to the radio would come from coupling of the EMP field to the antenna and the handset. Direct field penetration into the equipment case would not be a problem since it is made of metal and the apertures are very small (an examination of the set showed it to be well constructed with individually screened interior compartments within the metal case). These assumptions were verified during the RS05 exposure.

In phase one of the evaluation it was apparent that a problem existed. The heights of the radio antennae were too large for the 1-m simulator[2]. As a result, the 72-cm antenna was modified by reducing its height to 50-cm and capping it with a 20-cm top plate (an empirically derived substitution which was experimentally shown to produce the same EMP response. The details are presented in Annex A). Unfortunately, the 2.9-m antenna could not be altered in a similar fashion.

Phase two was performed in the 10-m parallel plate simulator DREMPS. This facility could easily accommodate either the 72-cm or 2.9-m antennae. Since portions of the full radio evaluation would have been redundant given the efforts of phase one, an effort was made to concentrate on results which could not be obtained earlier. Measurements of the magnetic field, antenna currents and handset currents were made and recorded. Details are available in Annex B.

4.1 Installation of the Units

In both phase one and two of the investigation the radio was placed at the end of the front taper of the EMP simulator as shown in Fig. 3. This method of installation is in accordance with the RS05 test methods of MIL-STD-462. Equipment not undergoing evaluation and the data acquisition and analysis equipment were located inside the shielded room.

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[2] The simulator is a transmission line calibrated to produce the correct field magnitude and shape. By placing an object inside the line the field is perturbed. The general rule of thumb is that for testing, the height of the object-under-test should not exceed approximately half the height or width of the line.
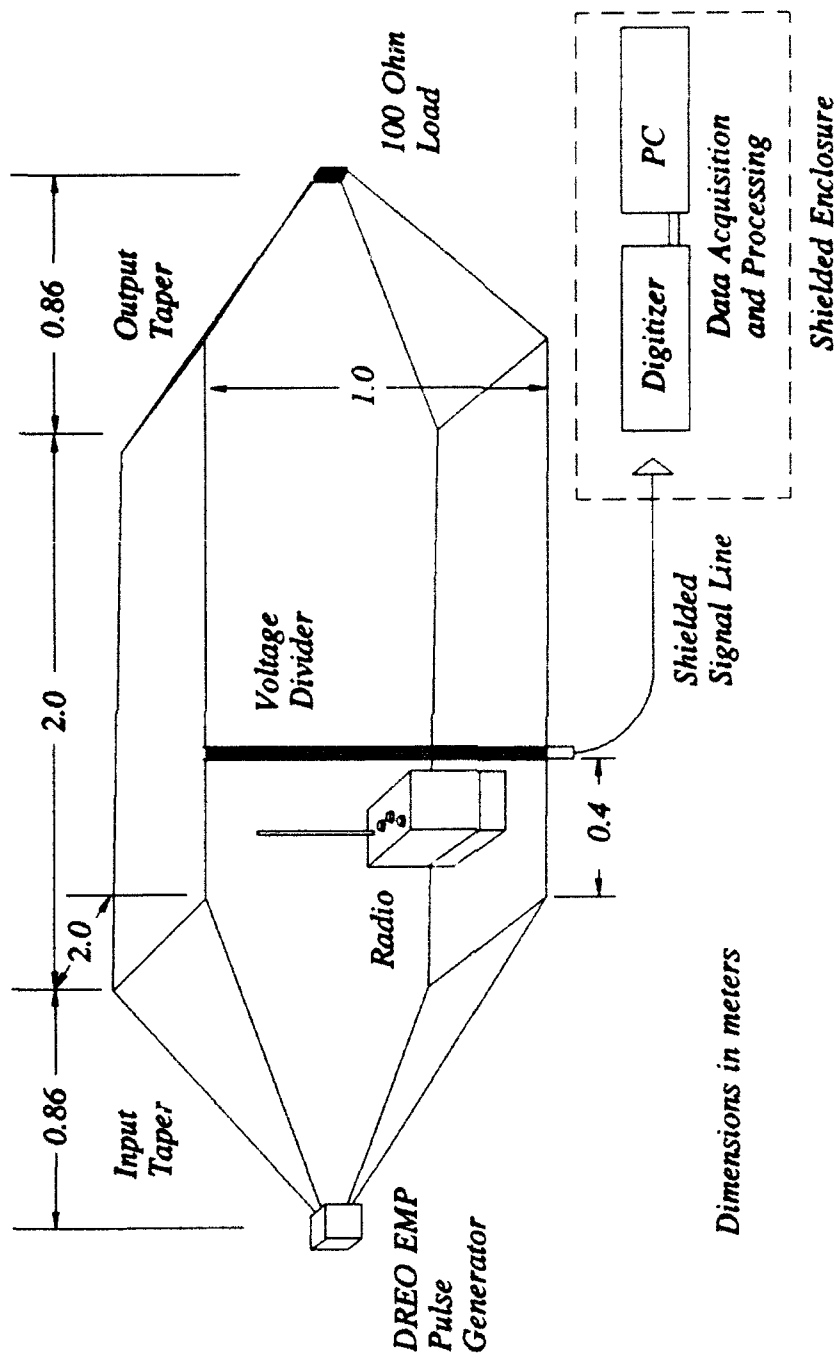
Figure 3: Schematic representation of the parallel-plate EMP simulator showing the radio placement, measurement point and measurement system.
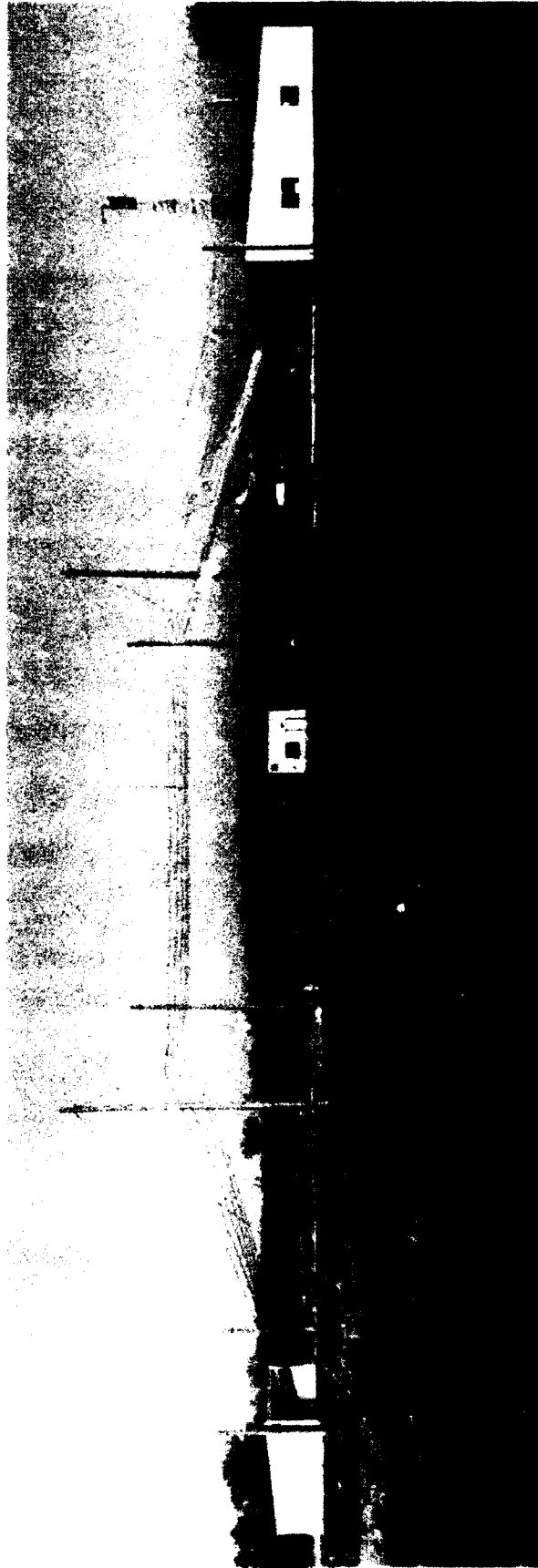
Figure 4: Photograph of the EMP simulator DREMPS located at the Defence Research Establishment in Ottawa. The transmission line is 10 m high, 20 m wide and approx 100 m long. The building on the right houses the 600 kV pulse generator, the building on the left is the terminating resistor and small building in the central background is the measurement room. At the time of the photograph an iLTIS jeep (located at the end of the front taper) is being EMP tested.

4.2 Unit Configurations

4.2.1 Phase One

The radiated susceptibility (RS05) evaluation was carried out in the following configurations:

1) The radio in the 1-m simulator with no antenna attached (Fig. 5a)
2) The radio approximately ½-m outside of the simulator with a fully extended 72-cm antenna (Fig. 5b). This location produces a sub-threat level field of approx. 20 kV/m.
3) The radio in the simulator with a modified plate antenna (Fig. 5c) (see Annex A).

4.2.2 Phase Two

Radiated susceptibility was only carried out with the radio centrally placed at the end of the input taper of the 10-m simulator in a configuration similar to that of Fig. 5c. This location provides the optimal EMP wave shape.

4.3 Unit Orientations

4.3.1 Phase One

Radiated susceptibility was also done in three different orientations:

1) With the front[3] of the radio facing the input of the parallel-plate cell (Fig. 6a)
2) With the front of the radio facing the side of the parallel-plate cell (Fig. 6b)
3) With the front of the horizontally inclined radio facing down (Fig. 6c).

However, not all orientations were exposed in each configuration. A detailed plan showing the configurations and orientations used (in chronological order) is presented in Table 1.

4.3.2 Phase Two

Since the vast majority of the pick-up is through the antenna and not the radio case, orientations 1 and 2 are clearly equivalent and worst-case scenarios. As a result, the RS05 evaluation in this phase was only done with the front of the radio facing the source and the antenna vertically extended.

4.4 Equipment Status

4.4.1 Phase One

The radio was examined in both power on and off state in configuration 1 but only in the power on state in the other configurations. As a procedural simplification the transmit mode was not investigated. The evaluation was done at 3 different receiving frequencies (30, 50 and 75 MHz) in all configurations and orientations. The specific values chosen represent the highest, lowest and middle frequencies of the operating band and are an attempt to maximize the coupling between the induced antenna currents and the radio. The handset was also incorporated into the system after the antenna analysis was complete. This was done so that if damage had occurred there would be some possibility of isolating problems introduced by the antenna and handset.

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[3] The front of the radio is defined such that the antenna of the unit is perpendicular to the ground and the labels on the radio controls are legible.

Test Positions
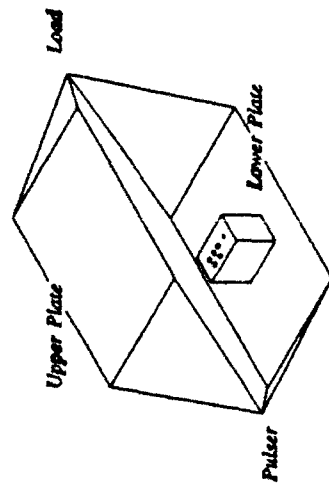
Figure 5a: First test position - radio in center of simulator with no antenna.
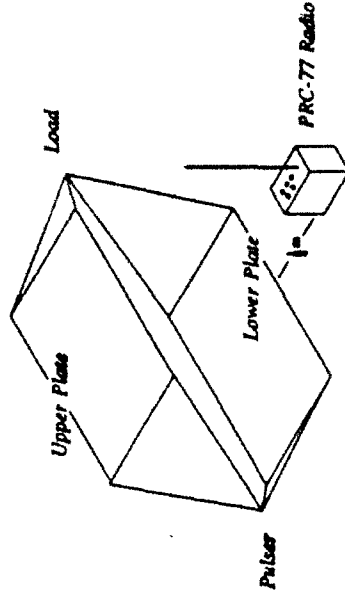
Figure 5b: Second test position - radio approximately 1/2-m outside cell
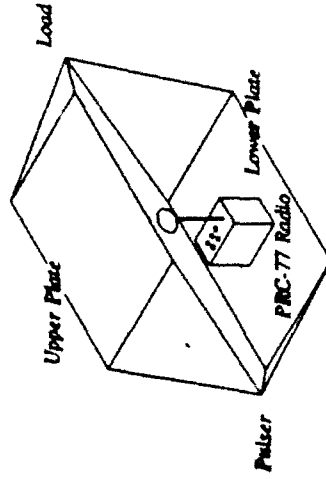
Figure 5c: Third test position - radio in center of simulator with plate antenna.

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Test Orientations
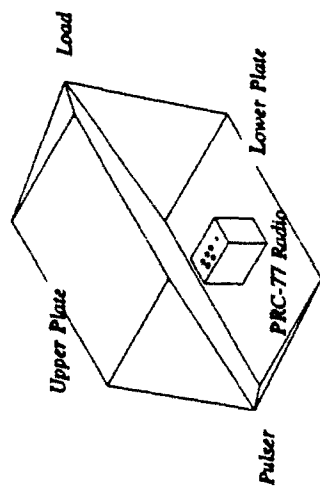
Figure 6a: First test orientation - front of
radio facing input of cell

Figure 6b: Second test orientation - front of
radio facing side of cell
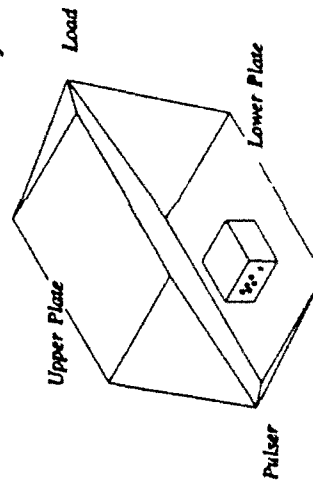
Figure 6c: Third test orientation - front of
radio facing down

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Test Sequence for the PRC-77 Radio

verbal/audio test and initial quantitative test

```
                                          ┌─ 30 MHz  (F.1.1.30)
                      ┌─ Orientation 1 ───┼─ 50 MHz  (F.1.1.50)
                      │                   └─ 75 MHz  (F.1.1.75)
                      │
                      │                   ┌─ 30 MHz  (F.1.2.30)
Power Off ── Configuration 1 ─── Orientation 2 ─┼─ 50 MHz  (F.1.2.50)
                      │                   └─ 75 MHz  (F.1.2.75)
                      │
                      │                   ┌─ 30 MHz  (F.1.3.30)
                      └─ Orientation 3 ───┼─ 50 MHz  (F.1.3.50)
                                          └─ 75 MHz  (F.1.3.75)
```

verbal/audio test

Sample Code

(N.1.1.50.reg)

Power Status (on, off)
Configuration (Fig. 5)
Orientation (Fig. 6)
Radio Frequency (MHz)
Antenna Type or handset presence

```
                                          ┌─ 30 MHz  (N.1.1.30)
                      ┌─ Orientation 1 ───┼─ 50 MHz  (N.1.1.50)
                      │                   └─ 75 MHz  (N.1.1.75)
                      │
                      │                   ┌─ 30 MHz  (N.1.2.30)
Power On ── Configuration 1 ─── Orientation 2 ─┼─ 50 MHz  (N.1.2.50)
                      │                   └─ 75 MHz  (N.1.2.75)
                      │
                      │                   ┌─ 30 MHz  (N.1.3.30)
                      └─ Orientation 3 ───┼─ 50 MHz  (N.1.3.50)
                                          └─ 75 MHz  (N.1.3.75)
```

verbal/audio test

```
                                          ┌─ 30 MHz  (N.3.1.30.reg)  ┐
                                          ├─ 50 MHz  (N.3.1.50.reg)  ├ Regular Antenna (72-cm)
                                          └─ 75 MHz  (N.3.1.75.reg)  ┘
Power On ── Configuration 3 ── Orientation 1 ─┤
                                          ┌─ 30 MHz  (N.3.1.30.plt)  ┐
                                          ├─ 50 MHz  (N.3.1.50.plt)  ├ Plate Antenna
                                          └─ 75 MHz  (N.3.1.75.plt)  ┘
```

verbal/audio test

```
                                          ┌─ 30 MHz  (N.2.1.30.nhd)  ┐
                      ┌─ Orientation 1 ───┼─ 50 MHz  (N.2.1.50.nhd)  │
                      │                   └─ 75 MHz  (N.2.1.75.nhd)  │ Plate Antenna
Power On ── Configuration 2 ─┤                                       ├ no handset attached
                      │                   ┌─ 30 MHz  (N.2.2.30.nhd)  │
                      └─ Orientation 2 ───┼─ 50 MHz  (N.2.2.50.nhd)  │
                                          └─ 75 MHz  (N.2.2.75.nhd)  ┘
```
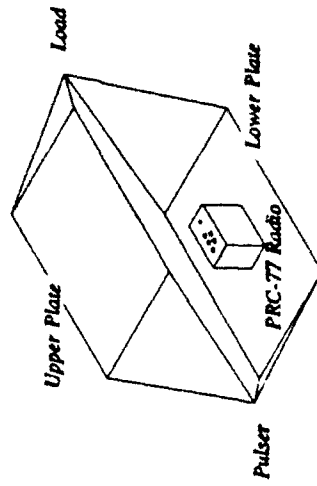
verbal/audio test

```
                                          ┌─ 30 MHz  (N.2.1.30.whd)  ┐
                      ┌─ Orientation 1 ───┼─ 50 MHz  (N.2.1.50.whd)  │
                      │                   └─ 75 MHz  (N.2.1.75.whd)  │ Plate Antenna
Power On ── Configuration 2 ─┤                                       ├ with handset attached
                      │                   ┌─ 30 MHz  (N.2.2.30.whd)  │
                      └─ Orientation 2 ───┼─ 50 MHz  (N.2.2.50.whd)  │
                                          └─ 75 MHz  (N.2.2.75.whd)  ┘
```

verbal/audio test and final quantitative test

Table 1: A list of the coding used to identify the configurations, orientations and status of the PRC-77 Radio.

