27 cap
25 cap

UCID - 16781

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LAWRENCE LIVERMORE LABORATORY

University of California/Livermore, California

FEASIBILITY OF OBSERVATION OF CAVITY GROWTH

BY E.M. "SCATTERING"

(U)

L. F. Wouters

April 1, 1969

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FEASIBILITY OF OBSERVATION OF CAVITY GROWTH

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This was a study of the feasibility of sensing the electromagnetic signal due to the interaction of a growing nuclear explosion cavity with an impressed, artificial, EM "illumination" field. Such an expanding, conducting sphere was presumed to thereby "write" its history in the (underground) EM field distribution. The measurement challenge would be to extract this time-dependent change (or "scattering" signal) in the presence of the strong direct background from the field generator. The analysis appeared to be a two-part problem:

"Visibility" - Is the scattered signal sufficiently large and discriminable?

"Quality" - Can its features be measured sufficiently well to obtain meaningful information concerning cavity growth - such as total hydrodynamic energy?

This brief paper and the extensive "Appendix" (UCID-16782) have the purposes of exhibiting the character and magnitude of the difficulties revealed by just the visibility phase, and of documenting its general conclusions, namely that the "optimum" embodiments involve either:

- a. Requirements which are beyond the present state of EM technology, or
- b. Requirements which invoke investments beyond the present range of programmatic interest and/or capacity.

The basic study system concept is illustrated in figure 1. It includes the field generator element, the nuclear explosion cavity and the field sensor. Other pertinent geometrical features and parameters are also indicated. Of course, the general configuration is not restricted to a single transmitter, nor to a single receiver. Likewise multi-element generator and sensor arrays may be advantageous.

Evidently, this enunciation opens a very broad range of possibilities in test conditions, system and element geometries, frequency choice, power and sensitivity, circuit sophistication, and so forth. Much of the study was thus occupied in choosing worthwhile condition parameters and invoking rational system criteria and selection rules. The prototype explosion (5 kt at 200 m. dob) was assigned the cavity growth history shown in figure 2. The general scheme appeared to be relatively insensitive to yield choice; this was selected as typifying a trial event.

The principal design criteria emerged as:

- Restriction of major hardware components to surface locations.
- Generator configured for maximum possible cavity coupling.
- Sensor configured for optimum Signal/Background ratio.

The electromagnetic analysis procedure itself is best summarized by simply reproducing the Table of Contents of the Appendix report; this appears here as Table I.

The Prototype Cases

Out of this melee, six "primitive" system configurations were chosen as best characterizing the several basic patterns. These are summarily identified (and illustrated) as follows:

Earth Conduction Schemes in Alluvium only:

Figure 3: D.C.

VLF (calculated at 2×10^4 Avis)

Quasistatic Magnetic Field Schemes in Alluvium or Granite:

Figure 4: VLF; Axial illumination, crossed loops.

Figure 5: VLF; Axial illumination, concentric quadrupole sensor.

Figure 6: VLF; Equatorial illumination, crossed loops.

Electromagnetic Radiation in Granite only:

MF; Spherical resonance regime (calculated at 2×10^6 Avis)

Talbe II compares the predicted performance of these systems.

Bear in mind that each case assumes the same illumination power of 100 kilowatts. N_f is the "Nulling factor"; it measures the degree of background suppression required to redress the S/B ratio to unity. This involves a varied pattern of intrinsic background suppression within the system configurations. The number does not include any auxiliary suppression schemes, such as local field nulling, electronic cancellation, etc. Even so, the scattered signals are shockingly small, and the required background suppression is almost impossibly large, in most cases.

Aside from those disconcerting numbers, the other striking broad feature is the magnitude of the hardware concepts - such as "loops" weighing 10 to 50 tons. The minimum price of a credible set of development experiments is about the equivalent of three "ordinary" nuclear events. (This is not the number of required event participations.)

The MF* scheme in granite appears to be marginally feasible - at least in the sense of "seeing" the cavity. (Its embodiment is similar to figure 6.) This scheme has the significant virtue that it would attempt to measure instantaneous cavity size in terms of a related, unique "resonant" frequency - rather than as a time-dependent amplitude. However, additional analysis alone does not appear to unambiguously decide technical feasibility with respect to potential data "Quality". While the experimental hardware would probably be less spectacular, the development price would not be much less. This is quite apart from the problems and cost of moving a representative fraction of the Test program to a suitable granite site. In alluvium, this scheme is defeated by overall propagation attenuations of order e^{-25} .

