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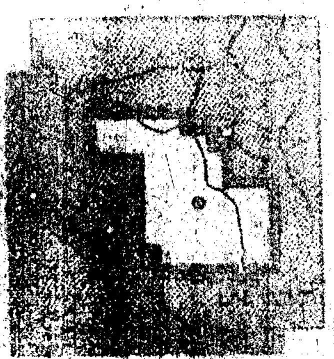
Operation UPSHOT-KNOTHOLE

NEVADA PROVING GROUNDS [redacted]

March-June 1953

Project 6.7

MEASUREMENTS AND ANALYSIS OF ELECTROMAGNETIC RADIATION FROM NUCLEAR DETONATIONS



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OPERATION UPSHOT-KNOTHOLE

Project 6.7

MEASUREMENTS AND ANALYSIS OF ELECTROMAGNETIC RADIATION FROM NUCLEAR DETONATIONS

REPORT TO THE TEST DIRECTOR

by

Physical Sciences Division 6.7 Committee

June 1956

[redacted]

Signal Corps Engineering Laboratories
Fort Monmouth, New Jersey

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ABSTRACT

Project 6.7 consists of two parts, one concerned with the detection and measurement of electromagnetic signals from a nuclear detonation at line-of sight ranges, and the other with the detection of electromagnetic signals emitted prior to the nuclear detonation itself.

Instrumentation for the first part was kept extremely simple in order that interpretation of results would not require complex reduction of data. Unfortunately the limited range of linearity of the equipment resulted in considerable distortion of the signals, and precluded satisfactory interpretation of the results.

In the second part, no pre-nuclear signals were detected from full-scale devices. Subsequently, experiments were carried out on chemical explosives and on nuclear devices complete except for the nuclear insertion. These experiments indicated that the pre-nuclear signals emitted were so weak that under the conditions of the UPSHOT-KNOTHOLE experiment, the pre-nuclear signals were below the threshold of detection.

FOREWORD

This report is one of the reports presenting the results of the 78 projects participating in the Military Effects Tests Program of Operation UPSHOT-KNOTHOLE, which included 11 test detonations. For readers interested in other pertinent test information, reference is made to WT-782, Summary Report of the Technical Director, Military Effects Program. This summary report includes the following information of possible general interest.

(a) An over-all description of each detonation, including yield, height of burst, ground zero location, time of detonation, ambient atmospheric conditions at detonation, etc., for the 11 shots.

(b) Compilation and correlation of all project results on the basic measurements of blast and shock, thermal radiation, and nuclear radiation.

(c) Compilation and correlation of the various project results on weapons effects.

(d) A summary of each project, including objectives and results.

(e) A complete listing of all reports covering the Military Effects Tests Program.

[redacted]

PREFACE

This project was divided into two parts. Part I, the measurement of the amplitude, duration, and polarization of the pulse of the electromagnetic radiation, was the original proposal of the Signal Corps Engineering Laboratories. Part II, the detection and recording of electromagnetic signals emitted by nuclear devices prior to the nuclear detonation, was added to the original proposal at the request of the Armed Forces Special Weapons Project and the Office of Naval Research. Part II is a continuation of a research project of the ONR, Oxcart I, to determine the feasibility under full scale conditions of the objective of this research project.

ACKNOWLEDGMENTS

Captain Walter T. Kerttula was not available to the Signal Corps Engineering Laboratories when the final draft of this report became due, and therefore a committee entitled the Physical Sciences Division 6.7 Committee was appointed by Dr. Craig M. Crenshaw, Division Director, to prepare the report. This committee consisted of Dr. Walter S. McAfee (Chairman), Mr. Walter Pressman, and Mr. Gerald Carp. Dr. E. M. Reilley, who was Capt. Kerttula's supervisor during the time when the experiments were planned and executed, has been of considerable help to the committee in this undertaking. Mr. N. Nisenoff, who assisted in the instrumentation and calibration of equipment for the experiments, has been of continuous help to the committee. The assistance of Dr. Reilley and Mr. Nisenoff is gratefully acknowledged.

In preparing the final copy, continuous use has been made of Captain Kerttula's earlier drafts and his data recordings.

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[redacted]

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The objectives of the experiments to be reported here were:

(1) To measure at short ranges the pulse shape, polarization, amplitude, and duration of the radio frequency signals emanating from nuclear detonations.

(2) To obtain a measure of the correlation of any of these parameters or of the amplitude spectrum with the yields of the weapons.

The preceding were the objectives of Project 6.7, Operation UPSHOT-KNOTHOLE. On about 25 February 1953 an additional task, to be referred to by the code name of Oxcart I, was added at the request of the Office of Naval Research and of Headquarters, AFSWP. The objectives of this task were to detect and record any electromagnetic signals emitted by nuclear devices prior to the nuclear detonation itself.

1.2 BACKGROUND

Prior to tests conducted during Operation TUMBLER-SNAPPER, only qualitative information had been obtained from Signal Corps experiments concerning the electromagnetic signal radiated during the detonation of an atomic weapon.1/ Conclusions drawn from data obtained during Operation GREENHOUSE (1951) and BUSTER-JANGLE (1951) were limited to the following:

(a) Electromagnetic energy in the radio frequency range is radiated from a nuclear detonation.

(b) The signal can be detected at great distance with standard HF communication receivers.

These tests had disclosed no unique characteristic of the radiation.

1/ Operation TUMBLER-SNAPPER, Project 9.5, "Electromagnetic Radiation over the Radio Spectrum from Nuclear Detonation." (S)

[redacted]

It was also known that other groups had obtained fragmentary data during 1951 but that no concerted attempt had been made to measure precisely the physical characteristics of the signal. Among those groups which had noticed or recorded transients ascribed to the detonation of nuclear explosives were:

(a) Sandia Corp.
(b) NBS
(c) LASL

1.3 OPERATION TUMBLER-SNAPPER EXPERIMENTS

Experiments were conducted by several groups from the Signal Corps Engineering Laboratories during Operation TUMBLER-SNAPPER.[1/] The following data were obtained:

(a) Broad-band oscilloscope recordings of signals received by mixing the outputs of a Beverage antenna and a vertical rhombic antenna

(b) Magnetic tape recordings of signals from the antenna system of (a) after passage through a series of band-pass filters

(c) Broad-band oscilloscope recordings of signals received by a short vertical antenna

(d) Chart recordings of rectified signals from the antenna used in (c) after passage through band-pass filters

(e) High-speed film recordings of signals received on a low-frequency receiver and two high-frequency receivers located 3,000 km from the weapons test site.

