GC-TR-88-1639

VOLUME III

RESEARCH AND DEVELOPMENT IN SUPPORT OF THE SURFACE CHEMISTRY BRANCH

GEO-CENTERS, INC.

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GEO-CENTERS, INC. programs in support of the Naval Research Laboratory Surface Chemistry Branch of the Chemistry Division have addressed problems dealing with the properties of and chemistry occurring on/at surfaces and interfaces. Of particular interest to the Navy are the programs and advances described below:

Modified ceramic and metal surfaces demonstrated significant improvements in tribological characteristics such as friction and wear resistance. In addition to the characterization and analysis of these materials, a large materials database was compiled. This information will assist in identifying important factors affecting stress propagation and tribological performance, and will aid in the development of models.

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VOLUME III

RESEARCH AND DEVELOPMENT

IN SUPPORT OF THE

SURFACE CHEMISTRY BRANCH

FINAL REPORT

PREPARED FOR
NAVAL RESEARCH LABORATORY
4555 OVERLOOK DRIVE, S.W.
WASHINGTON, D.C. 20375-5000
UNDER CONTRACT NUMBER N00014-86-C-2096

PREPARED BY
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JUNE 1988

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March 15, 1988

GEO-Centers, Inc.
7 Wells Avenue
Newton Centre, MA 02159

Attn: Russell Jeffries

Re: Report No. 1
Subcontract No. GC 1639-87-001

Gentlemen:

Enclosed are two (2) copies of the Final Report referenced above for work performed during January 1987 through April 1988, in accordance with the requirements of the referenced contract.

Sincerely,

Gladys M. Weller

Gladys M. Weller
Contracts Administrator

GMW/jc

Enclosures

FINAL REPORT

Subcontract No. 1639-87-001

LOCUS Project No. 3334

Prepared by: Information Systems Division

Approved by: [signature]
Charles Bocook
Asst. Vice President

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FINAL REPORT

Report No. 1

Subcontract No. 1639-87-001

LOCUS Project No. 3334

January 1987 through April 1988

This is the first Final Report on Subcontract Number 1639-87-001 covering technical progress for the reporting period.

Several efforts related to research in the EMI arena have been accomplished during 1987 and these are described below under separate headings.

Effort on Methods to Locate Rusty-Bolts (Rusty-Bolt Radar)

The first prototype of a device to excite, detect, and locate rusty-bolts was fabricated and tested. A block diagram of the prototype is shown in Figure 1. The prototype which operates in the UHF band radiates two fundamentals, f_1 and f_2, and receives a third order intermodulation product at f_3.

where f_1 = 425 mHz

f_2 = 435 mHz

$fimp = m*f_1 +- n*f_2$

f_3 = 445 mHz, where m=1 and n=2

order = m + n

The locator operates in two discrete modes, search and location. Shipboard topside areas are searched for operating rusty-bolts (a rusty bolt is a tunneling non-linear metal-oxide-metal junction). When one is excited with the UHF energy radiated by the prototype locator, the