4.4.2 Phase Two

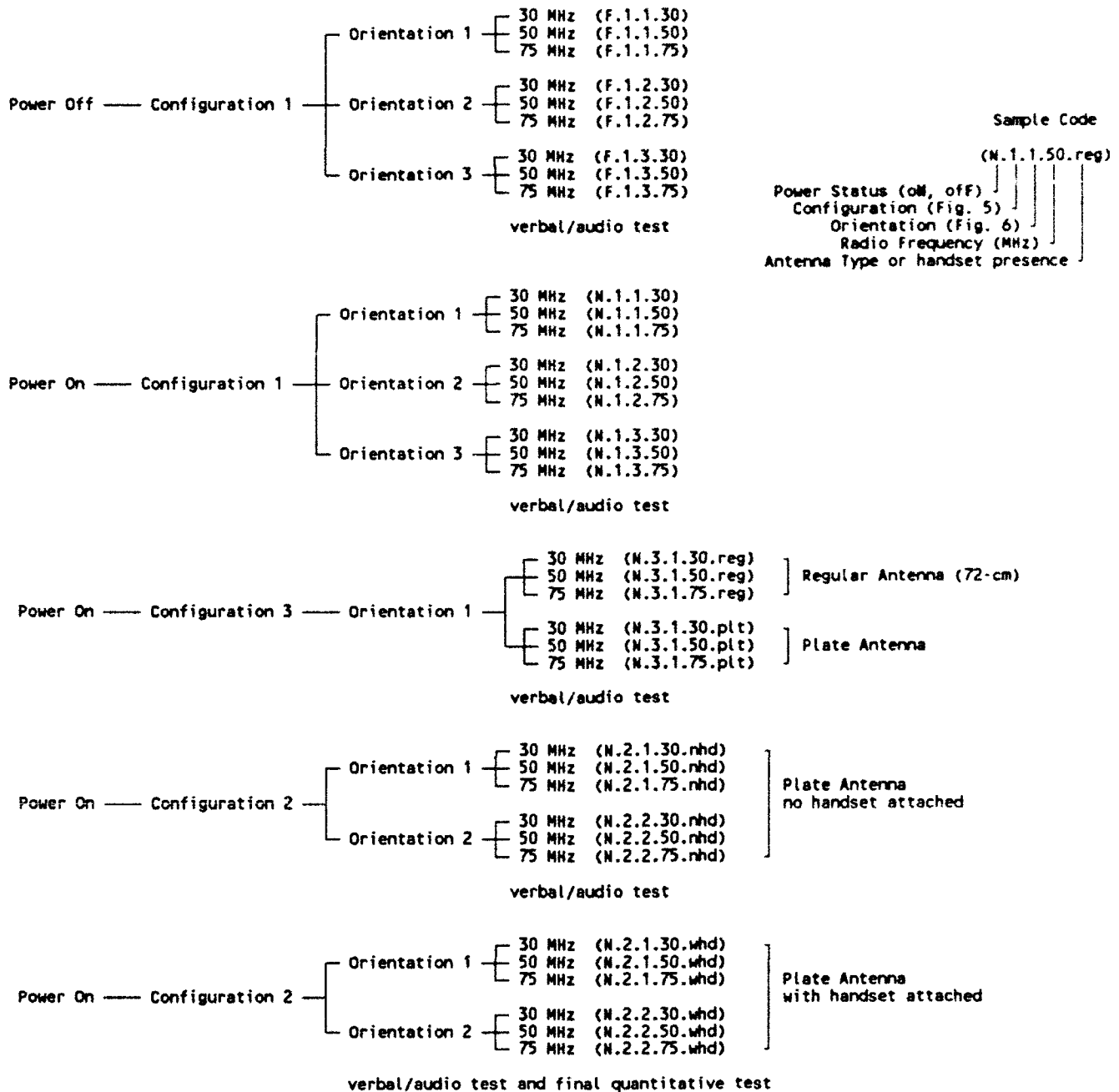The radio was examined with power on and at 3 different frequencies (30.20, 45.00 and 70.00 MHz). Both transmitting and receiving mode were investigated. A radio is usually most susceptible in its receive mode, however it is conceivable that the EMP response will superimpose on a transmitting waveform such that damage will occur when it would not have if the radio was subjected to either input separately.

As before, the evaluation proceeded in stages to minimize damage to the radio (had any occurred) and to maximize the information obtained. Initial radio exposures were done at 30 kV/m and the handset was incorporated only after the antenna exposure. In addition, in order to provide an intermediate height (between 72-cm and 2.9-m), a 2.1-m antenna was created by folding a 2.9-m antenna at one of its joints.

4.5 Susceptibility Criteria

The operation of the radio was demonstrated prior to and after the evaluation. In addition, quick intermediate checks were performed during EMP exposure. The radio was considered to have failed when either of the following occurred:

a) There was a catastrophic failure of the radio.

b) There was evidence of serious degradation of the radio.

Details of the radio checks are presented in Annex C, however, the procedures can be summarized as follows:

a) The first is a simple voice check where an audible test signal is transmitted and received between the radio being evaluated and a similar monitor radio. Alternatively, monitoring the amplitude of the 150 Hz signal (used to control the squelch) with a fixed receive and transmit antenna position is considered to be an enhanced audio check.

b) The second is a quantitative test performed by injecting an accurate FM signal into the co-axial antenna of the radio and monitoring the audio output at the unit's handset. The time and frequency domain of this signal were monitored while small changes were made to the FM modulation, carrier amplitude and carrier central frequency. The process was repeated at the beginning and end of the EMP evaluation in an effort to observe any small changes which may have been introduced by the exposures. Note that this latter test will not detect changes in either the transmit mode of the radio or the initial antenna tuning circuit.

4.6 General Procedure

The following steps were taken in the RS05 evaluation of the radio:

a) Calibration of the pulse generator in the absence of the PRC-77 to establish the unperturbed electric field wave shape.

b) Verification of the functional operation of the radio followed by installation of the unit in the first orientation.

c) Exposure of the radio to a minimum of 10 EMP pulses in accordance with MIL-STD-462, RS05 specification. The characteristics of the field to which the radio is exposed was measured and recorded.

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d) Steps (b) & (c) are to be repeated until all orientations are complete. Following exposure of the unit functional operation of the radio is to be verified.

e) Exposure of the radio in the other configurations is then to be carried out following the procedures outlined in (b) to (d) above.

5.0 DESCRIPTION OF INSTRUMENTATION

5.1 Phase One

Instruments used to generate the fields required for the EMP evaluation include;

- High-voltage power supply (Glassman, 75-kV DC, model PS/ER75R3.0),
- DREO double exponential EMP pulse generator,
- 1-meter, parallel-plate cell (Elgal, model no. EM 102).

Instrumentation used to measure the fields during the RS05 investigation include;

- Voltage divider (Physics International, model PIM-197A-1,
- Variable attenuator (Alan, model no. 50TX82.5N),
- Digitizer (Tektronix, model no. DSA 602; 400 MHz bandwidth),
- 10 meters RG-214 co-axial cable (double shielded).

Instrumentation used in conjunction with the PRC-77 during the RS05 investigation include;

- Standard AT-892, 72-cm antenna,
- Modified plate antenna (see Annex A).

Instrumentation used in conjunction with the PRC-77 during performance confirmation include;

- Signal Generator (Hewlett Packard, HP8656B),
- Digitizer (Tektronix, model no. DSA 602; 400 MHz bandwidth),
- a second PRC-77 monitor radio.

5.2 Phase Two

Instruments used to generate the fields required for the EMP evaluation include;

- DREO 10-meter parallel-plate simulator, DREMPS,
- Maxwell 600-kV double exponential EMP pulse generator.

Instrumentation used to measure the fields during the RS05 investigation include;

- DREO 5-cm H-Field loop probe,
- Eaton current probes, model no. 94106-2, 93686-7,
- 2 Nanofast 300 MHz fiber optic analog links,
- Digitizer (Tektronix, model no. DSA 602; 400 MHz bandwidth),
- Digitizer (Tektronix, model no. SCD 1000; 1 GHz bandwidth),
- various BNC and N-type co-axial cable.

Instrumentation used in conjunction with the PRC-77 during the RS05 investigation include;

- Standard AT-892, 72-cm antenna,
- Standard AT-271B, 2.9-m antenna,
- modified AT-271B, 2.1-m antenna (ie. folded at one of the joints).

Instrumentation used in conjunction with the PRC-77 during performance confirmation include;

- Signal Generator (Hewlett Packard, HP8656B),
- Digitizer (Tektronix, model no. DSA 602; 400 MHz bandwidth),
- a second PRC-77 monitor radio.

6.0 OBSERVATIONS AND CONCLUSIONS

6.1 RS05 Results

6.1.1 Phase One

Prior to the radio exposure, the EMP wave shape generated in an empty simulator was recorded (Fig. 7). The upper trace shows the envelope generated by 10 consecutive exposures and the lower trace is the average of the above. The high reproducibility of the waveforms ensures consistent exposure levels throughout the investigation. See Section 6.2.1 for a discussion of the wave shape.

Table 1 is the plan followed in the process of evaluating the PRC-77 radio. Each exposure represents a different orientation, configuration and radio status. At each point the radio was exposed to 10 EMP pulses with the average of these pulses recorded. Fig. 8 is the format used and is an indication of a typical waveform. The radio status is recorded in the upper-right corner and the simulator and sensor information is on the lower half of the page. The results, which are summarized in Table 2, indicate that the radio has passed the entire evaluation procedure when equipped with the 72-cm (or equivalent) antenna and the external handset.

6.1.2 Phase Two

Phase Two occurred approximately one year after Phase one and, as a result, several enhancements to the measurement system had been made. The most obvious of which was the completion of the 10 meter simulator, DREMPS, which allows the exposure of vehicle size equipment and eliminates the previous problems with the height of the radio antennae. Other more subtle but equally important changes include the development of an accurate H-field probe which, when used in conjunction with a fiber-optic transceiver, allows practically point source measurements of the magnetic and electric field in the simulator with almost no field perturbation. A second transceiver allows the current on the radio antenna or handset to be measured simultaneously. Finally, a sophisticated data acquisition package for the PC allows all these measurements to be quickly and accurately recorded for future reference and analysis.

The procedure followed in Phase One was essentially repeated at this point. Since the case of the radio was shown to be sufficiently shielded, that aspect of the evaluation was not repeated. The 72-cm antenna was exposed since in the previous phase only the modified plate could be used at full threat level. In addition, repeating the exposure of the smaller antenna allowed a confirmation of the previous results while affording an opportunity to make accurate antenna pick-up measurements (see Annex B).

Exposure of the 2.9-m antenna was also done in DREMPS. This proceeded by first exposing a 2.1-m antenna (ie. a 2.9-m antenna folded at one of the joints) to a sub-threat level 30 kV/m field. The full length

RSO5 TEST METHOD

Equipment Under Test Specifications

Device Type:	- - -
Test I.D.:	- - -
Configuration:	- - -
Orientation:	- - -
Receiver Frequency:	- - -
Power Status:	- - -
No. of Pulses:	10
Pulse Rate:	3/min
Operation Confirmed	- - -
Comments:	

EMP Simulator Specifications

Charging Voltage:	50 kV
Self-breakdown Voltage:	≈ 55 kV
Trigger Method:	Self-breakdown, pressure release

Sensor Specifications

		Sensor Specifications
Sensor Type:	PIM-197A-1 voltage divider	Sensor Type:
Sensor Location:	Right edge of center plate, 40 cm past front taper.	Sensor Location:
Cable Network:	Shielded N-Type, RG-214	Cable Network:
Attenuator Location:	20 dB (#3) on Alan 50TX82.5N at voltage divider	Attenuator Location:

Comments: Example of shot to shot deviation from average

Figure 7:   EMP wave shape as seen in an empty simulator. The measurement was made with a voltage divider located approximately 40 cm behind the front taper.

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 22-JAN-91 time: 14:53:01

EMP TEST DATA

RSO5 TEST METHOD

Tek ⬅➡ ░Custom░ ░Window░ ░░░░░
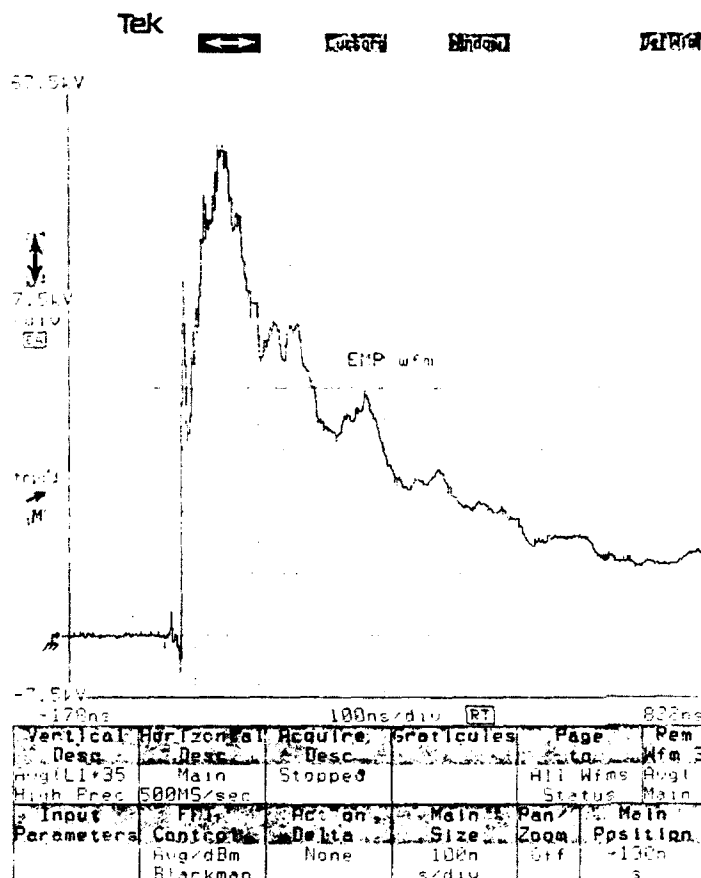
Equipment Under Test Specifications

Device Type:	PRC-77 Radio
Test I.D.:	F.1.1.30
Configuration:	1
Orientation:	1
Receiver Frequency:	30 MHz
Power Status:	Off
No. of Pulses:	10
Pulse Rate:	3/min
Operation Confirmed	
Comments:	no antenna or hand-set connected

EMP Simulator Specifications

Charging Voltage:	50 kV
Self-breakdown Voltage:	≈ 55 kV
Trigger Method:	Self-breakdown, pressure release

Sensor Specifications

Sensor Type:	PIM-197A-1 voltage divider
Sensor Location:	Right edge of center plate, 40 cm past front taper.
Cable Network:	Shielded N-Type, RG-214
Attenuator Location:	voltage divider

Sensor Specifications

Sensor Type:	
Sensor Location:	
Cable Network:	
Attenuator Location:	

Figure 8: Format used to record the EMP exposures for each test in phase one. The upper right corner records the details of the radio status while the lower portion details the sensor and simulator.

Field (kV/m) & Pol.	Radio Power	Config.	Orient.	Radio Freq. (MHz)	Antenna	hand-set	Code	EMP Status
50 (pos)	off	1	1	30 (Rx)	none	off	F.1.1.30	pass
50 (pos)	off	1	1	50 (Rx)	none	off	F.1.1.50	pass
50 (pos)	off	1	1	75 (Rx)	none	off	F.1.1.75	pass
50 (pos)	off	1	2	30 (Rx)	none	off	F.1.2.30	pass
50 (pos)	off	1	2	50 (Rx)	none	off	F.1.2.50	pass
50 (pos)	off	1	2	75 (Rx)	none	off	F.1.2.75	pass
50 (pos)	off	1	3	30 (Rx)	none	off	F.1.3.30	pass
50 (pos)	off	1	3	50 (Rx)	none	off	F.1.3.50	pass
50 (pos)	off	1	3	75 (Rx)	none	off	F.1.3.75	pass
50 (pos)	on	1	1	30 (Rx)	none	off	N.1.1.30	pass
50 (pos)	on	1	1	50 (Rx)	none	off	N.1.1.50	pass
50 (pos)	on	1	1	75 (Rx)	none	off	N.1.1.75	pass
50 (pos)	on	1	2	30 (Rx)	none	off	N.1.2.30	pass
50 (pos)	on	1	2	50 (Rx)	none	off	N.1.2.50	pass
50 (pos)	on	1	2	75 (Rx)	none	off	N.1.2.75	pass
50 (pos)	on	1	3	30 (Rx)	none	off	N.1.3.30	pass
50 (pos)	on	1	3	50 (Rx)	none	off	N.1.3.50	pass
50 (pos)	on	1	3	75 (Rx)	none	off	N.1.3.75	pass
50 (pos)	on	3	1	30 (Rx)	72-cm	off	N.3.1.30.reg	pass
50 (pos)	on	3	1	50 (Rx)	72-cm	off	N.3.1.50.reg	pass
50 (pos)	on	3	1	75 (Rx)	72-cm	off	N.3.1.75.reg	pass
50 (pos)	on	3	1	30 (Rx)	50-cm plt	off	N.3.1.30.plt	pass
50 (pos)	on	3	1	50 (Rx)	50-cm plt	off	N.3.1.50.plt	pass
50 (pos)	on	3	1	75 (Rx)	50-cm plt	off	N.3.1.75.plt	pass
50 (pos)	on	2	1	30 (Rx)	50-cm plt	off	N.2.1.30.nhd	pass
50 (pos)	on	2	1	50 (Rx)	50-cm plt	off	N.2.1.50.nhd	pass
50 (pos)	on	2	1	75 (Rx)	50-cm plt	off	N.2.1.75.nhd	pass
50 (pos)	on	2	2	30 (Rx)	50-cm plt	off	N.2.2.30.nhd	pass
50 (pos)	on	2	2	50 (Rx)	50-cm plt	off	N.2.2.50.nhd	pass
50 (pos)	on	2	2	75 (Rx)	50-cm plt	off	N.2.2.75.nhd	pass
50 (pos)	on	2	1	30 (Rx)	50-cm plt	on	N.2.1.30.whd	pass
50 (pos)	on	2	1	50 (Rx)	50-cm plt	on	N.2.1.50.whd	pass
50 (pos)	on	2	1	75 (Rx)	50-cm plt	on	N.2.1.75.whd	pass
50 (pos)	on	2	2	30 (Rx)	50-cm plt	on	N.2.2.30.whd	pass
50 (pos)	on	2	2	50 (Rx)	50-cm plt	on	N.2.2.50.whd	pass
50 (pos)	on	2	2	75 (Rx)	50-cm plt	on	N.2.2.75.whd	pass

Table 2: Results from Phase One of the EMP assessment of PRC-77 Radio. The radio showed no significant degradation as a result of the exposures.

antenna was then exposed to the same field. Finally, the above was repeated at a full-threat level field both with positive and negative polarity. The radio survived all exposures as indicated in Table 3.

6.2 Procedural Difficulties

6.2.1 Phase One

The front and back taper of the 1-m parallel-plate simulator are too abrupt. This creates an impedance mismatch at the cell transitions which generates a 10-15% reflection. This reflection is superimposed on the initial pulse and results in a corruption of the rise time. As a result, the electric field has a small downward dip, Fig. 7, and the magnetic field is increased by a similar factor (not shown) [Ref. 5]. The corrupted waveform doesn't have the ideal EMP wave shape, however, the frequency content of this pulse is similar to the MIL-STD-461C wave shape and, hence, this problem is considered negligible. Some of the oscillations in the above figure are a result of the relatively invasive voltage probe/cable combination and are strictly a manifestation of the measurement system, not an indication of a corrupted waveform.