The conclusions obtained from analysis of the experimental data were:

(a) The radiated pulse has its time origin coincident with that of "Teller" light.

(b) The duration of the radiation is at least 250 microseconds.

(c) The pulse is readily distinguishable from noise in a broad-band system. (No comparison was made with signals radiated from lightning discharges).

(d) The radiated energy is markedly concentrated in the low frequency part of the spectrum with no measurable signal above 15 mc.

(e) The major component of the electric vector is in the vertical plane.

(f) The initial polarity of the pulse is negative.

1.4 RECOMMENDATIONS FOR DATA IMPROVEMENT

The referenced report on Operation TUMBLER-SNAPPER contained the recommendations for future investigations:

(a) That the measurement system be improved with regard to: dynamic range, sensitivity, more appropriate frequency coverage, independence of local electric power, and precision of field strength measurement.

1/ Operation TUMBLER-SNAPPER, Project 9.5, "Electromagnetic Radiation over the Radio Spectrum from Nuclear Detonation." (S)

(b) That future work be concentrated on obtaining additional data on: frequency distribution of the energy, signal shape and duration, correlation of above with weapon yield, measurement of polarization and direction of arrival, determination of electrical and magnetic disturbances in the earth, and investigation of the variations of signal characteristics due to propagation effects over large distance.

1.5 RADIATION FROM CHEMICAL EXPLOSIVES

Work recently reported by Boyd and Hull[2/3/] of the Los Alamos Scientific Laboratory on radio signals produced by the detonation of chemical explosives is of significance for the work reported here. These investigators performed a series of experiments in which different amounts and types of chemical explosives were detonated in a region of controlled electrostatic field. The following results were obtained:

(a) The signal intensity was proportional to the electrostatic field.

(b) The signal intensity was proportional to the weight of explosive detonated.

(c) The initial polarity of the signal was determined by the polarity of the electrostatic field.

(d) At short distances the signal intensity was inversely proportional to the square of the distance.

No attempt was made to give a quantitative theory of the phenomenon.

2/ T. J. Boyd and J. A. Hull, Memorandum dated 30 December 1952 entitled "Electrical Phenomena Associated with Detonation Processes." (CRD)

3/ T. J. Boyd, Memorandum dated 3 September 1952, entitled "Electrical Phenomena Associated with Detonation Processes."

[redacted]

CHAPTER 2

INSTRUMENTATION AND PROCEDURES

2.1 INTRODUCTION

Operation UPSHOT-KNOTHOLE consisted of a test series of 11 atomic detonations at the Nevada Proving Ground between 17 March 1953 and 4 June 1953. Yields of the atomic devices varied from a minimum of 0.21 KT (Shot 3, 3 March) to a maximum of 61 KT (Shot 11, 4 June). The series included tower shots, air drops, and one cannon shot. A summary of the pertinent detonation data is included as Table 2.1. The locations of the detonation points and the "6.7 Initial" detection site are shown in Fig. 2.1. For the 6.7 Oxcart 1 experiment, participation was in effect limited to Shot 11. For this measurement the detection site was located 3,000 yd from the point of detonation.

Instrumentation for both types of experiments necessary for realization of the objectives of Project 6.7 was kept simple where possible. Recommendations made in the TUMBLER-SNAPPER report[1] were followed as a general guide for the primary objective, while available equipment was adapted or modified for the second part.

2.2 PART I (6.7 INITIAL)

2.2.1 Antennas

A block diagram of equipment used for Part I is shown in Fig. 2.2.

Three types of antennas were used during the experiments. These were a Beverage or wave antenna, shielded single-turn loops, and short vertical probes.

On Shots 1 through 8, a 1380 ft long Beverage antenna was used. It was suspended 14 ft above the ground on a true azimuth of 30° 15'. On Shots 9 and 10 a similar antenna of length 1250 ft oriented on a true azimuth of 135° 0', was used. The orientations were

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1/ Operation TUMBLER-SNAPPER, Project 9.5, "Electromagnetic Radiation over the Radio Spectrum from Nuclear Detonation" WT-548 (S)

[redacted]

chosen partly because of terrain limitations and partly as a compromise suitable for all shots.

Two sizes of loops were used; the smaller size was 1 ft in diameter and the larger was 5 ft. Two procedures were employed in feeding the loop outputs into the oscilloscopes. One method employed a balanced feed through difference amplifiers, while in the other, the balanced output of a single loop was attached to the inputs of two oscilloscopes having a common ground.

The probes were 52 in. lengths of copper tubing. When experimentation disclosed that the loops might have had insufficient gain, they were supplemented by probes. The probes were connected to the oscilloscopes by 8 ft lengths of RG-11/U coaxial cable. Calibration of these vertical antennas were carried out at several frequencies by means of a General Radio Model 1001A Signal Generator as a transmitter (feeding a 16 ft vertical antenna) and a Model 32A Ferris Radio Noise and Field Strength Meter. The effective height at very low frequencies determined by smoothing a number of measurements over the frequency range 160 kc/sec to 1 mc/sec was half the physical height. Due to the lack of precision in this set of measurements (day to day variation in the measurements were as large as 10 db), it is thought that any field strengths deduced using the above value for effective height have an uncertainty of at least 3 db. The assumed equivalent circuit for the input to the oscilloscope is given in Fig. 2.3. The antenna was arranged so that the lower end was about 8 ft above the ground. The lower end was connected to the oscilloscope input by 8 ft of RG-11/U coaxial cable. In Fig. 2.3, the symbols denote the following:

C_a = computed antenna capacitance (14.8 μμf)

C_b = antenna base capacitance ($\ll C_s + C_c$)

C_c = capacitance of coaxial cable (164 μμf)

C_s = input capacitance of oscilloscope (40 μμf)

R_s = input resistance of oscilloscope (1.0 megohm)

For frequencies above 8 kc/sec R_s has a magnitude less than one-tenth the parallel capacitive impedance. For these frequencies the input circuit becomes essentially a capacitive impedance divider, and the voltage available at the terminals is

$$V_o = 0.068 V_i$$

V_i is the open circuit antenna voltage and V_o is the output voltage to the amplifier.

Use of an effective height, h, equal to one-half the physical length of the antenna gives

$$V_i = 1/2\ hE,$$

where E = field strength at the antenna. In terms of the output voltage, the field strength is

$$E = 22.3\ V_o \text{ volts/meter.} \qquad (2.1)$$

[redacted]

2.2.2 Oscilloscopes and Cameras

Tektronix Model 513 D oscilloscopes were chosen for these experiments because of their excellent broad-band frequency response. A number of these oscilloscopes had been used successfully in previous weapons tests and were available. This oscilloscope has a flat response from a few cycles per second to 16 mc/sec and has a maximum vertical deflection sensitivity of 30 mv/cm.