Nothing has been said about the elaborate restrictions and controls which would need to be imposed on test site layouts and installations, in the interests of identifying the small signals of Table II.

The various cases considered during this study (not all reported here), taken together with the optimization criteria, appear to bracket

*Medium frequency (300 khz - 3 mhz)

the range of possibilities sufficiently well, that there is little chance that we missed a "miracle" - at least within the domain of "Figure One" concepts.

The broad conclusion for the general class of artificial illumination schemes is that these are not feasible on the basis of present technology and/or present programmatic criteria.

P.S. The "Appendix" is a thick, murky thing. If you really want one, let me know.

LFW

TABLE I - FEASIBILITY STUDY CONTENTS
(Appendix - UCID-16782)

Introduction

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Summary Tables

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The Air-Earth Interface

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 e. Cavity Resonance

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Resonance & Q

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The Optimum Illumination Problem

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Loop Signals; Earth Probe Signals

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The Optimum Coupling Problem

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Radiative Dipole Expressions

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Power Req't & Radiation Resistance

Induced Current; Cavity Moments

THE PROTOTYPE CASES

The Conduction Schemes

D.C. Conduction Case; Noise

VLF Conduction; Signal/Background

Quasistatic Magnetic Field Schemes

Axial Illum., Orthogonal loops

Axial Illum., Concentric loops

Equatorial Illum., Orthogonal loops

The Radiation Schemes

Element Dimensions, Frequencies

Transmitter Moments & Cavity Fields

Cavity Reradiation & Signals

TABLE II - FEASIBILITY STUDY SUMMARY

Basic Assumptions: Source Power: 100 kW
Source Voltage: 10 kV

SYSTEM	FIG.	CAVITY ILLUMIN.	SIGNAL	COMPETITION	PRIMITIVE HARDWARE FEATURES		FEASIBILITY	
			(A) Alluvium (G) Granite	N_f - Nulling factor (Required for unity S/B)	Generator	Sensor	Technical	Program
D.C. Conduction Alluvium	3	2.5×10^{-3} amps/m ²	(A) 5×10^{-4} Volt	Noise Constraints: Power Supply: <.001% ripple 60 c. currents: < 10^{-3} amps eff. Coil motion: <.005 G accel. Earth motion: .01 volt Casing current: 500 volts	22 casings 60 ft deep, 1 ft d. (or equiv.) Perforated & CuSO ₄ sol'n	5000 turn coil 30 ft diam. 25 tons Cu.	No	No
VLF Conduction	3	2.5×10^{-3} amps/m ²	(A) .05 Volt	$N_f \sim 7000$	do.	do. next case	No (Marginal)	No
VLF Axial Illumin.	4	5×10^{-8} Web/m ²	(A) .004 Volt (G) .06 Volt	$N_f \sim 5000$ $N_f \sim 300$	2 turn loop 1300 ft diam. 50 tons Cu	80 turn coil 30 ft diam 1 ton Cu	No (Marginal)	No
VLF Axial Illumin.	5	5×10^{-8} Web/m ²	(A) .006 Volt (G) .04 Volt	$N_f \sim 2 \times 10^5$ $N_f \sim 3 \times 10^4$	do.	do. (twice)	No	No
VLF Equatorial Illumin. Orthog. Loops	6	$.6 \times 10^{-8}$ Web/m ²	(A) .0015 Volt (G) .01 Volt	$N_f \sim 10^5$ $N_f \sim 10^4$	7 turn loop 60 ft diam. 1 ton Cu	do. (once)	No	No
MF Radiation Granite ($\omega \sim 2 \times 10^6$)	(6)	3×10^{-8} Web/m ²	(G) .15 Volt	$N_f \sim 600$	This hardware is <u>relatively</u> trivial		Yes* (Marginal)	No
							*On visibility grounds

Fig 1 THE BASIC CONCEPT

Fig 2 CAVITY GROWTH PARAMETERS

5 kt at 200 m. DOB ALLUVIUM

**Fig 3. EARTH CONDUCTION SCHEMES
IN ALLUVIUM (DC & VLF)**

Fig 4 VLF AXIAL ILLUMINATION, CROSSED LOOPS

**Fig 5 VLF AXIAL ILLUMINATION
QUADRUPOLE SENSOR**

Fig 6 VLF EQUATORIAL ILLUMINATION
CROSSED LOOPS

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External:

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