The antenna provided with the PRC-77 radio is 72-cm. When this height is added to the height of the radio, the total exceeds the simulator plate separation (1 meter). Therefore, some compromise had to be made in order to expose the radio inside the simulator. One alternative is to replace the 72-cm antenna by a shorter antenna with a capacitive top plate. In Annex A it has been empirically established that a 50-cm monopole with a 20-cm top plate is a reasonable match for the original antenna and the investigation proceeded with this substitution.

Both the calibration tests and the EMP exposures where done only in the receive mode of the radio. A more thorough EMP evaluation involving both the receive and transmit modes was done in DREMPS, however, quantitative testing of the radio performance was only recorded for the receive mode. See Annex C for more detail.

Finally, the radio was placed directly on the ground plane of the simulator. In reality, during an EMP the radio would probably be worn on the back of a soldier. A more accurate evaluation should be done with the radio suspended as in normal use, however space limitations prohibit this.

6.2.2 Phase Two

In DREMPS many of the problems mentioned above are eliminated because of the superior taper design and the larger physical dimensions of the working volume. For example, the radio, with a 3-m antenna, placed one meter above the ground still do not exceed half the height of the simulator.

One difficulty encountered was the erratic behaviour of one of the AT-892 (72-cm) antennae. The signal generated by this antenna was not reproducible and it was speculated that since it is constructed by riveting a series of anodized layers together, it is possible that a poor contact between two of these layers would periodically arc. Unfortunately, the problem only manifested itself for one day, therefore, the above hypothesis could not be confirmed. During the same time period all other antennas behaved normally.

6.3 Conclusions

The evaluation proceeded in stages such that each addition would add a greater degree of susceptibility to the radio. This procedure was followed in an attempt to isolate a particular fault if there had been a system failure. An effort was also made to vary the radio operating frequency, physical orientation etc. in order to ensure that the unit would be exposed to a worst-case scenario.

30 kV/m Testing of PRC-77 Radio

Pol.	Field (kV/m)	Ant. length (cm)	handset	Radio Freq. (MHz)	Radio Status	Measurement	EMP Status
neg	30	72	neutral	30.2	Rx	antenna	pass
neg	30	72	down	30.2	Rx	handset	pass
neg	30	72	up	30.2	Rx	handset	pass
neg	30	2.09	neutral	30.2	Rx	antenna	pass
neg	30	2.9	neutral	30.2	off	antenna	pass
neg	30	2.9	neutral	30.2	Rx	antenna	pass
neg	30	72	neutral	30.2	Tx	field only	pass
neg	30	2.09	neutral	30.2	Tx	field only	pass
neg	30	2.9	neutral	30.2	Tx	field only	pass

50 kV/m Testing of PRC-77 Radio

Pol.	Field (kV/m)	Ant. length (cm)	handset	Radio Freq. (MHz)	Radio Status	Measurement	EMP Status
neg	50	2.9	neutral	30.2	Tx	field only	pass
neg	50	2.9	down	30.2	Tx	field only	pass
neg	50	2.9	up	30.2	Tx	field only	pass
neg	50	2.9	neutral	45.0	Tx	field only	pass
neg	50	2.9	neutral	70.0	Tx	field only	pass
neg	50	2.09	neutral	30.2	Rx	field only	pass
neg	50	2.9	neutral	30.2	Rx	field only	pass
neg	50	2.9	down	30.2	Rx	field only	pass
neg	50	2.9	up	30.2	Rx	field only	pass
neg	50	2.9	down	45.0	Rx	field only	pass
neg	50	2.9	down	70.0	Rx	field only	pass
pos	50	2.09	down	30.2	Rx	field only	pass
pos	50	2.9	down	30.2	Rx	field only	pass
pos	50	2.09	down	30.2	Tx	field only	pass
pos	50	2.9	down	30.2	Tx	field only	pass

Table 3: Results from Phase Two of the EMP assessment of PRC-77 Radio. The radio showed no significant degradation as a result of the exposures.

This particular EMP as: assment was performed in two phases because development of the 10-m simulator dictated that large-object exposure could not be performed prior to the fall of 1992. However, earlier results in a 1-m simulator showed the radio to have sufficient protection in the following circumstances;

- penetration of the EMP into the case of the radio,
- 72-cm antenna to a sub-threat level (20 kV/m) field,
- plate antenna to a threat-level field,
- plate antenna and extended handset to a threat-level field.

In the second phase the evaluation confirmed survival under the additional circumstances of;

- 72-cm antenna to a threat level field,
- 72-cm antenna and extended handset to threat-level field,
- 2.1-m antenna to threat-level field,
- 2.1-m antenna and extended handset to threat-level field,
- 2.9-m antenna to threat-level field,
- 2.9-m antenna and extended handset to threat-level field.

In summary, the results of the radiated susceptibility investigation indicate that the radio, when equipped with either the 72-cm, ANT-892 or the 2.9-m, ANT-271B antenna, will survive exposure to an EMP with negligible changes to the operating system. In general, the work performed for this report has been an excellent opportunity to explore the dynamics of the field interaction both with the radio (and its antennae) and within the EMP simulator. The results have gone a long way in helping to understand the behaviour of these systems and, by using this knowledge, many of the minor difficulties encountered in this evaluation can easily be avoided or corrected in future testing.

7.0 REFERENCES

1) MIL-STD-451C/462

2) TM 11-5820-667-35, Radio Set AN/PRC-77 Maintenance Manual, 1987

3) C-53-328-A00/MN-000, Receiver-Transmitter RT-841/PRC-77 Maintenance Manual.

4) TM 11-5820-667-12, Radio Set AN/PRC-77 Maintenance Manual, 1987

5) S. Kashyap, J.S. Seregelyi, M. Dion, Measurement of EMP Transients using a Small, Parallel Plate Simulator, Conference on Precision Electromagnetic Measurements 1990, pg. 194.

ANNEX A: Modelling of a Top-Plate Monopole Antenna.

ABSTRACT:

A design criteria is established which allows an antenna that is too high to fit inside the one meter EMP simulator to be replaced by a shorter antenna with the same electrical characteristics. Measurements are made to confirm compatibility.

INTRODUCTION:

Prior to the construction of the 10-m simulator DREMPS, the size of an object which could be exposed to an EMP was limited because of the one meter plate separation in the Elgal simulator. Excessively large equipment created a local impedance mismatch and could also induce arcing. Monopoles or whip antennae are particulary susceptible to the latter and, as a result, it was necessary to devise a method which allowed the height of such a structure to be reduced without altering its electrical properties.

Placing a circular top plate on a short monopole capacitively loads the structure and simulates a longer antenna length. The procedure used to establish the correct dimensions is as follows:

• The resonances of 2.5-cm to 19-cm monopoles were determined and compared to the resonances of a 4.7-cm monopole with 2, 4 and 6-cm top plates. All monopoles were located on a 30-cm by 30-cm ground plane and responses were measured to 1.5 GHz.

• By comparing the above values, an empirical relationship between the apparent change in a monopole's height and the top plate diameter was established. These relationships will be maintained when the monopoles are simultaneously scaled in height and frequency response.

• Once suitable dimensions have been calculated, the two antennae are experimentally tested for compatibility.

EXPERIMENTAL RESULTS:

Frequency domain modelling:

The compatible antenna dimensions were established in the frequency domain. The comparison was made primarily by matching the resonances of the various monopoles with no compensation for the magnitude of the response at that resonance, hence, the selection criteria matches only the reactance of the monopoles.

The frequency domain measurements, made with a HP 8753B Network Analyzer, are summarized in Table A1 and Figures A1-A2. The results indicate how the dimensions of a top plate change the resonances of a monopole and also established the scaling factors for the conversion from centimeter-long to meter-long monopoles. From Table A1 it is determined that a 50-cm monopole with a 20-cm top plate is a reasonable substitute for a 72-cm monopole, see Figure A3. Unfortunately, there is no realistic top-plate diameter which will create a suitable alternative to the 2.9-m monopole.

Time Domain Confirmation:

In simulator:

Measurements were made of the response of the whip antenna and the plate antenna in order to confirm that the modifications result in a viable substitute for an EMP evaluation, see Fig. A4. The experiments were done with the antennae connected at the base plate of the EMP simulator and terminated into a 100 ohm load (50 ohm resistor in series with a 50 ohm cable). There is good agreement between the currents induced on the two antennae with the small deviations in the peak values being due to a minor scaling problem in the extrapolation[1].

The choice of termination impedance is somewhat arbitrary as long as the same value is used for all compatibility measurements. However, since it was originally thought that current injection may be necessary to complete the radio evaluation and that an antenna response would be required as an input for the current injection equipment, a 100 ohm value was chosen. This value is compatible with the current injection system (IRT Corp.; PINS-250), hence, it is possible to confirm the antenna compatibility and obtain a current injection waveform simultaneously. In retrospect, because portions of the evaluation were delayed until after the completion of DREMPS, the entire investigation could be completed using radiated susceptibility (RS) methods and current injection was not required.

In addition to the measured values, the theoretical response of a 72-cm. monopole terminated into a 100 Ω load was determined, see Fig. A5, using a Numerical Electromagnetic Code (NEC)[2]. A very good agreement is obtained between the experimental and theoretical response.

On Radio:

In addition to measuring the antennae response as independent units, they were also evaluated while being mounted on the PRC-77 radio. The current injected into the radio via the antenna port was measured during an ~ 20% (magnitude) EMP exposure and, as can be seen by comparing Figs. A6 and A7, the waveforms generated by the regular 72-cm antenna and the 50-cm plate antenna are very similar.

CONCLUSIONS:

It was been determined that a 50-cm monopole with a 20-cm top-plate is a reasonable substitute for the 72-cm whip antenna on the PRC-77 radio. It has also been established that there is no reasonable diameter top plate which will allow the 2.9 m antenna to be replaced.

---

[1] The scaling problem is due to the fact that the thickness of the top plate was substantial compared to the antenna height and diameter. Therefore, the exact height of the monopole was not clear. In addition, the original extrapolations were erroneously based on an a projected antenna height of 75-cm, not the required 72-cm.

[2] G.J. Burke et al., "Numerical Electric Code (NEC) - Method of Moments", Naval Ocean Systems Centre, Technical Doc. 116, 1977.
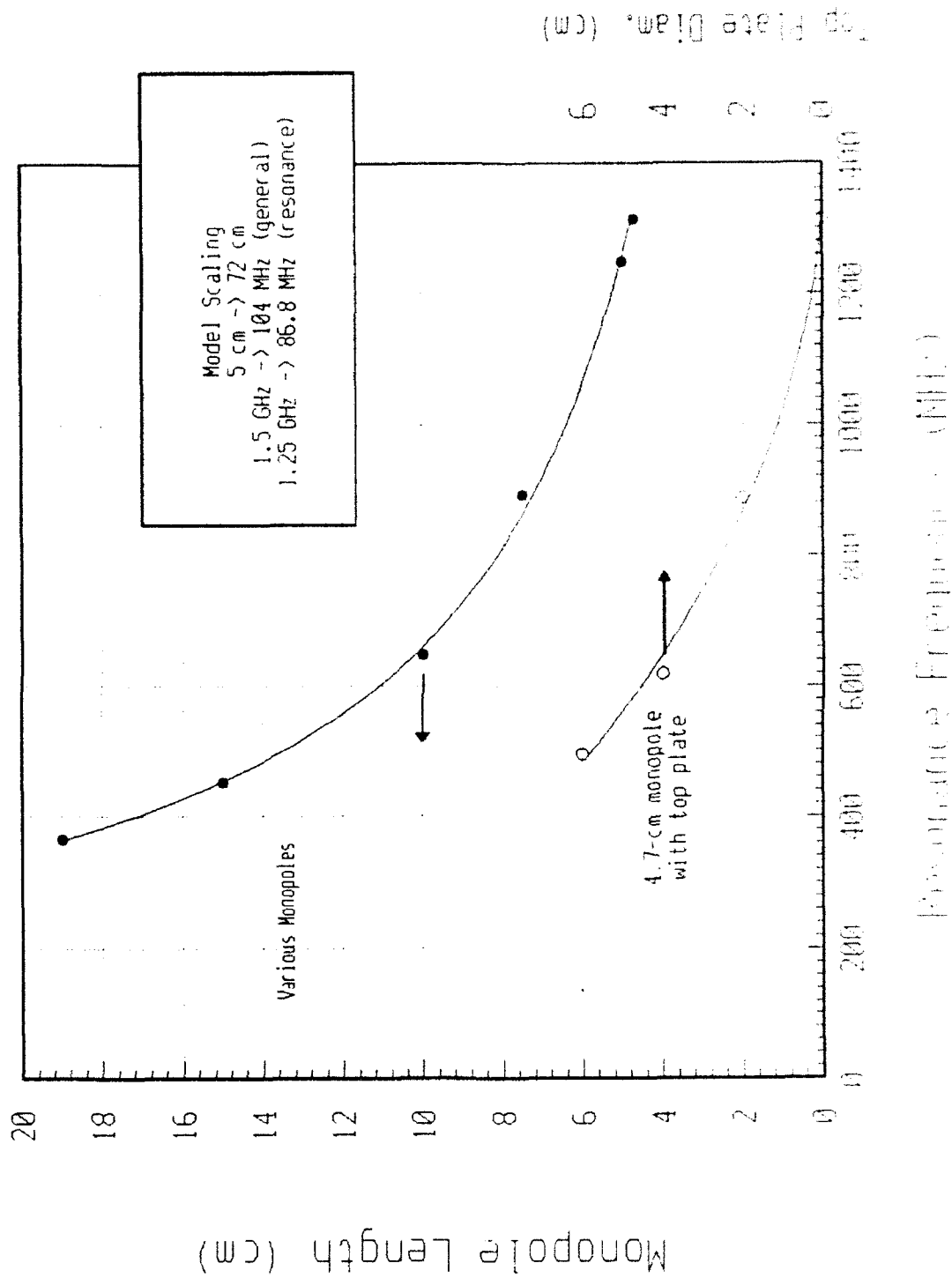
Figure A1: A summary of the resonance frequencies for various monopoles as determined in Appendix A1. The filled in points refer to straight monopoles and the empty circles refer to monopoles with top plates (the diameter of the plates are given along the right-hand axis).

Monopole height (cm)	Measured resonance (MHz)	Monopole (with plate) height (cm)	Interpolated plate size[2] (cm)	Radio antenna height (cm)	Scaling factor[4]	Final ant. height[5] (cm)	Final plate size[5] (cm)	New total height of radio (cm)	Scaled ant. diameter[6] (cm)
15	452	5[1]	(extrapolated) 7	75[3]	5	25	35	50.0	1.6
10	649	5	3.7	75	7.5	37.5	27.75	62.5	2.4
7.5	893	5	2	75	10	50	20	75.0	3.2
6.5	(interpolated) 1025	5	1.2	75	11.54	57.7	13.9	82.7	3.7
19	425	5	(extrapolated) 10.2	290	15.3	76.3	156.1	101.3	4.9
15	452	5	(extrapolated) 7	290	19.3	96.7	135.1	121.7	6.1
10	649	5	3.7	290	29.0	145	107.3	170.0	9.2
7.5	893	5	2	290	38.7	193.3	77.4	218.3	12.3
6.5	(interpolated) 1025	5	1.2	290	44.6	223.1	53.5	248.1	14.2

1. The monopole height is 4.7-cm and the top plate is 3-mm for a total of 5-cm.
2. The plate size is determined by finding the resonance frequency of the chosen monopole on Figure A1, projecting a line onto the 4.7-cm monopole curve and then reading the plate size which will cause this resonance frequency from the y-axis on the right side of the graph.
3. The scaling has been calculated based on a radio antenna height of 75-cm although the actual measurement is 72-cm. The discrepancy is not significant.
4. The scaling factor is determined by dividing the radio antenna height by the selected monopole height.
5. The final antenna height and plate size are determined by multiplying the 5-cm monopole height and the interpolated plate size by the scaling factor.
6. The response of a long antenna is generally insensitive to the antenna diameter. Therefore, the top plate and monopole thickness (and their variation in scaling) have not been considered.