The oscilloscopes were carefully calibrated prior to the tests with regard to sweep speed and sensitivity. However, it was found that calibrations had to be repeated just before each shot since the sweep circuits were not entirely stable. A standard signal generator, tuned to an appropriate frequency, was first connected to the oscilloscope input. Then the signal generator output amplitude was measured with a vacuum-tube voltmeter and a single-sweep photograph of the signal was recorded. This photograph was used for calibration of sweep-speed and deflection sensitivity.

The signals were photographed on Kodak Super XX film with Du Mont-Bolsey 35 mm oscilloscope cameras.

2.2.3 Auxiliary Equipment

The oscilloscopes have a single-ended input. This fact presents no problem for use with the probe and Beverage antennas. The Beverage antenna was connected to the oscilloscope through an amplifier of nearly unit-amplification factor. The probes were connected directly to the oscilloscopes without auxiliary amplifiers. Difference amplifiers were constructed for converting the double-ended outputs of the loop antennas to single-ended outputs. Each difference amplifier was connected to an oscilloscope through two stages of RC-coupled amplification. The overall system response was flat from 30 kc/sec to 17 mc/sec.

An EG&G fiducial marker was used to trigger the oscilloscopes. The impedance of several oscilloscopes in parallel was so low that the fiducial marker reset itself too quickly. This was overcome by connecting the fiducial marker into a cathode follower, the output of which was used to trigger the oscilloscope.

Initially, power for the auxiliary amplifier was obtained from two regulated power supplies. Later, the power supplies were found to be the source of certain spurious oscillations and a change was made to dry-cell batteries for plate power.

2.2.4 General Procedure

On a typical test, the equipment was turned on 2 or 3 hours before shot-time to allow ample time for warm-up. Sensitivities were set over a range of values with the most sensitive setting such that normal atmospheric noise caused only a slight broadening of the base-line. Under these conditions, any signal observed could reasonably be assumed to be due to the detonation. There remained the possibility that, by coincidence, a spurious signal due to a lightning flash or

[redacted]

some [illegible] disturbance could occur and be photographed at the time the scopes were triggered by the light from the detonation.

In order to obtain information on the noise near shot time, the fiducial marker was triggered and exposures of the oscilloscope traces taken several times prior to the shot. The last such exposure was usually taken at H-hour minus 5 min. Generally the oscillograms showed no noise, and a record consisted only of the feed-through of the trigger pulse.

For the shot itself, the shutters of the camera were opened at about H-hour minus 60 sec and left open until the shock wave passed.

2.3 PART II (OXCART 1)

2.3.1 General

This task was added after instrumentation for participation in Project 6.7 had been completed. Because of extreme time limitations, readily available equipment was used which could be adapted for the purpose. The experiments required that signals emitted prior to the Teller light be recorded. In operation the Teller light triggered the fiducial marker, which after suitable delay triggered the oscilloscope sweep. This method was chosen in preference to that of triggering on the incoming signal since, at the time of the experiments, nothing was known concerning the amplitude or expected time of arrival of the signal. Also premature triggering by noise pulses is avoided and the Teller light gives a known time reference for the record.

Using the delayed fiducial marker as a trigger made it necessary to delay the incoming signal long enough to permit recording it on the oscilloscope after the arrival of the Teller light. A relative delay of the signal of 150 to 200 μsec with respect to the fiducial marker delay was adequate to allow all signals of interest to be recorded.

Block diagrams of the instrumentation for this phase of the project are shown in Figs. 2.4 through 2.6.

2.3.2 Delay Circuits

The only suitable delay lines available were 1200 μsec quartz delay lines having a 4 mc/sec pass band centered at 9 mc/sec. In order to pass the expected low frequency signal through the delay line, it was necessary to have the output of the antenna modulate a 9 mc/sec carrier which was generated by a local oscillator. The signal from the delay line was amplified, detected by a crystal diode, and presented on the recording oscilloscope.

With a 1200 μsec signal delay, it was necessary to delay the triggering pulse in order to provide a differential delay of 150 to 200 μsec. This was accomplished by means of a multivibrator having a variable delay. With the multivibrator delay set at 1050 μsec and an oscilloscope sweep of 200 μsec, it was possible to record any signal

[redacted]

occurring from 150 μsec prior to the Teller light up to 50 μsec after the light.

The antennas used in these experiments were a horizontal wire, a one-meter vertical probe, and, for shot 11, the Beverage antenna used for "6.7 Initial."

2.3.3 Experimental Procedure

The stations used for these experiments were too close to ground zero to be manned. The equipment was turned on manually some 2 to 3 hr prior to shot time, and was left on until some time after the shot. Only the camera shutters were operated remotely. They were opened by the minus 5 sec, EG&G timing signal and closed when the timing circuits were turned off a few seconds after the shot.

System sensitivities were set according to background noise. Under the best conditions obtained, the background noise was about 5 mv peak to peak at the output of the vertical antenna.

TABLE 2.1 - Summary of UPSHOT-KNOTHOLE Pertinent Detonation Data

Shot Number	Shot Name	Date (1953)	Yield (KT)	Shot Type
1	Annie	17 March	16	300 ft Tower
2	Nancy	24 March	24	300 ft Tower
3	Ruth	31 March	0.21	300 ft Tower
4	Dixie	6 April	11	Air drop, 6022 ft above ground level
5	Ray	11 April	0.22	100 ft Tower
6	Badger	18 April	24	300 ft Tower
7	Simon	25 April	43	300 ft Tower
8	Encore	8 May	26	Air drop, 2423 ft above ground level
9	Harry	19 May	27	300 ft Tower
10	Grable	25 May	15	Cannon shot, 300 ft above ground level
11	Climax	4 June	61	Air drop, 1350 ft above ground level