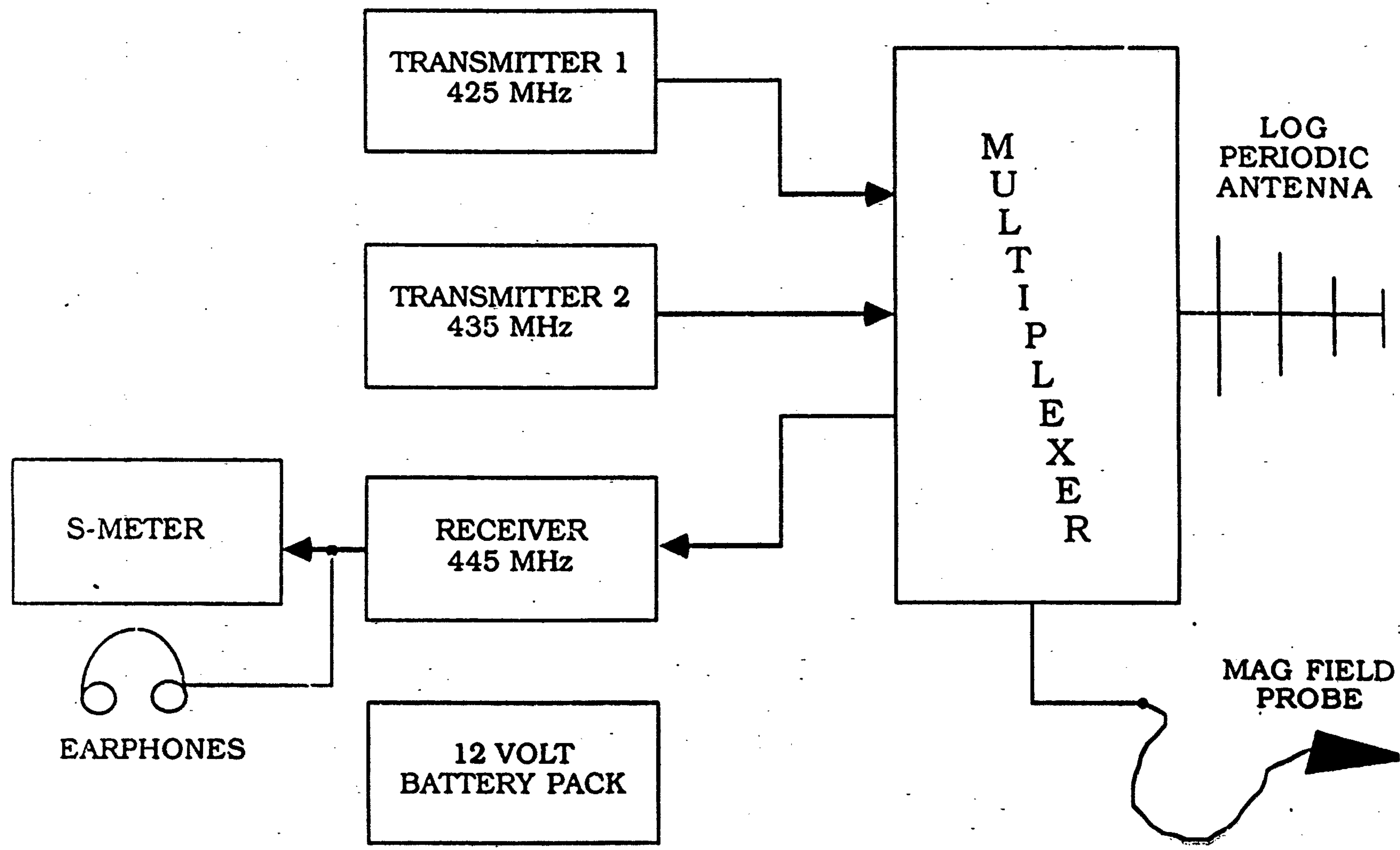

FIGURE 1 - RUSTY-BOLT LOCATOR PROTOTYPE

rusty-bolt mixes the two fundamental signals and generates the intermodulation products; one of four 3rd order intermodulation products is detected by a receiver tuned to 445 mhz. When the receiver receives this re-radiated energy, in the search mode, it desquelches and produces an audio tone in the earphones. Table 1 shows the approximate range and resolution performance in the search mode.

After a rusty-bolt has been detected in the search mode the illuminated area (approx 10' by 10') can be scanned with a small loop antenna attached to the receiver and the exact 'location' determined. Table 1 also shows the range and resolution performance in the location mode. The intermodulation signal is a maximum when the loop antenna is physically centered over the rusty-bolt.

This prototype was tested at State College PA. in August 1987 and is now being licensed so that it can be tested aboard ships.

An advanced version of this technique was designed, see Figure 2 and Figure 3, with two additional features, as follows: 1) provide an assessment of the detected rusty-bolt as to whether it is significant as an interferer in the HF band and 2) generate other than 3rd order intermodulation products in the HF band. This was done by choosing two fundamentals, f_1 and f_2, which are separated by 2 to 1 plus or minus a slight frequency difference. Two frequency plans to accomplish this objective are shown in Table 2.

$$f_{imp} = m^*f_1 +- n^*f_2$$

where $f_1 = 452.5$ mhz (or 451.25 mhz)

$f_2 = 900$ mhz

order = m + n

Preliminary approval has been obtained to use these frequencies in the radar bands and since the radar frequencies are to be used it has been suggested by the US Navy licensing community that this device be called a "Rusty-Bolt Radar".