Table A1: The above table uses frequency domain data (resonances) from Figure A1 to determine the scaling factors required to replace a monopole antenna of a given height by a shorter monopole with a top plate.
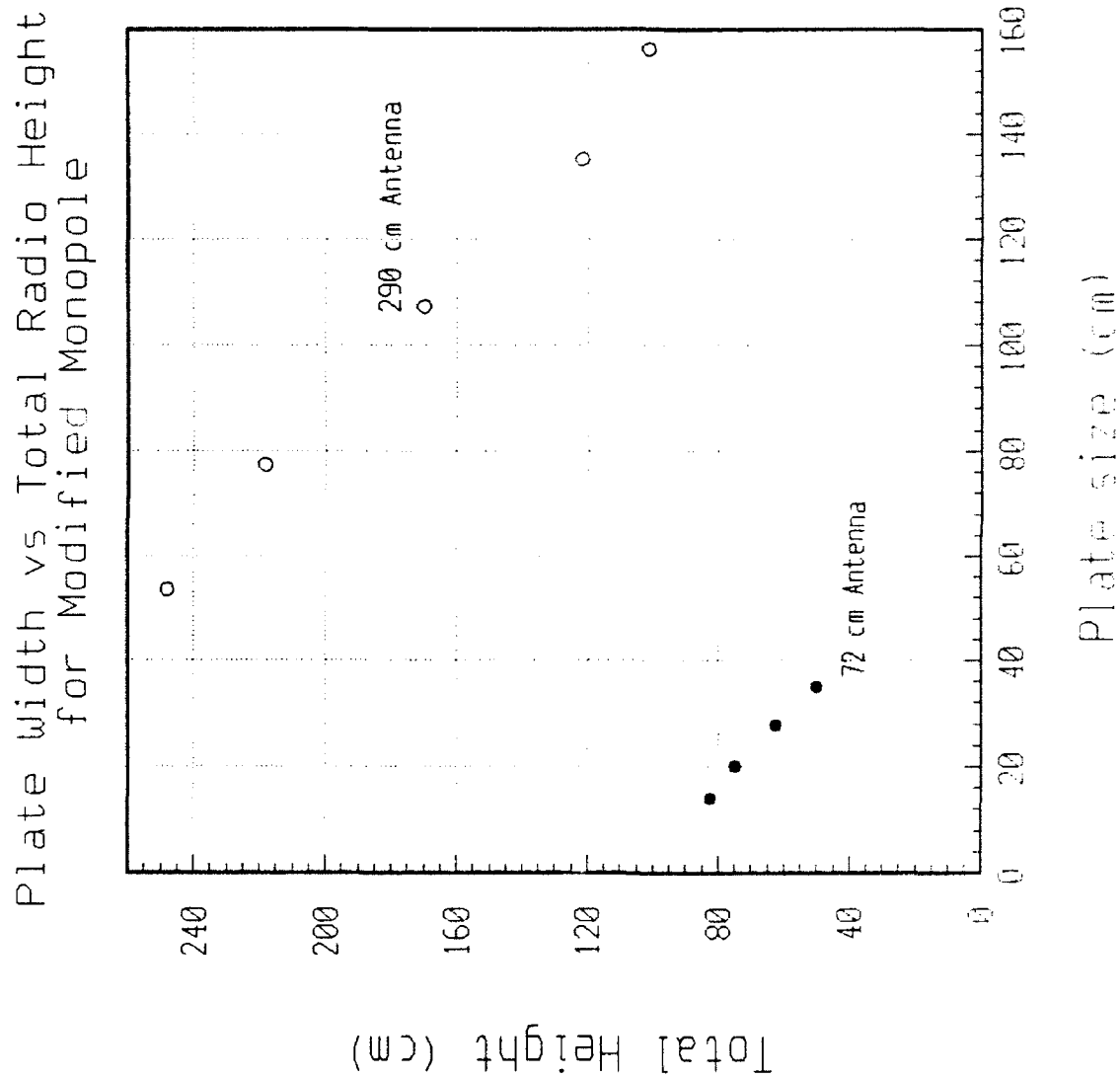
Figure A2: A summary of the total radio (radio and antenna) height as a function of top plate diameter for the 72-cm and 290-cm antennae. Note that there is no reasonable plate substitution size for the latter.
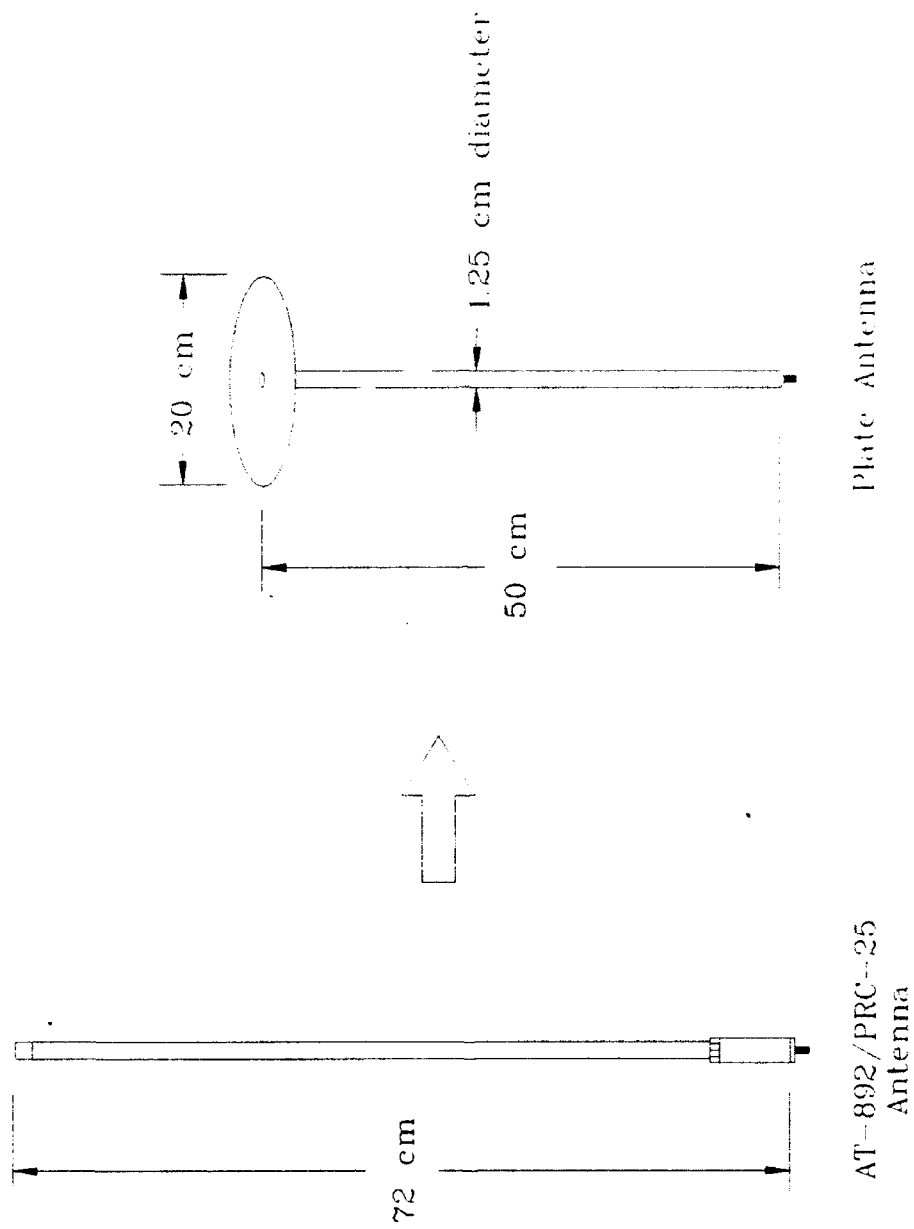
20 cm

1.25 cm diameter

50 cm

Plate Antenna

AT-892/PRC-25
Antenna

72 cm

Figure A3: The total height of the radio and its antenna exceed the working volume of the 1-m EMP simulator. The addition of a top plate as shown in the above drawing reduces the antenna height and, thus, allows the radio assembly to be placed inside the parallel plate simulator.
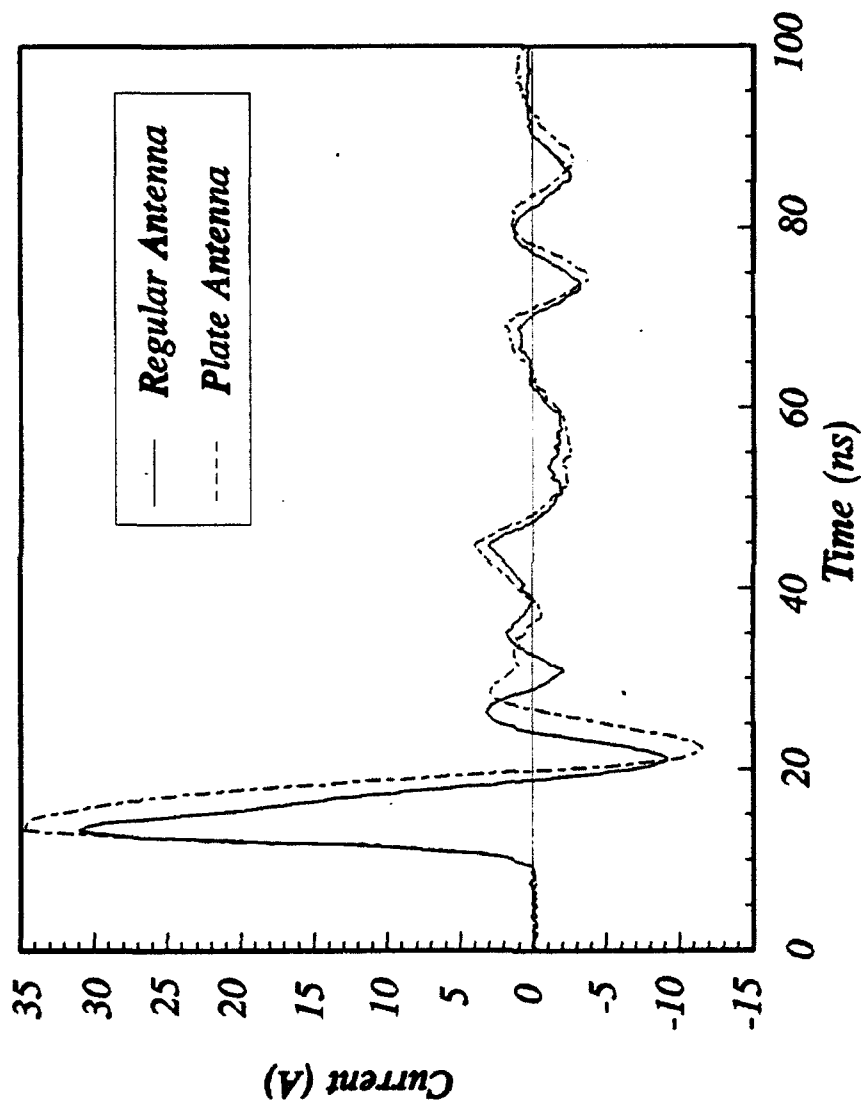
Figure A4: Response of a regular 72 cm antenna and a 50 cm monopole with a 20 cm top plate. The measurements were made in the EMP simulator with a 100 ohm load. Small deviations are a result of minor scaling problems in the extrapolations of Table A1.
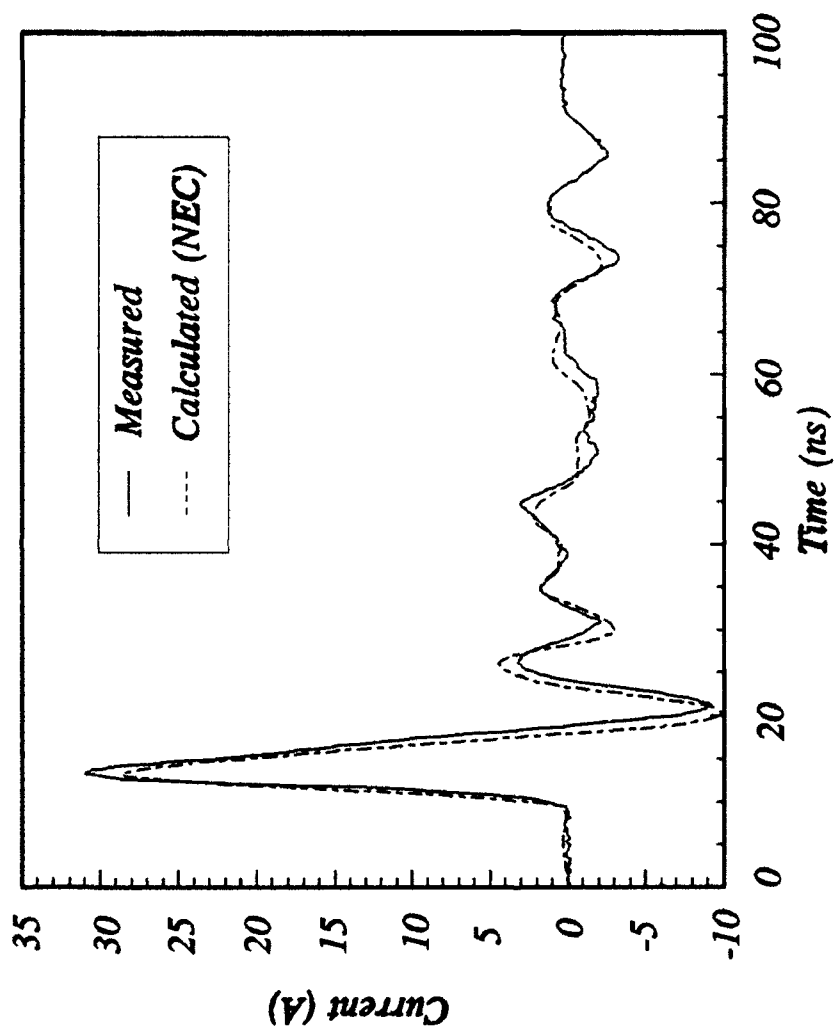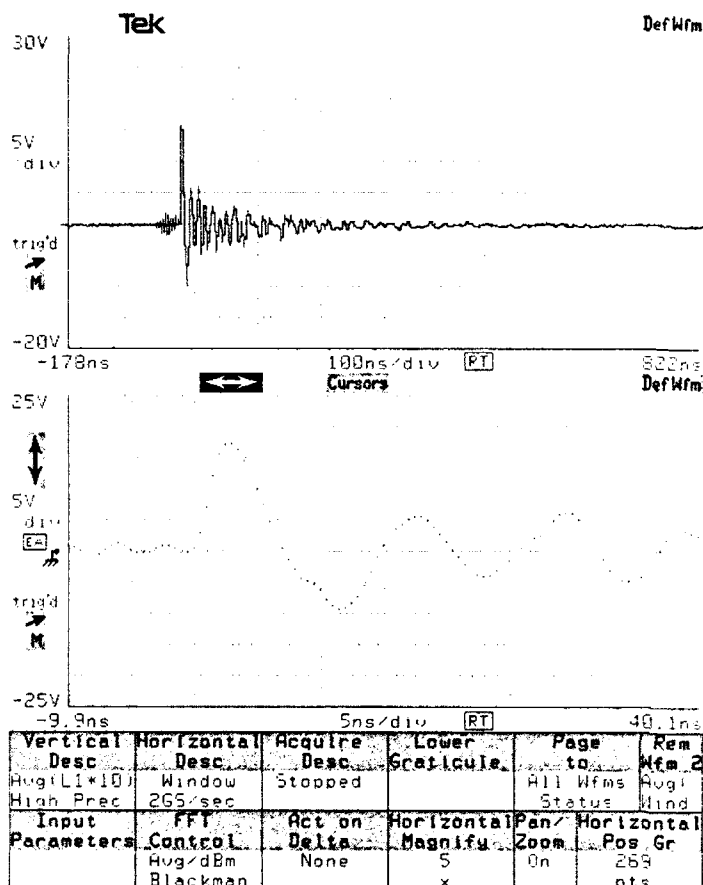
Figure A5: Comparison of the measured and calculated response of a 72 cm monopole exposed to an EMP. The calculation was done using the Numerical Electromagnetic Code (NEC). Note the good agreement.

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 25-JAN-91 time: 14:22:35

RSO5 TEST METHOD

Equipment Under Test Specifications

Device Type:	PRC-77 Radio
Test I.D.:	N.3.1.75.reg
Configuration:	3
Orientation:	1
Receiver Frequency:	75 MHz
Power Status:	On
No. of Pulses:	10
Pulse Rate:	3/min
Operation Confirmed	
Comments:	- no hand-set connected - regular antenna

Vertical Desc	Horizontal Desc	Acquire Desc	Lower Graticule	Page to	Rem Wfm 2
Avg(L1*10) High Prec	Window 2GS/sec	Stopped		All Wfms Status	Avg Wind
Input Parameters	FFT Control	Act on Delta	Horizontal Magnify	Pan/ Zoom	Horizontal Pos Gr
	Avg/dBm Blackman	None	5 x	On	269 pts

EMP Simulator Specifications

Charging Voltage:	50 kV
Self-breakdown Voltage:	≈ 55 kV
Trigger Method:	Self-breakdown, pressure release

Sensor Specifications

Sensor Type:	Eaton Current Probe, 94106-2
Sensor Location:	10 cm from base of antenna
Cable Network:	Shielded N-Type (RG-214), BNC
Attenuator Location:	20 dB, Alan 50HT42 N at Current Probe

Sensor Specifications

Sensor Type:	
Sensor Location:	
Cable Network:	
Attenuator Location:	

Figure A6: Current induced 10-cm from the base of a 72-cm antenna mounted on the PRC-77 radio.

EMP TEST DATA

RSO5 TEST METHOD

Equipment Under Test Specifications

Device Type:	PRC-77 Radio
Test I.D.:	N.2.1.30.whd
Configuration:	2
Orientation:	1
Receiver Frequency:	30 MHz
Power Status:	On
No. of Pulses:	10
Pulse Rate:	3/min
Operation Confirmed	verbal/audio test
Comments:	- no handset connected
	- modified plate antenna

EMP Simulator Specifications

Charging Voltage:	50 kV
Self-breakdown Voltage:	≈ 55 kV
Trigger Method:	Self-breakdown, pressure release

Sensor Specifications

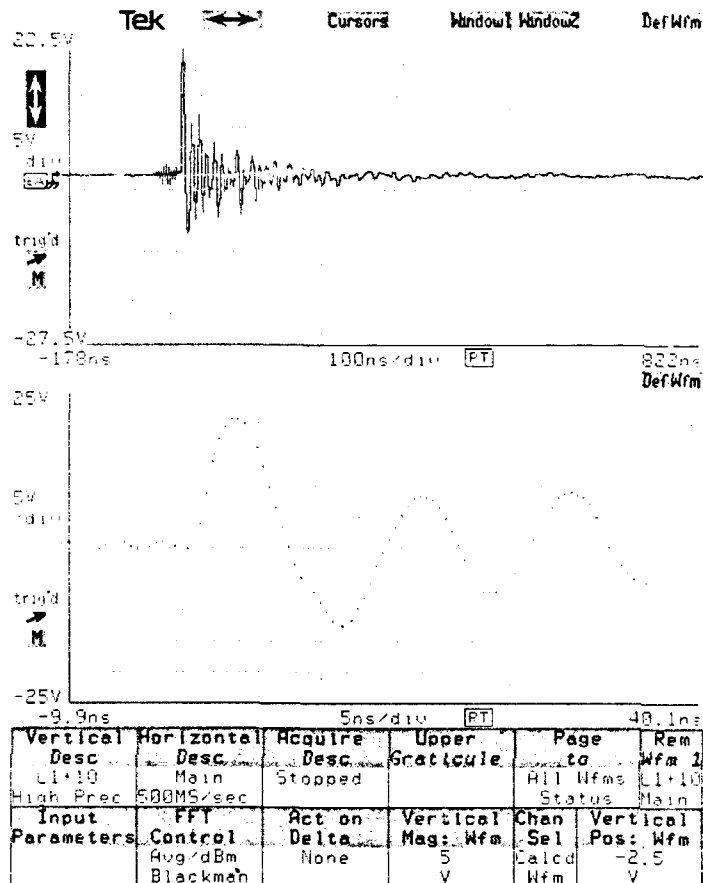|	
Sensor Type:	Eaton Current Probe, 94106-2
Sensor Location:	10 cm from base of antenna
Cable Network:	Shielded N-Type (RG-214), BNC
Attenuator Location:	20 dB, Alan 50HT42 N at Current Probe

Sensor Specifications

Sensor Type:	
Sensor Location:	
Cable Network:	
Attenuator Location:	

Figure A7: Current induced 10-cm from the base of a 50-cm plate antenna mounted on the PRC-77 radio.

ANNEX B: Measurement and Analysis

ABSTRACT:

During the EMP evaluation the measurements where performed in such a way as to isolate the effects of various portions of the radio (for example the antenna). In this fashion it was possible to deduce how these individual elements effect the susceptibility of the PRC-77. The following is a summary of these results.