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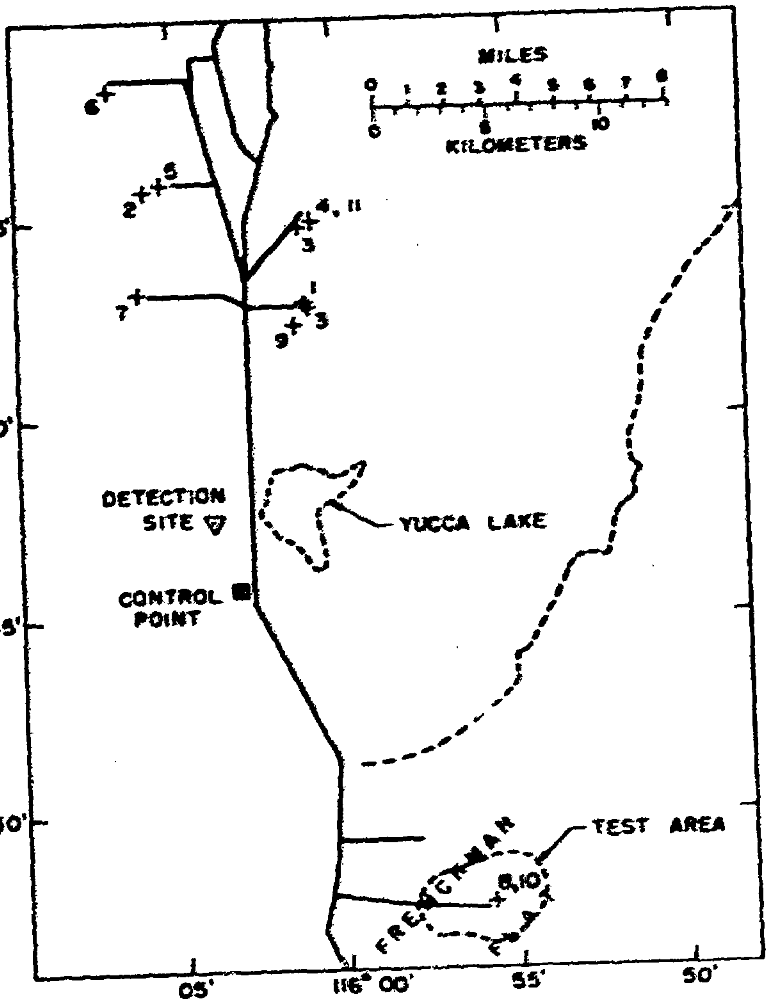

Fig. 2.1 Location of Detonation Sites and Detection Point

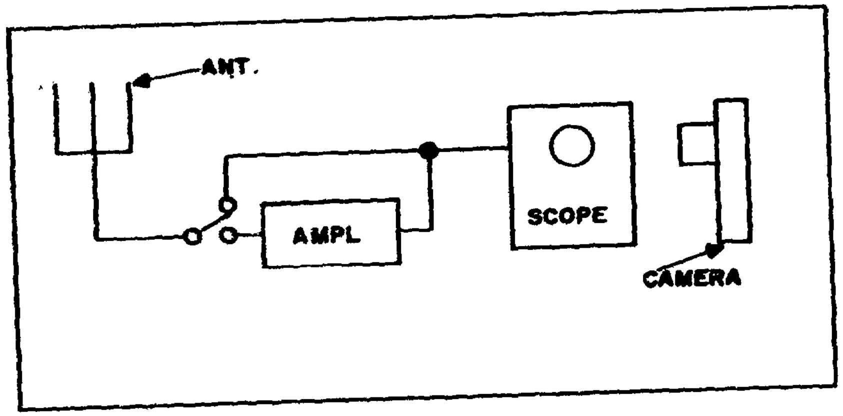

Fig. 2.2 Block Diagram of Project "6.7 Initial" Instrumentation

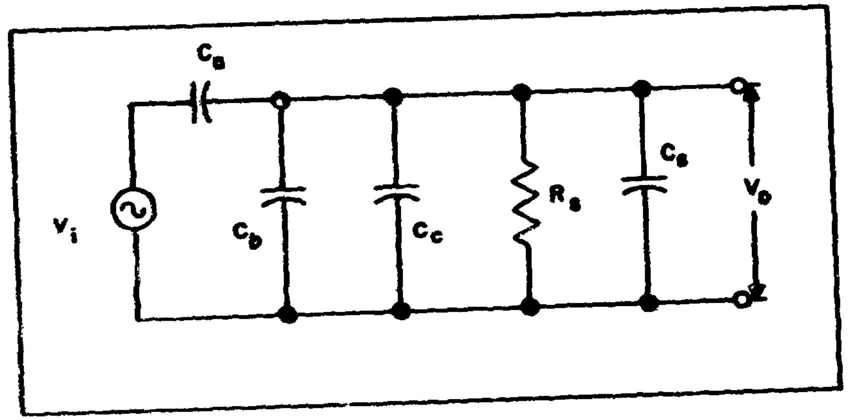

Fig. 2.3 Vertical Antenna Equivalent Circuit

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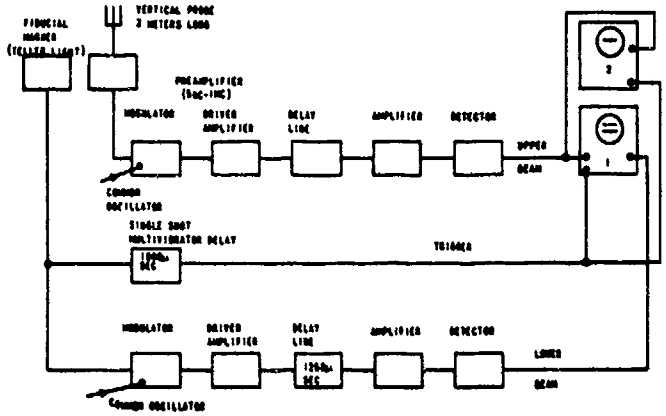

Fig. 2.4 "Oxcart 1" Instrumentation, Oscilloscopes 1 and 2

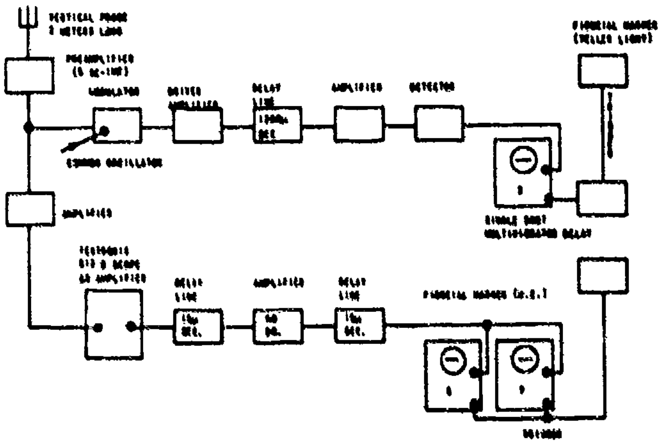

Fig. 2.5 "Oxcart 1" Instrumentation, Oscilloscopes 3, 6, and 7

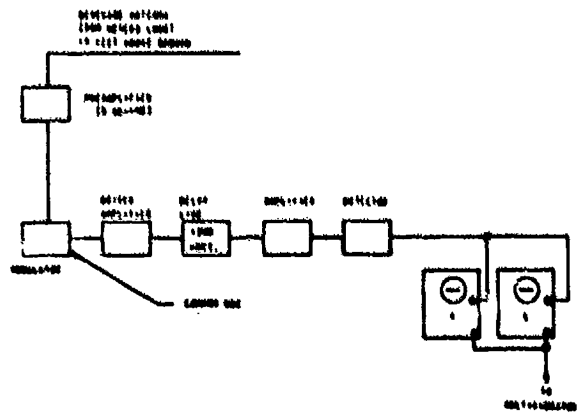

Fig. 2.6 "Oxcart 1" Instrumentation, Oscilloscopes 4 and 5

[redacted]

CHAPTER 3

RESULTS AND DISCUSSION

3.1 PART I (6.7 INITIAL)

3.1.1 Summary of Results

A summary of participation in Part I and results of the measurements is given in Table 3.1. It can be seen from the table that a wide range of oscilloscope deflection sensitivities and sweep speeds was employed. This was done because very little information was available on the magnitude, duration and the wave shape of the electromagnetic pulse. Consequently it was not anticipated that positive results would be obtained in all cases or even a majority of cases.

Analysis of the test data indicated that eleven usable oscillograms were obtained. These oscillograms are included in this report as Figs. 3.1 through 3.11. Amplitude spectra of Figs. 3.5 and 3.11 have been calculated and are included as Figs. 3.12 and 3.13 respectively. In these calculations, Fourier coefficients were computed over a fundamental time period equal to the duration of the signal plus a quiescent period after the signal equal to three times the duration of the signal. The envelopes of these Fourier amplitudes normalized with respect to their maximum values constitute the plots of Figs. 3.12 and 3.13. Examination of the eleven oscillograms reveals a lack of consistency in wave shape from shot to shot and no clear correlation with yield is apparent. Thus the data obtained fall far short of expectations. Further discussion of the oscillograms is included in Section 3.1.3

3.1.2 Instrumentation

The experience of this project indicates the need for further study and improvement of instrumentation. In particular, the antennas used in this type of experiment require careful study.

In this experiment, single turn shielded loops were chosen as the primary antennas. This choice was made for the following reasons:

[redacted]

the loop antenna has simple characteristics and hence should yield easily interpreted results, and its response is to a large degree independent of ground constants and surrounding objects. It was believed that these characteristics would outweigh the strong frequency dependence and relative insensitivity of this antenna. Unfortunately, the undamped loops used on this experiment had a tendency to ring upon receiving the signal associated with a nuclear detonation. Consequently, analysis of the recorded data proved to be impossible.

The Beverage antenna was used only because it had been used in previous experiments and comparison with these results was desired. Although this type of antenna has a relatively large effective height, its performance is strongly dependent upon ground constants. Theoretical determination of its response is therefore difficult.

The vertical whip antenna was used because its response is frequency independent for those frequencies where it is physically small compared with the wavelength. However, it is dependent upon ground constants and surrounding objects and must be properly calibrated to yield reliable field strength measurements.

An unfortunate source of error was the limited dynamic range of the preamplifier and cathode follower circuit. Post-operational tests indicated that the maximum output of this circuit was approximately +2 volts and -1 volt. This fact was not known to the experimenters in the field and resulted in severe distortion and limiting of the signal into the oscilloscope whenever the preamplifier was used. In addition, the preamplifier response dropped off below 30 kc/sec, and as was later determined, the maximum energy of the signal was in the 10 to 15 kc/sec region.

3.1.3 Discussion of Results

The recorded wave forms are shown in Figs. 3.1 through 3.11 and with the accompanying captions are self-explanatory. A cm is defined for these figures as the distance between grid lines. In Figs. 3.3, 3.6 and 3.7, where no grid lines are shown, the scale is the same as in the remaining photographs.

Spectrum analyses were made of the two oscillograms which are believed to be most representative of the true wave shape of the radio frequency radiation associated with a nuclear detonation. Figure 3.12 gives the spectrum of the oscillogram, Fig. 3.5, obtained using the large loop antenna on Shot 3. The energy has a major peak at 10.8 kc and a minor peak at 35 kc with the major portion of radiated rf energy being below 60 kc. Figure 3.13 gives the spectrum of the oscillogram, Fig. 3.11, obtained using the 52-in. vertical whip antenna on Shot 10. The energy peaks rather sharply at 11 kc and has small plateau at 32 kc, with the major portion of the energy being below 42 kc. In general, it was found that the energy of the radio frequency signal was predominately in the low frequency region, with the peak occuring at approximately 11 kc.

Both horizontal and vertical loops were used during Shots 7 and 8 in an effort to obtain data on the polarization of the pulse. For Shot 7, the vertical loop gave a much stronger signal. For Shot 8, a strong signal was received on both. Because of these specific results and the general unreliable results obtained with the vertical loop on other shots, no conclusions can be drawn with respect to polarization.

It is worth noting that Figs. 3.1, 3.2, 3.4, 3.6, 3.7 and 3.10 were all obtained using a Beverage antenna. With the exception of Fig. 3.10, all those oscillograms show many fluctuations which are essentially of one polarity. It is not known whether this appearance is caused by the natural phenomenon itself, spurious radiations, or the method of equipment assemblage.

For two of the 11 oscillograms it was possible to compute peak field strengths for signals recorded with the probe antenna. These were computed by measuring the voltage deflections on the oscillograms and inserting these voltage values in Equation 2.1. For Shot 7, Fig. 3.9 gives a peak field strength in excess of 132 volts/meter. For Shot 10, Fig. 3.11 gives a field strength greater than 32 volts/meter.

3.2 PART II (OXCART 1)

The principal participation in this part of the project was for Shot 11, (see Table 3.2) with limited participation for Shots 4 through 10. The results were negative. With a threshold sensitivity of 6 mv/meter, no signals were detected.

Subsequent experiments were conducted at Sandia Base with chemical explosives and Mark III weapons complete except for the nuclear insertion. The maximum field strength at 50 yd due to the detonation of a Mark III weapon (chemical portion only) was approximately 20 mv/meter. Based upon these tests at Sandia Base, the field strengths at the UPSHOT-KNOTHOLE receiver sites of signals associated with the chemical explosive portions of the nuclear weapons detonated were below both the threshold of detection, as determined by the voltage sensitivity settings and the ambient noise level.