INTRODUCTION:

The procedures followed in this evaluation were designed to isolate the various systems of the radio (for example, the current induced on the handset). An effort was made to measure the response and its variation as the unit was subjected to a progressively more severe electric field. The following is a summary of the relationships deduced during the evaluation.

RESULTS:

Input Pulse:

Figure B1 is a typical input pulse used in this evaluation. The peak field value can be adjusted from approximately 20-50 kV/m without a change in wave shape. Lower values can be obtained with small variations in the pulse width. Clearly the shape and magnitude of this pulse will influence the evaluation, of particular importance are the small, high-frequency variations (ie. the lumps and bumps) on the input. Since most antennae produce a "derivative like" response, these features become prominent in the measured antenna currents. Another way to think of this is to remember that a whip antenna (monopole) will couple to an electromagnetic wavelength which is comparable (or smaller) in size to the antenna length. Therefore, coupling is more efficient at higher frequencies and, hence, the antenna response looks something like a derivative of the input field.

Variation With Antenna Length:

Figure B2 is a summary of how the current induced in an antenna varies with the length. Obviously the longer the antenna the greater the peak value. A general rule of thumb for short antennae (relative to the shortest wavelength in the input pulse) is that the peak current value will be 80 amps times the length of the antenna in meters. Unfortunately, the antennae used in this evaluation are not short, therefore, the above can only be considered a "guestimate". The frequency of the oscillations (resonance) in the current wave shape is also related to the antenna length and corresponds to four times the height of the monopole (whip antenna).

Variation with Antenna Load:

In addition to the peak value and the oscillation frequency mentioned above, the current wave shape also has a damping term which determines the change in magnitude of the oscillations with respect to time. This damping term is determined by the matching of the antenna impedance to the antenna load. In general, for a resistive load, the smaller the impedance the smaller the damping effect and the larger the number of oscillations. Relationships for complex terminations are not as simple and are being investigated further at this time.
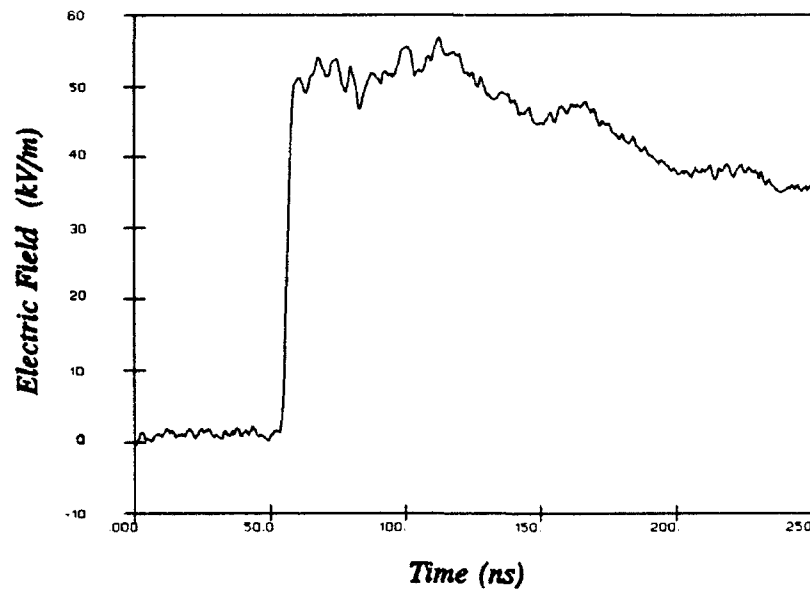
Figure B1:   A typical Electric field wave form generated in the working volume of DREMPS.
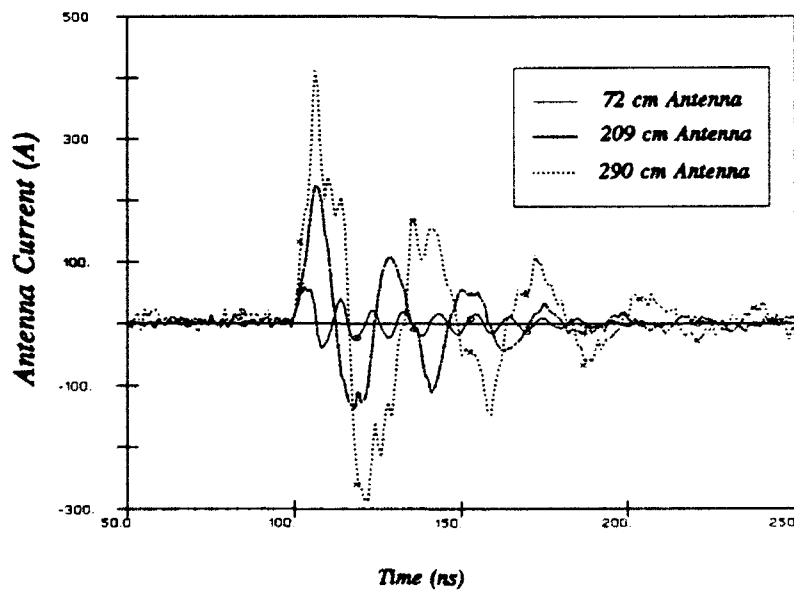

Figure B2:   Current induced in 72-cm, 209-cm and 290-cm antennae by an EMP (Figure B1). Both the peak current value and antenna resonance frequency increase with the antenna length.

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The peak values of the induced current will also be influenced by the antenna termination. This can be understood by thinking of the antenna and the load as two coupled circuits. The maximum power transfer will occur when the impedance of the two are matched, hence, variations in coupling current are expected as the termination value is varied. Alternatively, the antenna can be thought of as a non-linear transmission line with the antenna load acting as a termination. This model will also produce a variation in the measured current with respect to the load impedance.

Figure B3 is the current induced in a 72-cm monopole with both a 100 ohm resistance and the PRC-77 acting as the antenna load. Note the variation in the peak values and damping term. The large number of oscillations in the radio response indicates a low termination value. This may be a result of a matched complex impedance in the radio tuner (which is not unreasonable considering this is consistent with the radio operation) or a short circuit resulting from an electrical arc at or near the antenna port. Further experimentation would be necessary to resolve the situation, however, the former solution seems to be the most probable.

Variation with Radio Status:

In order to establish how the induced current varies with the status of the radio, current measurements where made with the unit in power off mode and in the receive mode. The transmit mode was not measured because the radio emissions would saturate the ferrite core of the current probes used on the antenna and lead to erroneous results (and possibly damage the fiber optic link used to transmit the measured signal to the shielded enclosure where it was recorded). As can be seen form Figure B4 there is no difference between the two measured results. This is reasonable since the front end of the radio is essentially composed of passive elements, hence, the load impedance should not vary with the power status.

Current Induced in Handset:

Although the antenna is often the primary source for external pick-up, the handset is also capable of coupling a substantial current into the radio. In the worst-case situation (which is what was used in the evaluation) the handset is fully extended vertically in either the up or down position. In either case (and experimentation shows they produce similar responses), the handset and its cable can simply be considered to be a monopole as discussed above. The current typically induced is shown if Figure B5. Note that the peak values exceed those of the 72-cm whip antenna but not those of the longer antennae.
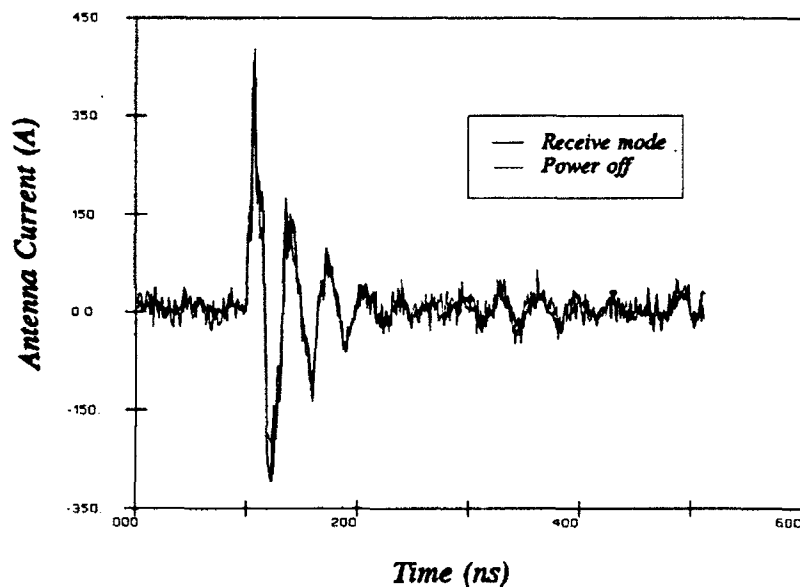
Figure B3: Variation in current induced in 290-cm antenna with the PRC-77 in receive mode and power off. Note there is little change. No current measurements where made in the Transmit mode.
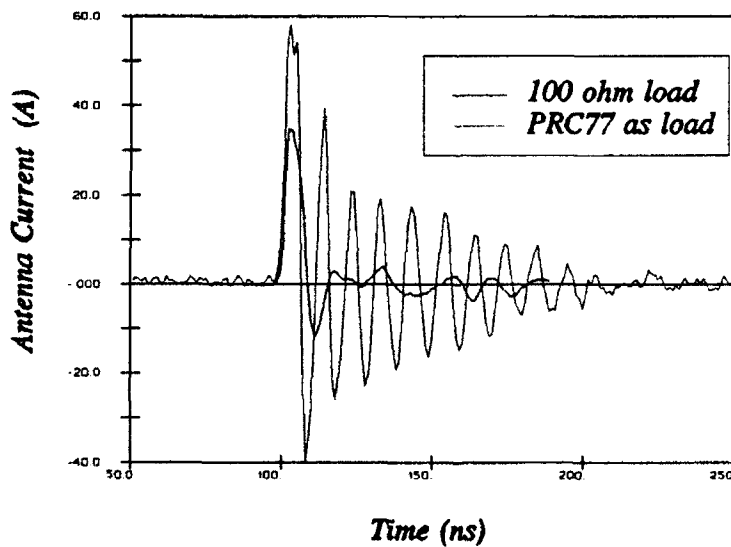
Figure B4: Variation in induced current with load. The highly damped curve is a 72-cm antenna terminated in 100 ohms while the oscillating curve is the complex impedance of the radio. The oscillations may be indicative of a short at the antenna port.

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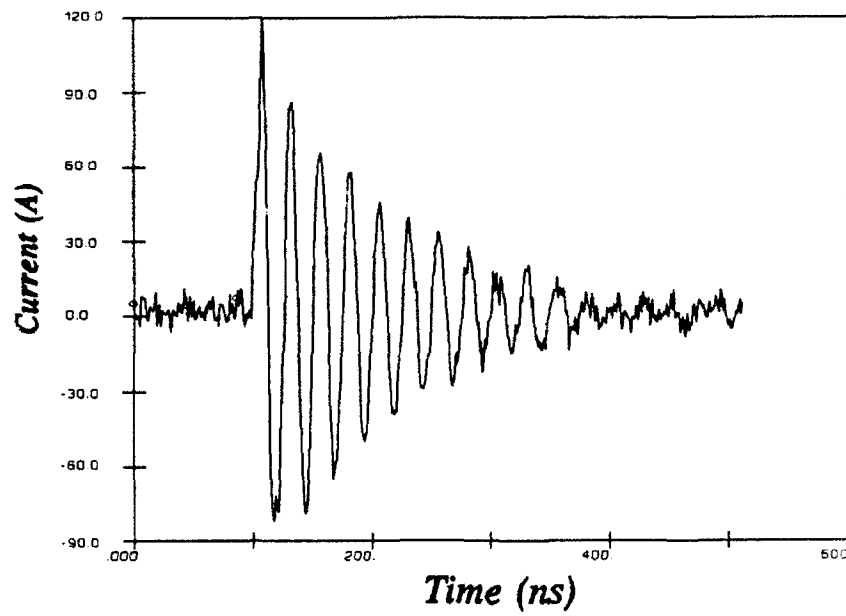
Figure B5:   Current induced in the vertically ext... ...d handset of the PRC-77.

ANNEX C: Calibration and Perfo. ..nce Check of Radio

ABSTRACT:

Details of the calibration procedure and performance checks used during the EMP evaluation are discussed. Results of the radio monitoring are presented and it is shown that the PRC-77 survived the EMP exposures with only minor degradation in performance.

INTRODUCTION:

In order to evaluate how the PRC-77 was effected by EMP exposure, a performance check of the radio prior to and after the evaluation was required. In addition, since the investigation proceeded in an incremental fashion with each step providing an additional degree of susceptibility, it is possible to perform a series of intermediate tests on the radio to establish when (and if) damage occurs. This technique minimizes the damage induced on the unit while maximizing the information obtained from the evaluation.

It should be noted that the procedures used to monitor the radio were far from optimal. For example, an extensive analytical test was performed only for the receive mode (the transmit mode was tested but in a simpler fashion). In addition, since only changes in the radio performance were of interest, little effort was made to calibrate the radio against an absolute standard. Finally, the method used to record the SNR is questionable and will be changed in future evaluations.

MONITORING PROCEDURES:

The operation of the radio was checked using a number of procedures, depending on the status of the EMP evaluation. The procedures are as follows:

1) The first is a simple voice check between the radio being evaluated and a similar monitor radio. Although this appears to be an overly simple and highly subjective criteria, it is sufficient for the relatively simple "go/no-go" criteria established for the EMP evaluation. The advantage of this test is that it is very quick and both the transmit and receive mode can easily be checked between series of EMP exposures (between changes in orientation etc. for example).

2) The second performance check is a more quantitative version of the above and was primarily performed in the second phase of the EMP evaluation. In this case the receive mode was monitored by placing a second radio at a fixed location approximately 30 m from the test radio. This second radio was set to transmit it's 150 Hz internal tone (used for the squelch control) or alternatively an externally induced 1 kHz tone. The test radio was set to receive mode and the audio signal from the handset was monitored on an oscilloscope. With it's whip antenna removed, the volume control on the test radio was then adjusted such that the amplitude of the received signal was only a factor of 2-3 above the ambient noise level. This was done so that the Automatic Volume Control inherent in the radio could not compensate for any degradation which may occur. The signals received above formed the baseline for periodic checks during the EMP evaluation which confirmed the radio's continued performance. Note that the radios were returned to their calibration locations for these performance tests.

In order to monitor the transmit mode, the test radio was placed at a fixed location approximately 30 m from a shielded enclosure. A monopole was placed on this enclosure and the induced signal (basically the carrier) was viewed on an oscilloscope. By recording the signal strength at the beginning of a test sequence and repeating the measurement at the end, any significant changes to the radio would be detected.

As with the voice check above, this procedure is not intended to be an exhaustive test of the radio but a quick check to ensure it has passed the "go/no-go" criteria of the EMP evaluation.

3) The final monitoring procedure was a quantitative test performed by injecting an accurate signal from a Hewlett Packard HP8685B FM signal generator into the co-axial antenna of the radio and measuring the audio output at the unit's handset. The measurement was made with a Tektronix DSA 602 digitizer which allows conversion of the time domain signal into the frequency domain. Therefore, it was relatively simple to accurately measure the variations in the audio signal response while making changes to the FM deviation, carrier amplitude and carrier central frequency as summarized in Table C1.

The set of measurements was repeated at the beginning and end of phase one and at the end of phase two of the EMP evaluation and a comparison of the results was made to determine if any degradation had occurred in the radio.

MONITORING RESULTS AND CONCLUSIONS:

Since the tests were relatively qualitative, the results of monitoring procedures 1) and 2) can be quickly summarized by saying that the PRC-77 suffered no apparent damage during the EMP evaluation.

The results of the third procedure are summarized in Tables C2 to C10. The contents of the tables represent a compilation of the relevant data determined from the variation of certain input parameters in the FM signal generator as per Table C1. The topic of each Table is summarized below:

Table	Frequency [MHz]	Parameter Varied
C2	30	frequency deviation
C3	30	carrier amplitude
C4	30	carrier frequency
C5	50	frequency deviation
C6	50	carrier amplitude
C7	50	carrier frequency
C8	75	frequency deviation
C9	75	carrier amplitude
C10	75	carrier frequency

Appendix C1 is a sample of raw data and has been included at the end of this Annex as an example of the nature of the calibration procedure. The data is the final calibration at a carrier frequency of 30 MHz and is summarized in portions of Tables C2 to C4.

Each of the Tables contains information relevant to the analysis of the radio. For example, Tables C2, C5 and C8 explore the variation in the audio signal with respect to the frequency deviation of the input signal. Two pieces of information are extracted; the first is the obvious check of the signal magnitude as represented by the RMS value. The second is the amplitude of the second harmonic (2 kHz) in the Fourier

Transform of the signal relative to the fundamental (1 kHz). This value is a measure of the sinusoidal distortion of the signal as the frequency deviation increases. There are only small deviations between the initial and final data which could be attributed to measurement error.

Tables C3, C6 and C9 measure the variation with respect to input signal amplitude expressed as a signal to noise ratio (SNR). The value was obtained by measuring the peak value of the fundamental and comparing this to the noise baseline determined at approximately 8-9 kHz. This method is not optimal since it is prone to errors induced by the sampling rate and window size in the FFT, etc. and as a result some of the SNR values are questionable. Other methods will be used in future evaluations.

Table C4, C7 and C10 explore the results of varying the central frequency of the carrier by various amounts. The RMS values obtained from the audio signal are consistently a few percent lower after the EMP exposures, however such small changes are well within measurement error and are not considered important.

In conclusion, although this final monitoring procedure is a more detailed check and, hence, provides more information about the radio, it is still reasonable to summarize the results by stating that the PRC-77 suffered no significant damage as a result of the EMP exposures. There are a number of faults in the monitoring process, for example the transmit mode of the radio was not extensively tested. Also, since the initial and final calibration were performed almost 2 years apart, the minor changes in the radio performance may be attributed to aging of the unit, small changes in the evaluation procedures, etc. Clearly, if a criteria more stringent than the "go/no-go" requirement were set for the radio, then a more exhaustive monitoring procedure with more caution in its implementation would have been justified and used. As mentioned previously at various stages of this report, this entire evaluation was one of the first performed at DREO and there are no clients requesting specific information. As a result, these simplifications were considered acceptable since no serious compromise has been made in the evaluation validity or conclusions.

FM Signal Generator:		Radio:	
Frequency:	30, 50 or 75 MHz	Carrier:	to match FM generator
Frequency Deviation:	1 to 10 kHz	Volume:	5 units
FM Modulation:	1 kHz	co-axial antenna	
Amplitude:	0.1 to 10.0 μV		

Table C1: Input parameters (bold) used in the monitoring procedure of the PRC-77 radio. Each value was varied individually while the audio output at the handset of the radio was recorded. The values obtained at the end of the EMP evaluation were compared to those obtained in the initial calibration to establish if any radio degradation had occurred.