Fig. 3.1 Shot 2, Beverage Antenna; Sweep Speed 100 μsec/cm, Sensitivity 21 v/cm

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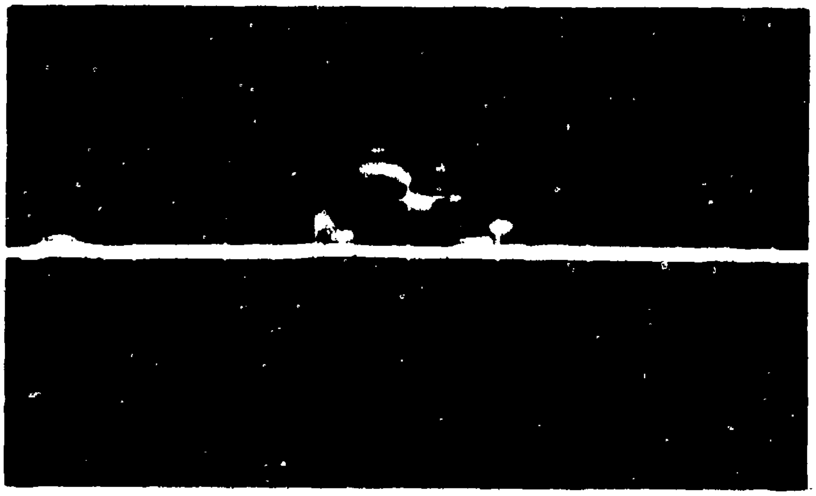

Fig. 3.2 Shot 2, Beverage Antenna; Sweep Speed 10 μsec/cm, Sensitivity 7 v/cm

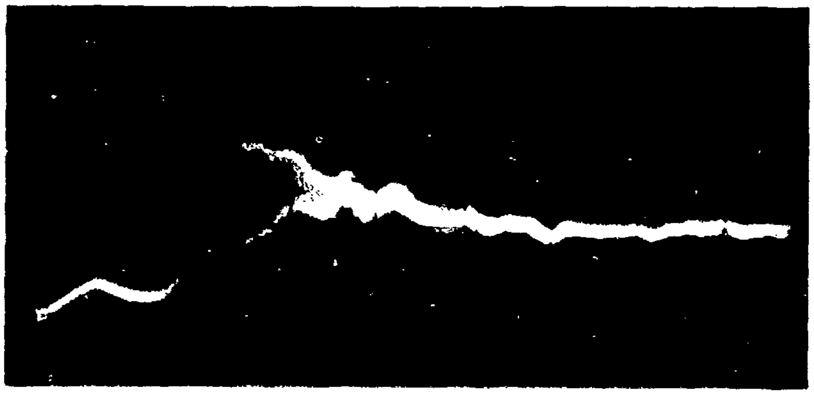

Fig. 3.3 Shot 2, 5 ft Loop; Sweep Speed 10 μsec/cm, Sensitivity 0.01 v/cm

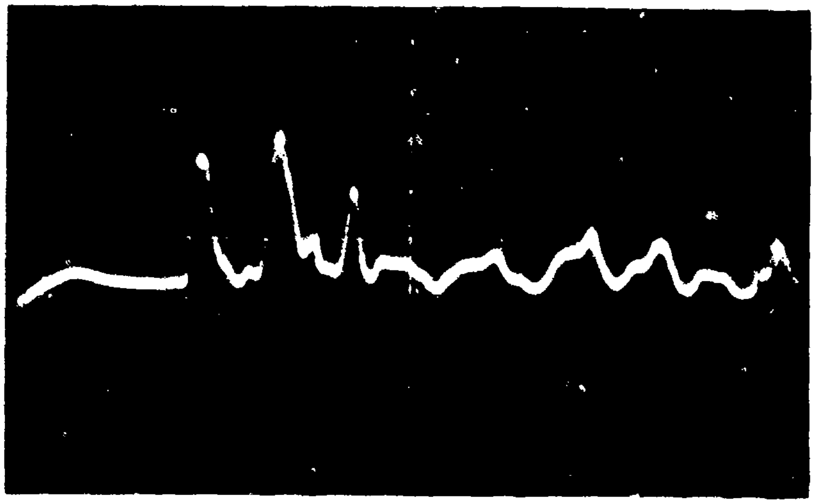

Fig. 3.4 Shot 3, Beverage Antenna; Sweep Speed 10 μsec/cm, Sensitivity 2.7 v/cm

[redacted]