Frequency Deviation [kHz]	Initial Calibration		Final Calibration	
	RMS Audio Signal [mV]	Magnitude of second harmonic relative to fundamental in FFT of the Audio Signal [dB]	RMS Audio Signal [mV]	Magnitude of second harmonic relative to fundamental in FFT of the Audio Signal [dB]
1.0	24.09	-41	22.29	-36
2.0	48.41	-30	47.06	-30
3.0	70.54	---	69.43	-26
4.0	94.92	-22	92.10	-23
5.0	112.2	-22	113.0	-22
6.0	133.6	-21	133.2	-22
7.0	· 151.1	-20	150.2	-20
8.0	170.5	-19	166.1	-17
9.0	183.3	-17	178.3	-17
10.0	193.3	-16	187.1	-16

FM Signal Generator:

Frequency: 30.000 MHz
Freq. Deviation: varies
FM Modulation: 1 kHz
Amplitude: 5 μV

Radio:

Carrier: 30.00 MHz
Volume: 5 units
co-axial antenna

Table C2: Records the change in the PRC-77 operating characteristics when the frequency deviation was varied from 1 to 10 kHz about a carrier frequency of 30 MHz. The initial calibration took place prior to the EMP evaluation and the final occurred afterward. The minor deviations are probably due to aging of the radio and small changes in the monitoring procedure.

Amplitude [μV]	Initial SNR	Final SNR
0.1	< 1	< 1
0.25	~1	~1
0.5	2	2
1.0	6	4
2.5	13	11
5.0	27	11
10.0	---	32

FM Signal Generator:

Frequency:	30.000 MHz
Freq. Deviation:	2 kHz
FM Modulation:	1 kHz
Amplitude:	varies

Radio:

Carrier:	30.00 MHz
Volume:	5 units
co-axial antenna	

Table C3: Records the change in the PRC-77 operating characteristics when the carrier amplitude was varied from 0.1 to 10 μV with a carrier frequency of 30 MHz. The initial calibration took place prior to the EMP evaluation and the final occurred afterward. The deviations are probably due to changes in the monitoring procedure and the somewhat ambiguous definition of the SNR (future evaluations and testing will rely on a superior SNR measurement criteria).

Frequency [MHz]	Initial RMS Audio Signal [mV]	Final RMS Audio Signal [mV]
29.982	17.6	15.6
29.984	21.6	19.6
29.986	26.6	23.0
29.988	32.3	32.1
29.990	38.3	36.7
29.992	43.9	42.0
29.994	48.2	47.1
29.996	51.3	49.1
29.998	50.3	47.5
30.000	47.7	45.5
30.002	43.7	44.6
30.004	39.2	37.0
30.006	35.4	33.5
30.008	31.4	30.7
30.010	27.8	26.5
30.012	22.9	22.5
30.014	18.7	18.1
30.016	14.1	14.5

FM Signal Generator:

Frequency: varies
Freq. Deviation: 2 kHz
FM Modulation: 1 kHz
Amplitude: 5 μV

Radio:

Carrier: 30.00 MHz
Volume: 5 units
co-axial antenna

Table C4: Records the change in the PRC-77 operating characteristics when the carrier frequency was varied around a central frequency of 30 MHz. The initial calibration took place prior to the EMP evaluation and the final occurred afterward. The minor deviations are probably due to aging of the radio and small changes in the monitoring procedure.

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	Initial Calibration		Final Calibration	
Frequency Deviation [kHz]	RMS Audio Signal [mV]	Magnitude of second harmonic relative to fundamental in FFT of the Audio Signal [dB]	RMS Audio Signal [mV]	Magnitude of second harmonic relative to fundamental in FFT of the Audio Signal [dB]
1.0	24.53	-34	24.03	-35
2.0	47.83	-30	47.70	-30
3.0	71.74	-26	71.15	-26
4.0	91.11	-24	93.93	-24
5.0	115.6	-23	115.1	-22
6.0	137.5	-22	134.8	-22
7.0	155.8	-21	152.5	-20
8.0	171.5	-18	167.7	-18
9.0	184.1	-18	180.1	-18
10.0	194.4	-17	189.6	-17

FM Signal Generator:

Frequency:	50.000 MHz			
Freq. Deviation:	varies			
FM Modulation:	1 kHz			
Amplitude:	5 μV			

Radio:

Carrier:	50.00 MHz
Volume:	5 units
co-axial antenna	

Table C5: Records the change in the PRC-77 operating characteristics when the frequency deviation was varied from 1 to 10 kHz about a carrier frequency of 50 MHz. The initial calibration took place prior to the EMP evaluation and the final occurred afterward. The minor deviations are probably due to aging of the radio and small changes in the monitoring procedure.

Amplitude [μV]	Initial SNR	Final SNR
0.1	<1	<1
0.25	~1	~1
0.5	4	2
1.0	7	6
2.5	13	12
5.0	32	13
10.0	45	15

FM Signal Generator:

Frequency:	50.000 MHz
Freq. Deviation:	2 kHz
FM Modulation:	1 kHz
Amplitude:	varies

Radio:

Carrier:	50.00 MHz
Volume:	5 units
co-axial antenna	

Table C6: Records the change in the PRC-77 operating characteristics when the carrier amplitude was varied from 0.1 to 10 μV with a carrier frequency of 50 MHz. The initial calibration took place prior to the EMP evaluation and the final occurred afterward. The deviations are probably due to changes in the monitoring procedure and the somewhat ambiguous definition of the SNR (future evaluations and testing will rely on a superior SNR measurement criteria).

Frequency [MHz]	Initial RMS Audio Signal [mV]	Final RMS Audio Signal [mV]
49.982	17.5	16.7
49.984	21.7	20.4
49.986	26.8	25.4
49.988	32.7	31.5
49.990	38.8	36.0
49.992	43.9	42.8
49.994	48.7	47.5
49.996	51.6	50.6
49.998	51.4	50.5
50.000	48.9	48.1
50.002	44.6	44.4
50.004	40.0	39.7
50.006	36.0	35.6
50.008	32.3	31.8
50.010	28.4	27.6
50.012	23.6	22.8
50.014	19.2	18.0
50.016	14.4	13.5

FM Signal Generator:

Frequency:	varies
Freq. Deviation:	2 kHz
FM Modulation:	1 kHz
Amplitude:	5 μV

Radio:

Carrier:	50.00 MHz
Volume:	5 units
co-axial antenna	

Table C7: Records the change in the PRC-77 operating characteristics when the carrier frequency was varied around a central frequency of 50 MHz. The initial calibration took place prior to the EMP evaluation and the final occurred afterward. The minor deviations are probably due to aging of the radio and small changes in the monitoring procedure.

	Initial Calibration		Final Calibration	
Frequency Deviation [kHz]	RMS Audio Signal [mV]	Magnitude of second harmonic relative to fundamental in FFT of the Audio Signal [dB]	RMS Audio Signal [mV]	Magnitude of second harmonic relative to fundamental in FFT of the Audio Signal [dB]
1.0	24.28	-38	24.06	-34
2.0	48.49	-29	48.80	-30
3.0	74.48	-26	72.37	-26
4.0	94.69	-26	95.48	-24
5.0	117.2	-24	116.9	-23
6.0	136.4	-22	136.7	-23
7.0	155.0	-21	154.5	-20
8.0	169.5	-19	169.8	-18
9.0	186.8	-18	181.2	-17
10.0	196.6	-17	191.7	-17

FM Signal Generator:

Frequency:	75.000 MHz
Freq. Deviation:	varies
FM Modulation:	1 kHz
Amplitude:	5 μV

Radio:

Carrier:	75.00 MHz
Volume:	5 units
co-axial antenna	

Table C8: Records the change in the PRC-77 operating characteristics when the frequency deviation was varied from 1 to 10 kHz about a carrier frequency of 75 MHz. The initial calibration took place prior to the EMP evaluation and the final occurred afterward. The minor deviations are probably due to aging of the radio and small changes in the monitoring procedure.

Amplitude [μV]	Initial SNR	Final SNR
0.1	<1	<1
0.25	2	2
0.5	3	3
1.0	9	6
2.5	19	13
5.0	40	13
10.0	63	49

FM Signal Generator:

Frequency: 75.000 MHz
Freq. Deviation: 2 kHz
FM Modulation: 1 kHz
Amplitude: varies

Radio:

Carrier: 75.00 MHz
Volume: 5 units
co-axial antenna

Table C9: Records the change in the PRC-77 operating characteristics when the carrier amplitude was varied from 0.1 to 10 μV with a carrier frequency of 75 MHz. The initial calibration took place prior to the EMP evaluation and the final occurred afterward. The deviations are probably due to changes in the monitoring procedure and the somewhat ambiguous definition of the SNR (future evaluations and testing will rely on a superior SNR measurement criteria).

Frequency [MHz]	Initial RMS Audio Signal [mV]	Final RMS Audio Signal [mV]
74.982	12.3	9.5
74.984	15.9	14.8
74.986	20.1	18.8
74.988	24.8	22.8
74.990	29.4	28.3
74.992	33.5	32.0
74.994	37.5	35.2
74.996	41.4	40.2
74.998	45.6	44.9
75.000	49.9	48.8
75.002	51.9	51.0
75.004	51.3	50.0
75.006	47.7	46.7
75.008	43.0	42.0
75.010	37.8	36.9
75.012	31.5	30.4
75.014	25.5	24.1
75.016	20.9	19.8
75.018	17.0	16.0
75.020	10.2	13.5

FM Signal Generator:
Frequency: varies
Freq. Deviation: 2 kHz
FM Modulation: 1 kHz
Amplitude: 5 μV

Radio:
Carrier: 75.00 MHz
Volume: 5 units
co-axial antenna

Table C10: Records the change in the PRC-77 operating characteristics when the carrier frequency was varied around a central frequency of 75 MHz. The initial calibration took place prior to the EMP evaluation and the final occurred afterward. The minor deviations are probably due to aging of the radio and small changes in the monitoring procedure.

Appendix C1

Raw Data From PRC-77 Calibration

Pages 48 to 64 are an indication of the format used for the calibration data. The data shown on pages 48 to 57 is the variation in the frequency deviation during the final radio test (at the end of the EMP exposures of Phase Two). The top curve in the plot is the time-domain response of the audio signal received at the handset. The lower curve is the FFT of this signal and was included as a means of quantifying the harmonic distortion displayed as the frequency deviation of the FM input signal was increased from 1 to 9 kHz. This distortion is represented by the magnitude of the second harmonic relative to the first in Tables C2, C5 and C8 (summaries of this and similar data sets). The RMS values of the time domain signals were also included in the table summary.

The data shown on pages 58 to 64 is again the audio response of the radio but this time the amplitude of the FM input signal was varied from 0.1 to 10.0 μV. This data is summarized in Tables C3, C6 and C9 as a signal-to-noise ratio (SNR). The measurement of this ratio proved to be difficult with the methods used in this analysis and other techniques means will be used in the future.
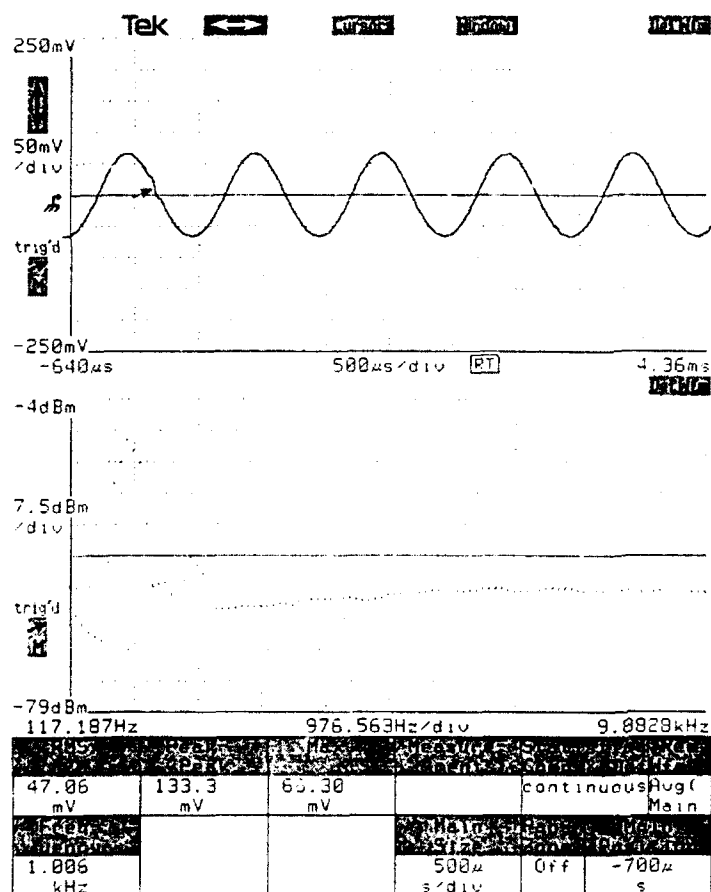
DSA 602 DIGITIZING SIGNAL ANALYZER
date: 21-DEC-92 time: 15:00:49

RMS	**Peak-Peak**	**Max**	**Measure-ments**	**Statistics Rem**
	64.84	31.22		Comp & DefWfm 1
	mv	mv		continuousHvg Main
Freq-uency			**Main Size**	**Pan/Zoom**
			500μ s div	Off

Final Radio Test (Phase Two) - Variation in Modulation Index

FM Signal Generator:
    Frequency: 30.000 MHz
    Freq. Deviation: 1 kHz ✓
    FM Modulation: 1 kHz
    Amplitude: 5 μV
Radio:
    Carrier: 30.00 MHz
    Volume: 5 units
    co-axial antenna

* Averaging in Time Domain
* FFT of Average in Frequency Domain

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 21-DEC-92 time: 15:01:56

Tek `<->`   Cursors   History   MEASURE

```
250mV

50mV
/div
  A
trig'd

-250mV
   -640µs           500µs/div  [RT]        4.36ms
                                           VERT
-4dBm

7.5dBm
/div

trig'd

-79dBm
 117.187Hz          976.563Hz/div      9.8928kHz
```

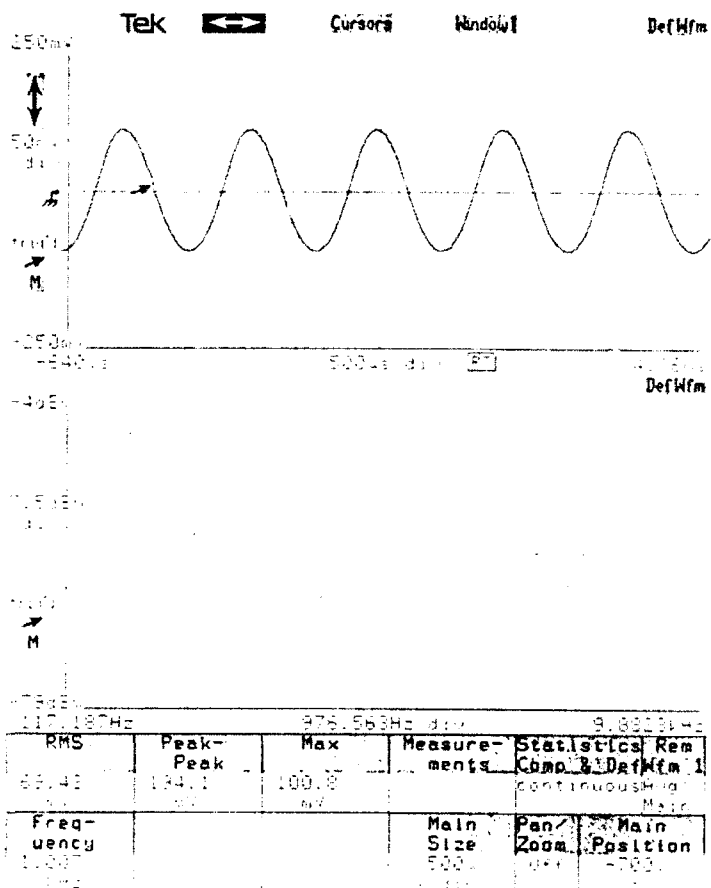| 47.06 mV	133.3 mV	65.30 mV		continuous	Avg(Main
1.006 kHz			500µ s/div	Off	-700µ s

Final Radio Test (Phase Two) - Variation in Modulation Index

FM Signal Generator:
    Frequency: 30.000 MHz
    Freq. Deviation: 2 kHz ✓
    FM Modulation: 1 kHz
    Amplitude: 5 µV
Radio:
    Carrier: 30.00 MHz
    Volume: 5 units
    co-axial antenna

• Averaging in Time Domain
• FFT of Average in Frequency Domain

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DSA 602 DIGITIZING SIGNAL ANALYZER
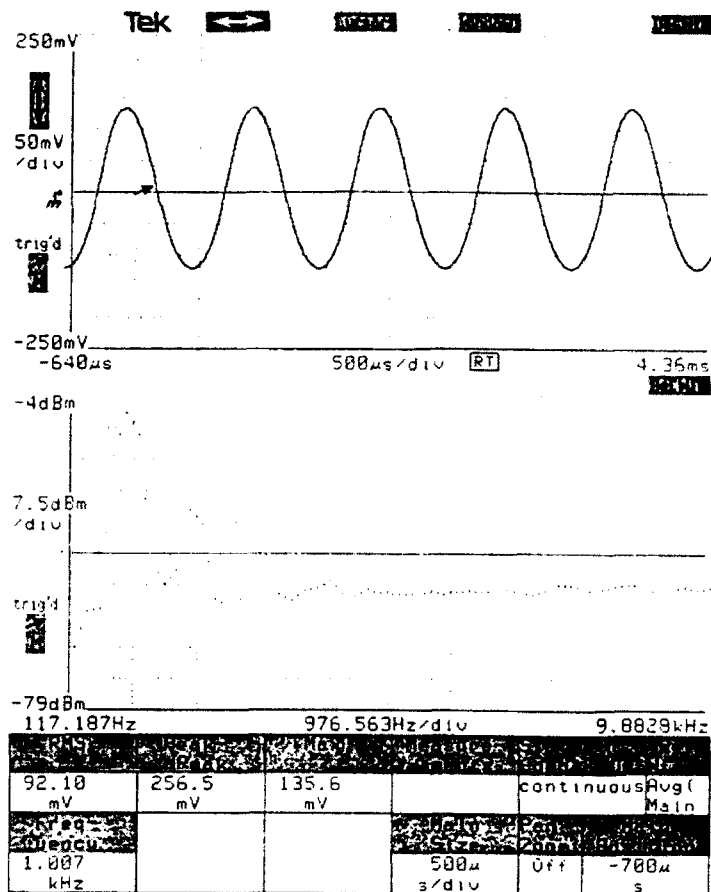## date: 21-DEC-92 time: 15:02:52