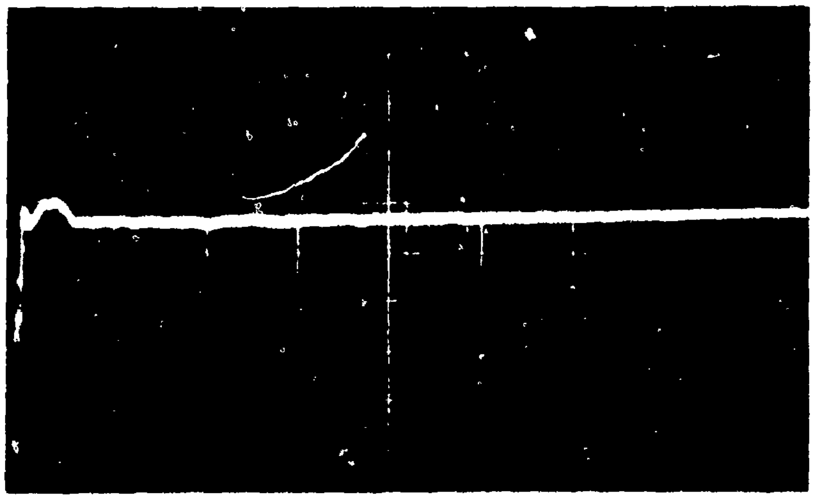

Fig. 3.5 Shot 3, 5 ft loop; Sweep Speed 10 μsec/cm, Sensitivity 0.1 v/cm

Fig. 3.6 Shot 4, Beverage Antenna; Sweep Speed 10 μsec/cm, Sensitivity 2.1 v/cm

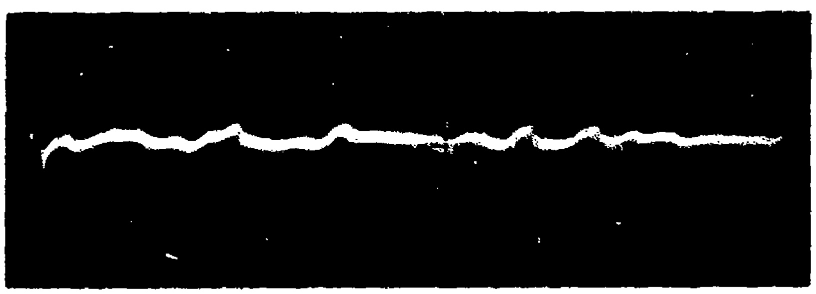

Fig. 3.7 Shot 5, Beverage Antenna; Sweep Speed 10 μsec/cm, Sensitivity 7 v/cm

Fig. 3.8 Shot 7, 52 in. Whip, Sweep Speed 10 μsec/cm, Sensitivity, 1 v/cm

Fig. 3.9 Shot 7, 52 in. Whip; Sweep Speed 100 μsec/cm, Sensitivity 1.0 v/cm

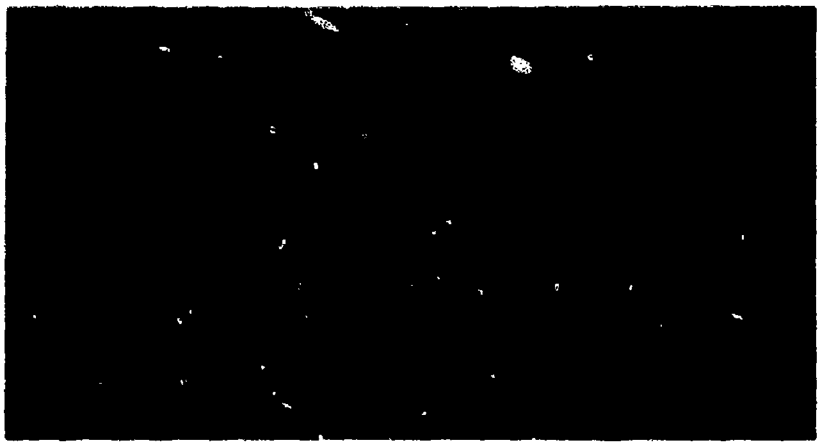

Fig. 3.10 Shot 8, Beverage Antenna; Sweep Speed 0.1 μsec/cm, Sensitivity 0.7 v/cm

[redacted]

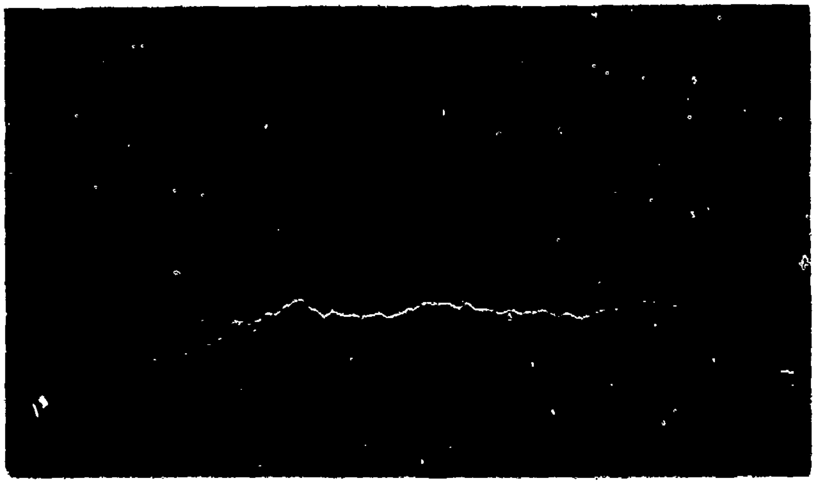

Fig. 3.11 Shot 10, 52 in. Whip; Sweep Speed 10 μsec/cm, Sensitivity 1.0 v/cm

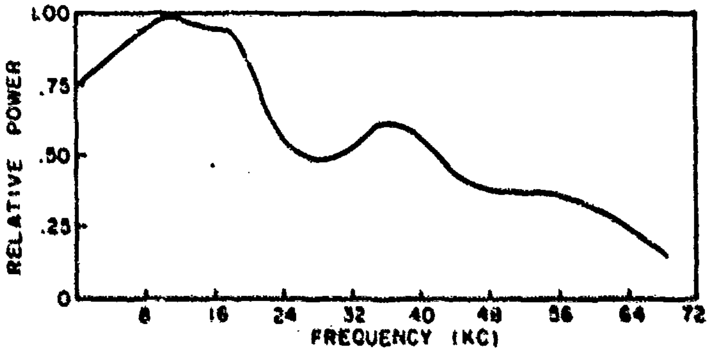

Fig. 3.12 Frequency Analyses of Figure 3.5

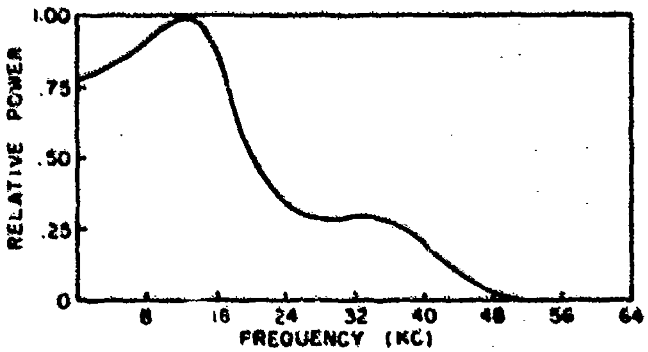

Fig. 3.13 Frequency Analyses of Figure 3.11

TABLE 3.1 - Participation and Results of Project "6.7 Initial" Measurement

Shot No.	Equipment			Results**	Comments
	Antenna	Sweep Speed (μ sec/cm)	Oscilloscope Sensitivity* (v/cm)		
1	Beverage	14	0.003	N.R.	Due to mechanical or electrical failure of equipment, no data obtained.
	Beverage	100	0.3	N.R.	
	5 ft loop	50	0.003	N.R.	
	5 ft loop	600	0.01	N.R.	
	1 ft loop	109	0.003	N.R.	
	1 ft loop	140	0.05	N.R.	
	1 ft loop	1,000	0.03	N.R.	
2	Beverage	100	21	3.1	Amplifiers overloaded.
	Beverage	10	7	3.2	Amplifiers overloaded.
	5 ft loop	10	0.01	3.3	Trace shows ringing. Upper envelope probably indicative of true wave-sweeps.
	5 ft loop			N.R.	Oscilloscope failed.
	1 ft loop	10	0.003	N.R.	No data due to improper connection.
	1 ft loop	1,000	0.003	N.R.	
	1 ft loop	10	0.03	N.R.	
3	Beverage	10	2.7	3.4	Amplifiers overloaded
	Beverage	1	2.7	N.R.	Amplifiers overloaded
	5 ft loop	10	0.1	N.R.	
	5 ft loop	10	0.1	3.5	
	5 ft loop	1	0.1	N.R.	
	5 ft loop	1	0.1	N.R.	
	1 ft loop	10	0.01	N.R.	

[redacted]

TABLE 3.1 - (cont)

Shot No.	Equipment			Results**	Comments
	Antenna	Sweep Speed (μ sec/cm)	Oscilloscope Sensitivity* (v/cm)		
4	Beverage	10	2.1	3.6	Amplifiers overloaded.
	Beverage	1	2.1	N.R.	
	5 ft loop	10	0.1	N.R.	
	5 ft loop	10	0.1	N.R.	
	5 ft loop	1	1.0	N.R.	
	5 ft loop	1	1.0	N.R.	
	1 ft loop	10	0.1	N.R.	
5	Beverage	10	7.0	3.7	Amplifiers overloaded.
	Beverage	1	0.7	N.R.	
	5 ft loop	1	0.03	N.R.	
	5 ft loop	0.1	0.03	N.R.	
	5 ft loop	1	0.03	N.R.	
	5 ft loop	1	0.03	N.R.	
	1 ft loop	10	0.003	N.R.	
6	Beverage	10	7.0	N.R.	
	Beverage	1	0.7	N.R.	
	5 ft loop	1	0.003	N.R.	
	5 ft loop	100	0.003	N.R.	
	5 ft loop	1	0.003	N.R.	
	52 in. whip	1	0.3	N.R.	
	52 in. whip	10	1.0	N.R.	

TABLE 3.1 - (cont)

Shot No.	Equipment: Antenna	Equipment: Sweep Speed (μ sec/cm)	Equipment: Oscilloscope Sensitivity* (v/cm)	Results**	Comments
7	Beverage	10	7.0	N.R.	
	Beverage	1	0.7	N.R.	
	5 ft loop	1	0.01	N.R.	
	5 ft loop	100	0.03	N.R.	
	5 ft loop,horiz	1	0.01	N.R.	
	52 in. whip	10	1.0	3.8	off scale
	52 in. whip	100	1.0	3.9	
8	Beverage	100	2.1	N.R.	
	Beverage	0.1	0.7	3.10	
	5 ft loop	10	0.003	N.R.	
	5 ft loop	1	0.003	N.R.	
	5 ft loop,horiz	10	0.003	N.R.	
	52 in. whip	1	0.3	N.R.	
	52 in. whip	100	0.3	N.R.	
9	NO PARTICIPATION				
10	Beverage	100	0.7	N.R.	
	Beverage	1	0.7	N.R.	
	5 ft loop	10	1.0	N.R.	
	5 ft loop,horiz	10	1.0	N.R.	
	52 in. whip	10	1.0	3.11	
11	NO PARTICIPATION				

* Includes pre-amplifier whenever used.
** Figure number listed whenever usable oscillograms were obtained; N.R. indicates no usable recording.

[redacted]

TABLE 3.2 - Participation and Results of Project 6.7 Oxcart 1 Measurements

Shot No.	Antenna	Sweep Speed (μ sec/cm)	Sensitivity* (v/cm)	Results**	Comments
11	2 Meter whip	30		N.R.	1200 μsec delay
	52 in. whip	30	0.5	N.R.	1200 μsec delay
	52 in. whip	30	0.08	N.R.	1200 μsec delay
	Beverage	30	0.03	N.R.	1250 μsec delay
	Beverage	30	0.1	N.R.	1250 μsec delay
	52 in. whip	30	1.7	N.R.	30 μsec delay
	52 in. whip	30	8.0	N.R.	30 μsec delay

* Includes pre-amplifier whenever used.
** Figure number listed whenever usable oscillograms were obtained;
N.R. indicates no usable recording.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

4.1.1 Part I (6.7 Initial)

a. Electromagnetic radiations are emitted in the low rf range during a nuclear explosion. This is a confirmation of what was known.

b. The data do not indicate any correlation between pulse characteristics and bomb yield.

c. Results obtained from crossed loops were insufficient to permit a definite conclusion concerning the polarization of the signal.

d. In general, the phenomenon appears to be quite complex and experimental techniques must be improved before conclusive data can be obtained.

e. Shielded-loop antennas are not suitable for this type of measurement. They are unsuitable in two respects: (1) a single turn loop affords insufficient gain and (2) an under-damped loop antenna rings upon receiving a sharp pulse.

The results here are not in complete agreement with earlier work. In most cases there is only a failure to corroborate earlier results rather than a positive disagreement. The apparatus employed in these experiments was extremely simple; it consisted of an antenna connected directly to the oscilloscope input for most of the results shown. The amplifiers of the oscilloscope had a flat response from a few cycles per second up to 16 mc/sec. Unfortunately, as later tests showed, the range of linear response of the cathode follower was extremely limited. This fact was not known to the experimenters, and it resulted in considerably distorted signals for most shots on which results were obtained.

4.1.2 Part II (Oxcart 1)

No definite conclusions could be drawn from the experiments

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performed at the Nevada Proving Grounds for this part of the project. The data were inconclusive because of high background noise and equipment difficulties.

Later experiments on high explosives showed that no signals could have been expected under the test conditions.

4.2 RECOMMENDATIONS

4.2.1 Part I (6.7 Initial)

The importance of arriving at a quantitatively precise understanding of the mechanism by which electromagnetic waves are generated during nuclear explosions cannot be over-stated. These experiments have contributed very little toward the understanding of the basic phenomena, which was the primary aim. They have added to the information which can lead to the designing of better experiments for investigating basic questions and should be pursued in that respect. Although a considerable amount of information has become available since these experiments were performed, precise information relating spectral content and shape or peak field strength with type or energy yield of the weapon is still wanting. Moreover, an explanation of the fundamental mechanisms involved is also lacking.

It is therefore recommended that these experiments be continued at a subsequent test.

4.2.2 Part II (Oxcart 1)

These experiments and the subsequent experiments on high explosives demonstrate that no signals of interest for the purpose of Oxcart 1 exist prior to the main nuclear signal. No further experiments are recommended.

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