Final Radio Test (Phase Two) - Variation in Modulation Index

FM Signal Generator:
    Frequency: 30.000 MHz
    Freq. Deviation: 3 kHz ✓
    FM Modulation: 1 kHz
    Amplitude: 5 μV
Radio:
    Carrier: 30.00 MHz
    Volume: 5 units
    co-axial antenna

* Averaging in Time Domain
* FFT of Average in Frequency Domain

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Initial Radio Test - Variation in Modulation Index

FM Signal Generator:
    Frequency: 30.000 MHz
    Freq. Deviation: 4 kHz ✓
    FM Modulation: 1 kHz
    Amplitude: 5 μV
Radio:
    Carrier: 30.00 MHz
    Volume: 5 units
    co-axial antenna

• Averaging in Time Domain
• FFT of Average in Frequency Domain

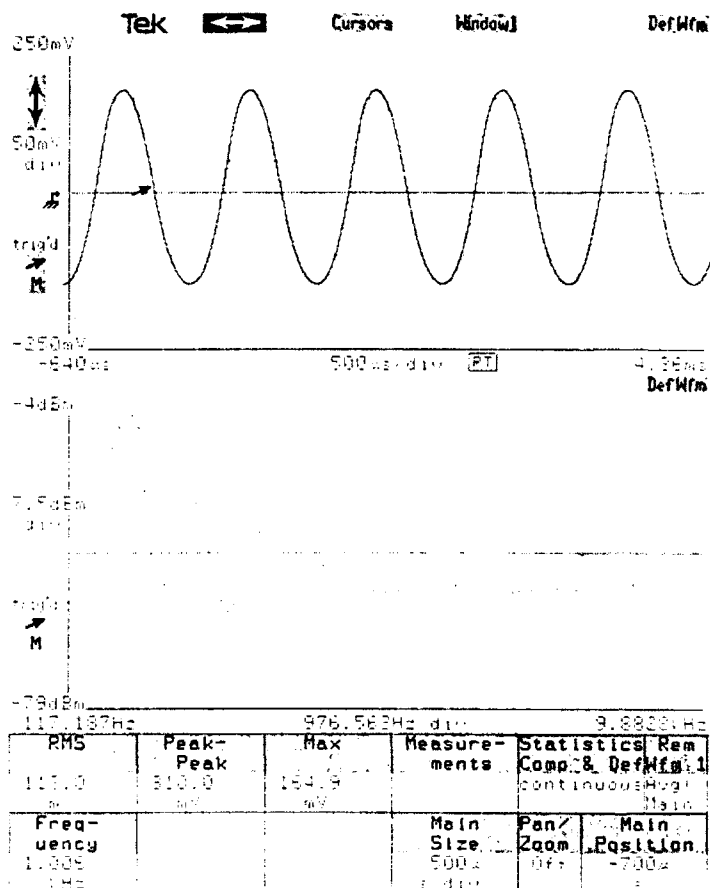DSA 602 DIGITIZING SIGNAL ANALYZER
date: 21-DEC-92 time: 15:07:46

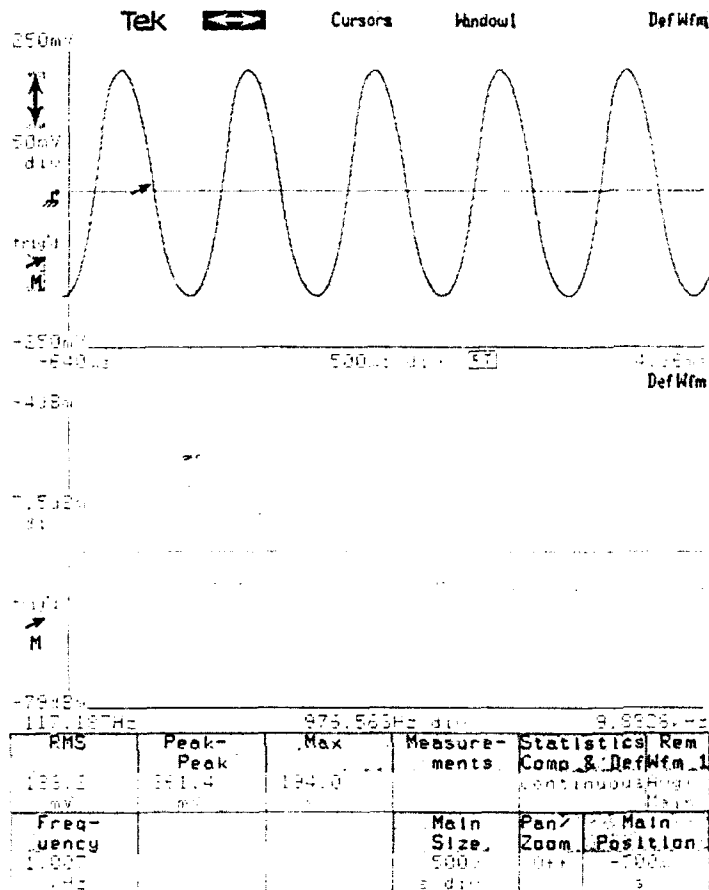**Final Radio Test (Phase Two) - Variation in Modulation Index**

FM Signal Generator:
        Frequency: 30.000 MHz
        Freq. Deviation: 5 kHz ✓
        FM Modulation: 1 kHz
        Amplitude: 5 μV
Radio:
        Carrier: 30.00 MHz
        Volume: 5 units
        co-axial antenna

• Averaging in Time Domain
• FFT of Average in Frequency Domain

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 21-DEC-92 time: 15:08:45

Final Radio Test (Phase Two) - Variation in Modulation Index

FM Signal Generator:

Frequency:	30.000 MHz
Freq. Deviation:	6 kHz ✓
FM Modulation:	1 kHz
Amplitude:	5 µV

Radio:

Carrier:	30.00 MHz
Volume:	5 units
co-axial antenna	

• Averaging in Time Domain
• FFT of Average in Frequency Domain
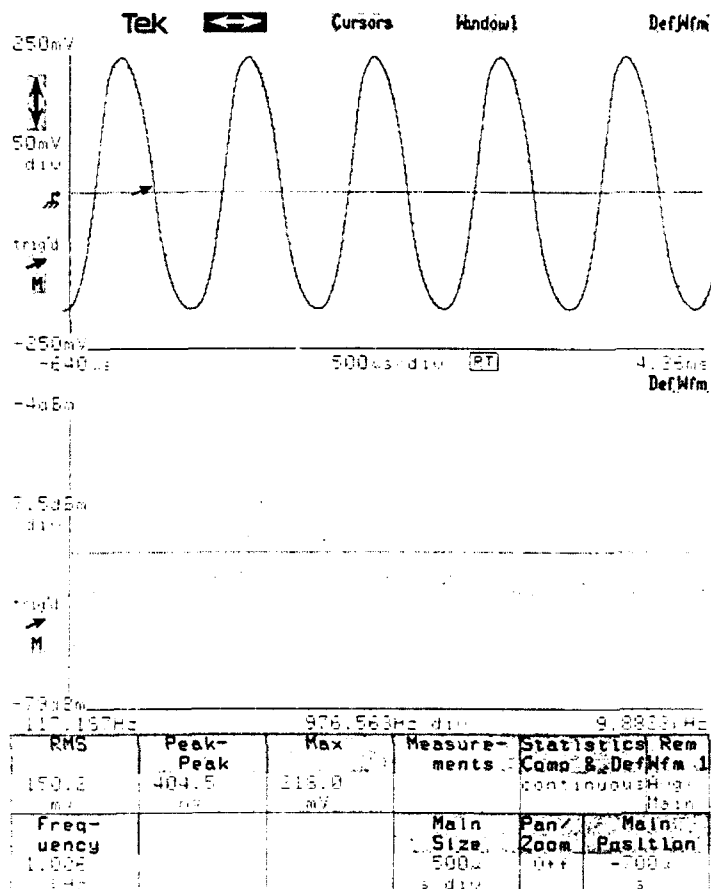
Final Radio Test (Phase Two) - Variation in Modulation Index

FM Signal Generator:
Frequency:	30.000 MHz
Freq. Deviation:	7 kHz ✓
FM Modulation:	1 kHz
Amplitude:	5 µV

Radio:
Carrier:	30.00 MHz
Volume:	5 units
co-axial antenna	

* Averaging in Time Domain
* FFT of Average in Frequency Domain

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 21-DEC-92 time: 15:10:20

RMS	Peak-Peak	Max	Measure-ments	Statistics Rem Comp & DefWfm 1
166.1 mV	440.8	235.2		continuousAvg Main
Freq-uency 1.006 Hz			Main Size 500μ s div	Pan/ Zoom Off	Main Position -700 z s

Final Radio Test (Phase Two) - Variation in Modulation Index

FM Signal Generator:
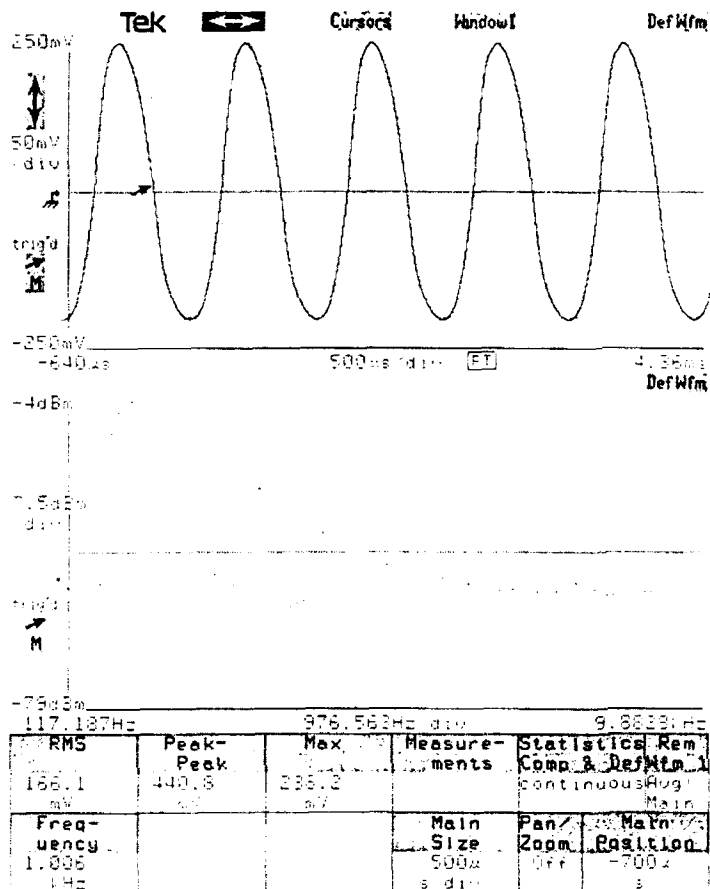   Frequency: 30.000 MHz
    Freq. Deviation: 8 kHz ✓
    FM Modulation: 1 kHz
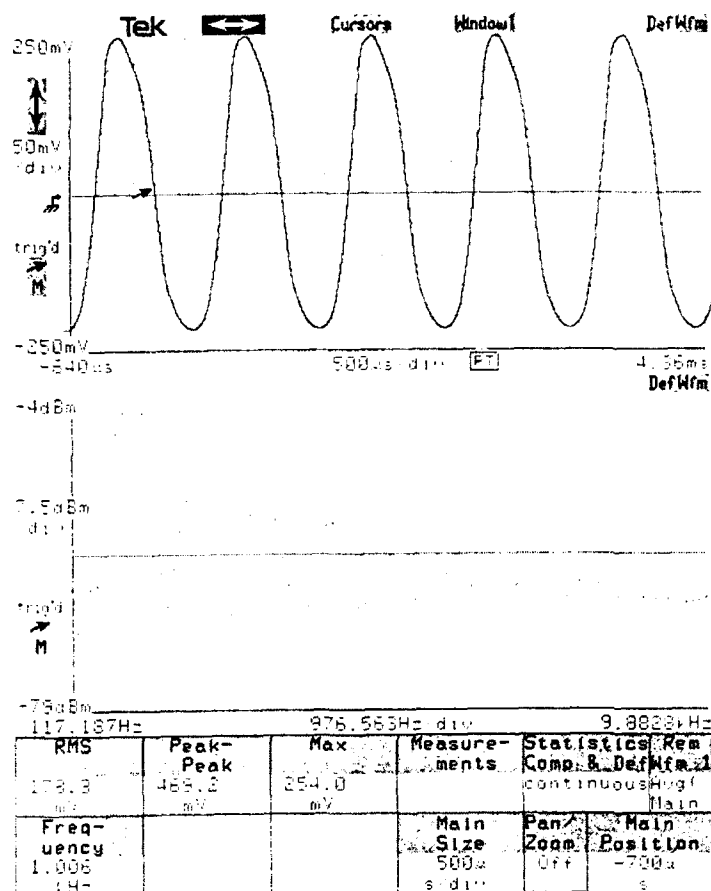   Amplitude: 5 μV
Radio:
    Carrier: 30.00 MHz
    Volume: 5 units
    co-axial antenna

• Averaging in Time Domain
• FFT of Average in Frequency Domain

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DSA 602 DIGITIZING SIGNAL ANALYZER
date: 21-DEC-92 time: 15:11:27

RMS	Peak-Peak	Max	Measure-ments	Statistics Rem Comp & DefWfm 1
178.3 mV	489.2 mV	254.0 mV		continuousAvg Main
Freq-uency 1.006 kHz			Main Size 500u s div	Pan/Zoom Off	Main Position -700u s

Final Radio Test (Phase Two) - Variation in Modulation Index

FM Signal Generator:
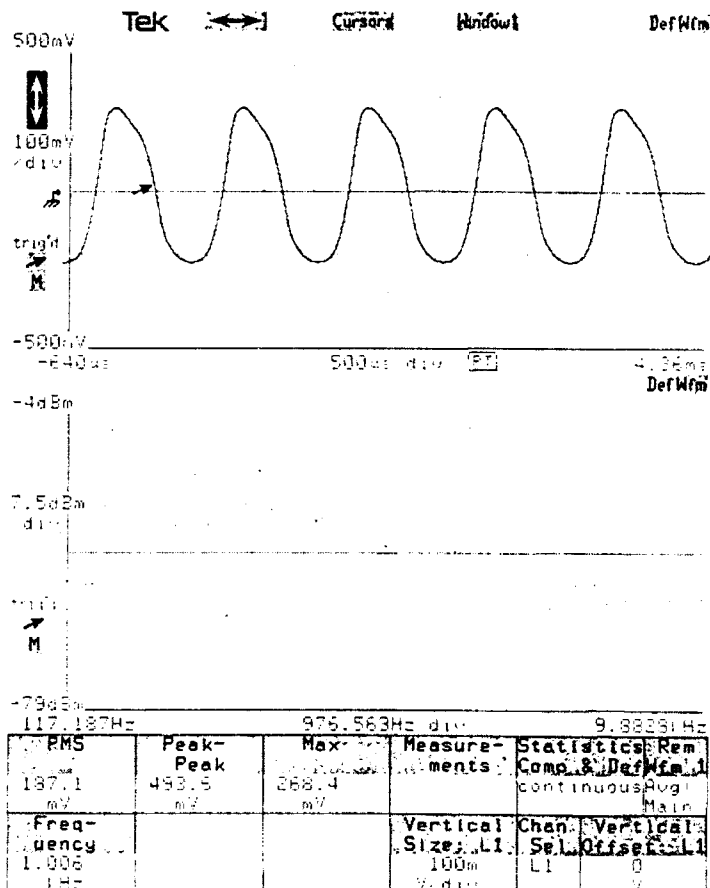   Frequency: 30.000 MHz
    Freq. Deviation: 9 kHz ✓
    FM Modulation: 1 kHz
    Amplitude: 5 μV
Radio:
    Carrier: 30.00 MHz
    Volume: 5 units
    co-axial antenna

• Averaging in Time Domain
• FFT of Average in Frequency Domain

RMS	Peak-Peak	Max	Measure-ments	Statistics Comp. & Def Wfm 1	Rem
197.1 mV	493.5 mV	268.4 mV		continuous Avg Main	
Freq-uency 1.006 Hz			Vertical Size L1 100m V/div	Chan Sel L1	Vertical Offset L1 0 V

Final Radio Test (Phase Two) - Variation in Modulation Index

FM Signal Generator:
- Frequency: 30.000 MHz
- Freq. Deviation: 10 kHz ✓
- FM Modulation: 1 kHz
- Amplitude: 5 μV

Radio:
- Carrier: 30.00 MHz
- Volume: 5 units
- co-axial antenna

- Averaging in Time Domain
- FFT of Average in Frequency Domain

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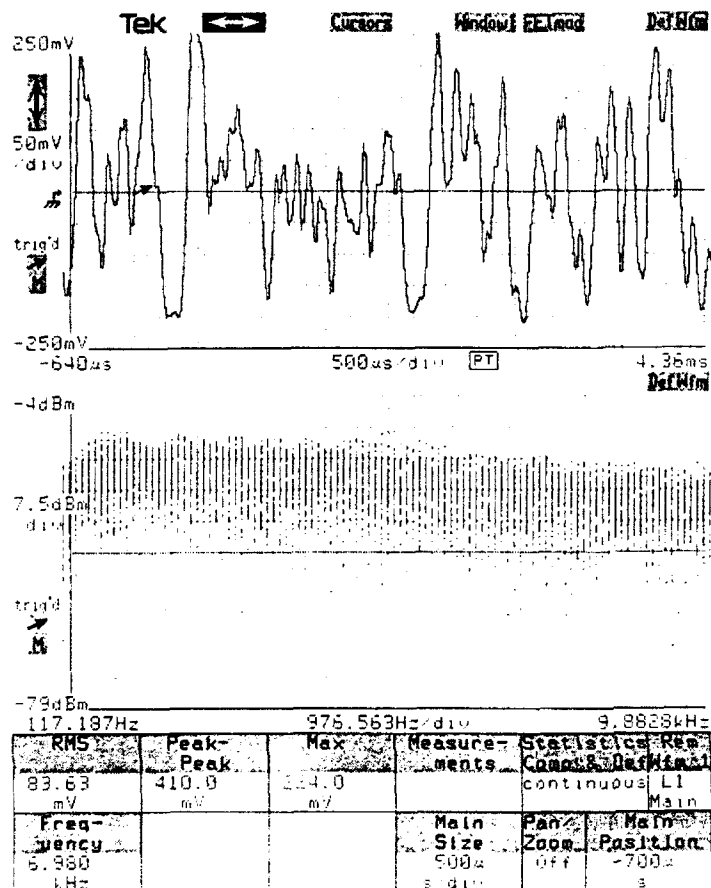# DSA 602 DIGITIZING SIGNAL ANALYZER
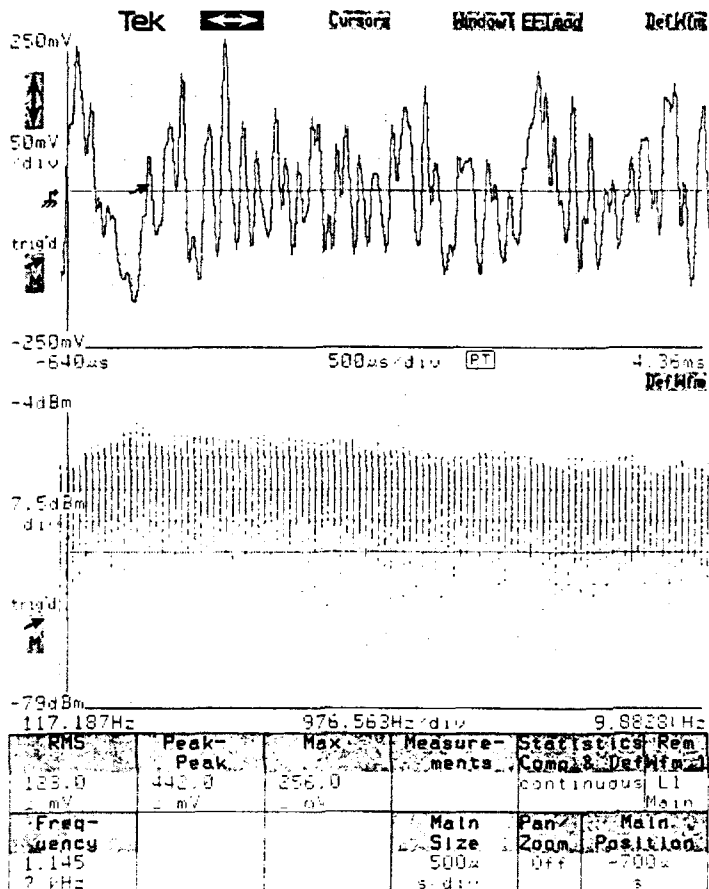## date: 21-DEC-92 time: 16:15:18

Final Radio Test (Phase Two) - Variation in Amplitude

FM Signal Generator:
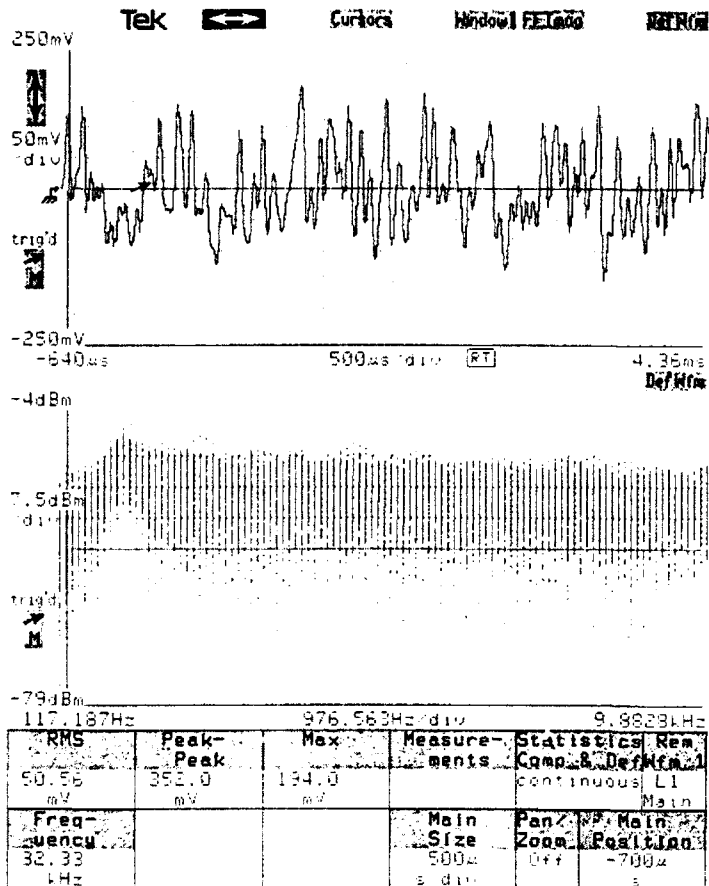   Frequency: 30.000 MHz
    Freq. Deviation: 2 kHz
    FM Modulation: 1 kHz
    Amplitude: 0.1 μV ✓
Radio:
    Carrier: 30.00 MHz
    Volume: 5 units
    co-axial antenna

• No Averaging in Time Domain
• Infinite Persistence in Frequency Domain

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DSA 602 DIGITIZING SIGNAL ANALYZER
date: 21-DEC-92 time: 16:15:58

RMS	Peak-Peak	Max	Measure-ments	Statistics Comp & Def Wfm	Rem
125.0 mV	443.0 mV	256.0 mV		continuous	L1 Main
Freq-uency 1.145 2 kHz			Main Size 500μ s div	Pan Zoom Off	Main Position -700μ s

Final Radio Test (Phase Two) - Variation in Amplitude

FM Signal Generator:

Frequency:	30.000 MHz
Freq. Deviation:	2 kHz
FM Modulation:	1 kHz
Amplitude:	0.25 μV ✓

Radio:

Carrier:	30.00 MHz
Volume:	5 units
co-axial antenna	

* No Averaging in Time Domain
* Infinite Persistence in Frequency Domain

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 21-DEC-92 time: 16:16:51

RMS	Peak-Peak	Max	Measure-ments	Statistics Comp & Def	Rem Wfm 1
50.56 mV	352.0 mV	134.0 mV		continuous	L1 Main
Freq-uency 32.33 kHz			Main Size 500u s/div	Pan/ Zoom Off	Main Position -700u s

Final Radio Test (Phase Two) - Variation in Amplitude

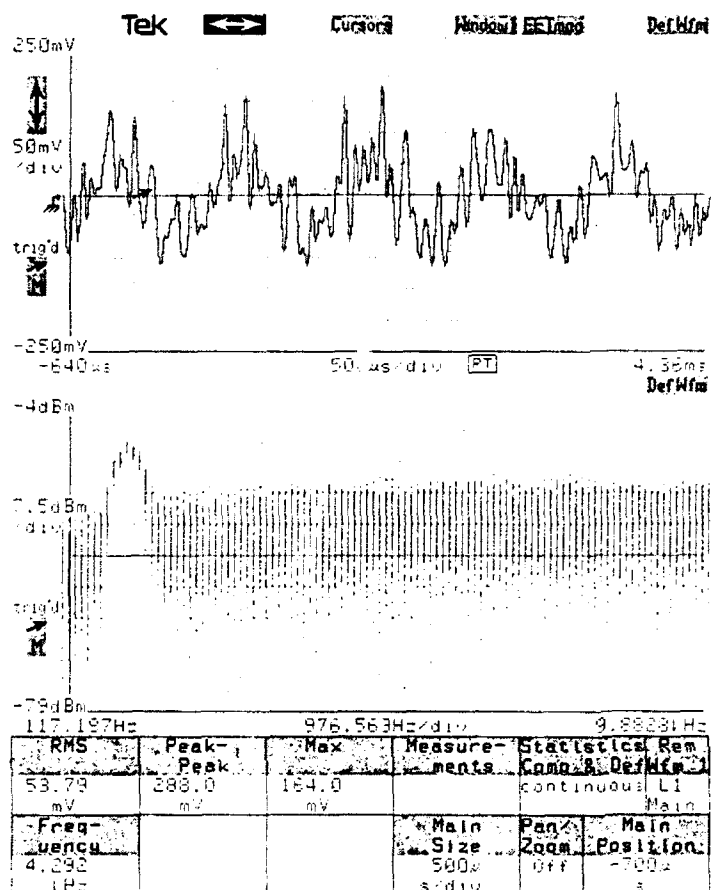FM Signal Generator:
    Frequency: 30.000 MHz
    Freq. Deviation: 2 kHz
    FM Modulation: 1 kHz
    Amplitude: 0.5 μV
Radio:
    Carrier: 30.00 MHz
    Volume: 5 units
    co-axial antenna

* No Averaging in Time Domain
* Infinite Persistence in Frequency Domain

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 21-DEC-92 time: 16:18:03

RMS	Peak-Peak	Max	Measure-ments	Statistics Comp & DefWfm	Rem
53.79 mV	283.0 mV	164.0 mV		continuous L1	Main
Freq-uency 4.293 kHz			Main Size 500µ s/div	Pan/Zoom Off	Main Position -700µ s

Final Radio Test (Phase Two) - Variation in Amplitude

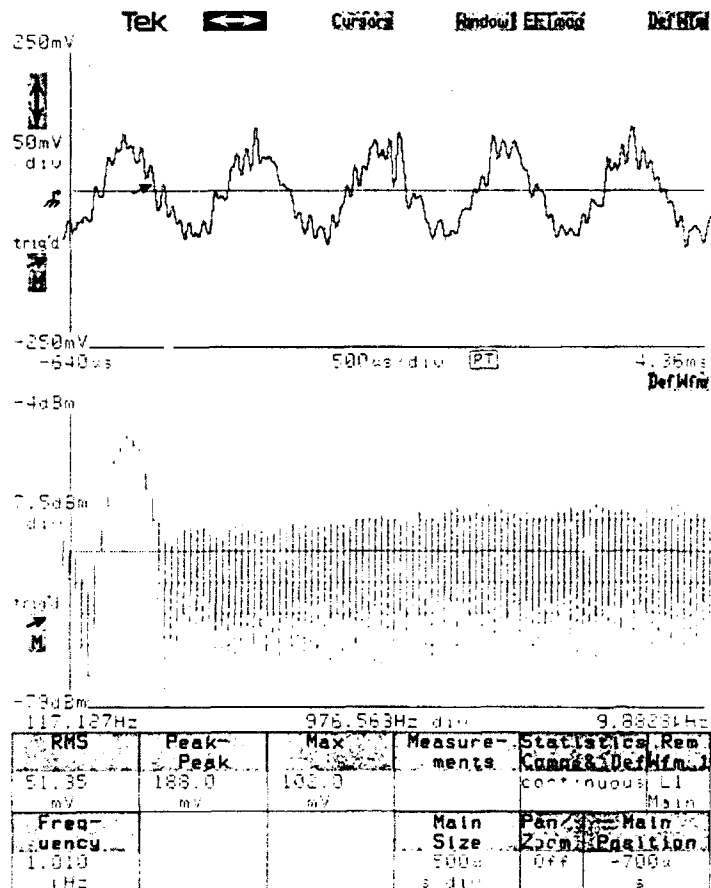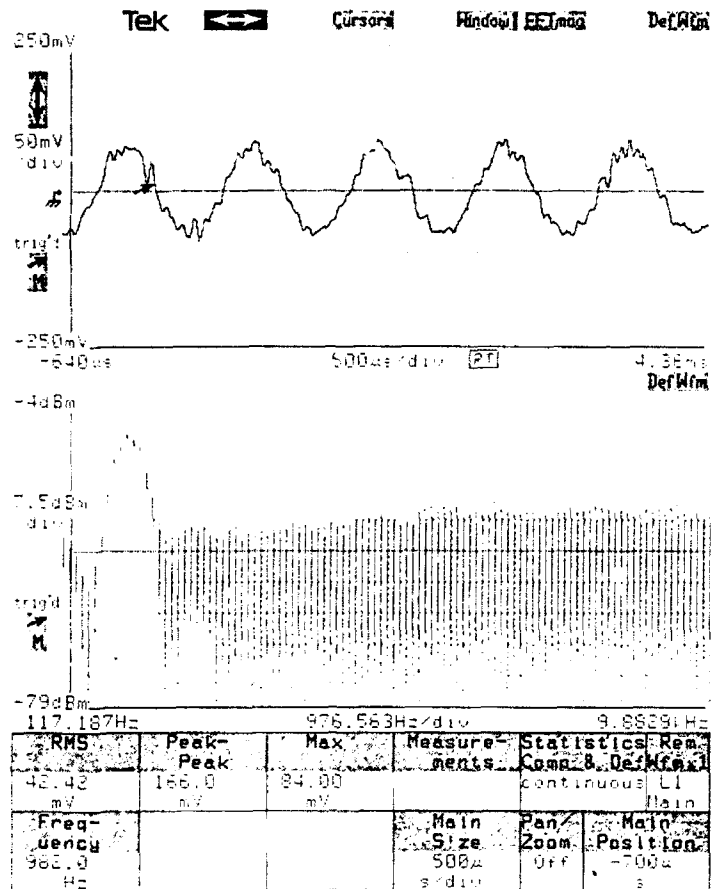FM Signal Generator:
    Frequency: 30.000 MHz
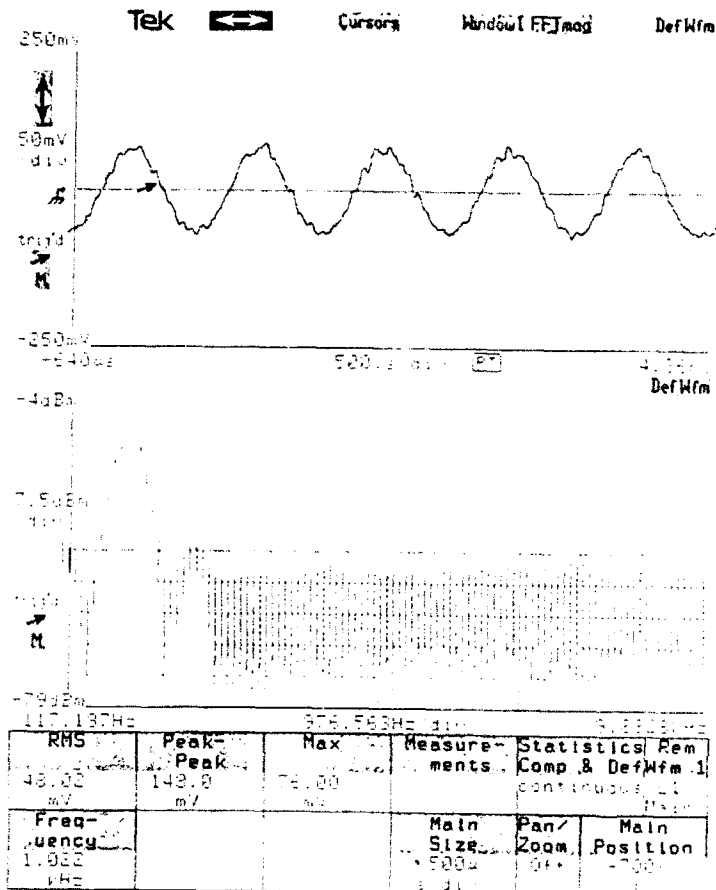   Freq. Deviation: 2 kHz
    FM Modulation: 1 kHz
    Amplitude: 1.0 µV ✓
Radio:
    Carrier: 30.00 MHz
    Volume: 5 units
    co-axial antenna

• No Averaging in Time Domain
• Infinite Persistence in Frequency Domain

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Tek ⟷ Cursors Window FFT acc DefTra

250mV

50mV
/div

trig'd

-250mV
-640us   500us/div (PT)   4.36ms
                                          DefWfm

-4dBm

7.5dBm
/div

trig'd
M

-79dBm
117.127Hz   976.563Hz/div   9.8828kHz

RMS	Peak-Peak	Max	Measure-ments	Statistics Rem Comp&1DefWfm 1
51.35 mV	186.0 mV	102.0 mV		continuous L1 Main
Freq-uency			Main Size	Pan/ Main Zoom Position
1.010 1 Hz			500u s/div	Off -700u s

Final Radio Test (Phase Two) - Variation in Amplitude

FM Signal Generator:
    Frequency: 30.000 MHz
    Freq. Deviation: 2 kHz
    FM Modulation: 1 kHz
    Amplitude: 2.5 µV ✓
Radio:
    Carrier: 30.00 MHz
    Volume: 5 units
    co-axial antenna

* No Averaging in Time Domain
* Infinite Persistence in Frequency Domain

DSA 602 DIGITIZING SIGNAL ANALYZER
date: 21-DEC-92 time: 16:19:30

Final Radio Test (Phase Two) - Variation in Amplitude

FM Signal Generator:
Frequency:	30.000 MHz
Freq. Deviation:	2 kHz
FM Modulation:	1 kHz
Amplitude:	5.0 µV ✓

Radio:
Carrier:	30.00 MHz
Volume:	5 units
co-axial antenna	

• No Averaging in Time Domain
• Infinite Persistence in Frequency Domain

Final Radio Test (Phase Two) - Variation in Amplitude

FM Signal Generator:
Frequency:	30.000 MHz
Freq. Deviation:	2 kHz
FM Modulation:	1 kHz
Amplitude:	10.0 μV

Radio:
Carrier:	30.00 MHz
Volume:	5 units
co-axial antenna	

* No Averaging in Time Domain
* Infinite Persistence in Frequency Domain

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(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence Research Establishment Ottawa Ottawa, Ontario K1A 0Z4	2. SECURITY CLASSIFICATION (overall security classification of the document. including special warning terms if applicable) UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C or U) in parentheses after the title.)

EMP Hardening Investigation of the PRC-77 Radio Set (U)

4. AUTHORS (Last name, first name, middle initial)

Seregelyi, J.S., Gardner, C., Walsh, J.A., and Apps, R.

5. DATE OF PUBLICATION (month and year of publication of document) March 1993	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 64	6b. NO. OF REFS (total cited in document) 5

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

   DREO REPORT

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

   Defence Research Establishment Ottawa
   3701 Carling Ave
   Ottawa, Ontario K1A 0K2

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant) PROJECT 041LT	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) DREO Report 1167	10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)

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(U) The susceptibility of a PRC-77 Radio to a simulated nuclear electromagnetic pulse (EMP) was investigated. Detailed evaluation procedures and results are presented. It is shown that under normal operating conditions, with either the 72-cm or 2.9-m antenna, it is very unlikely that there will be any damage to the radio in the event of an EMP. It should be noted that this was one of the first evaluations performed in the Defence Research Electromagnetic Pulse Simulator (DREMPS) and the investigation was viewed primarily as a means of optimizing general analysis techniques.

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Electromagnetic Pulse (EMP)
Hardening
PRC-77 Radio Set