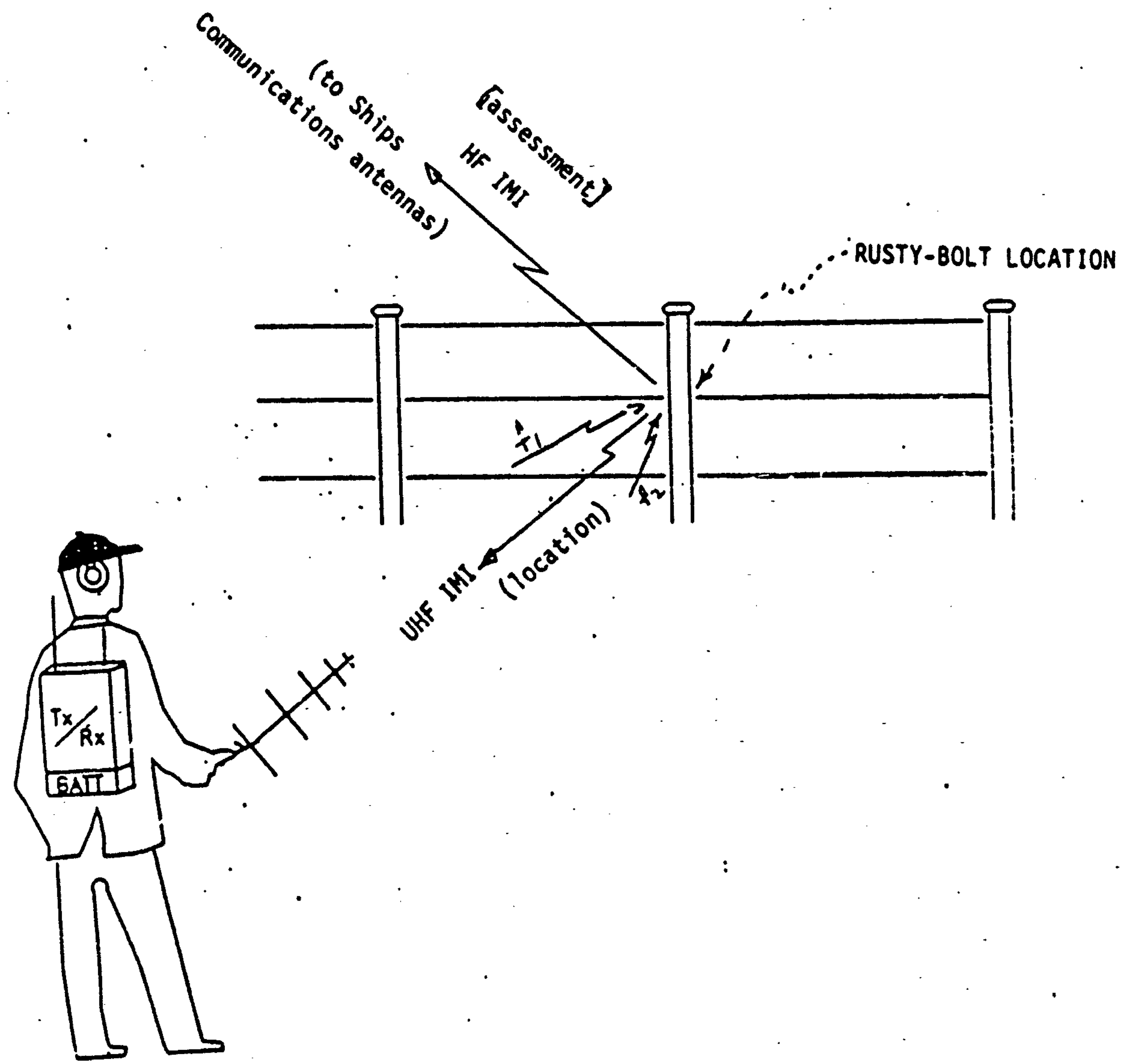

FIGURE 2 - RUSTY-BOLT RADAR CONCEPT

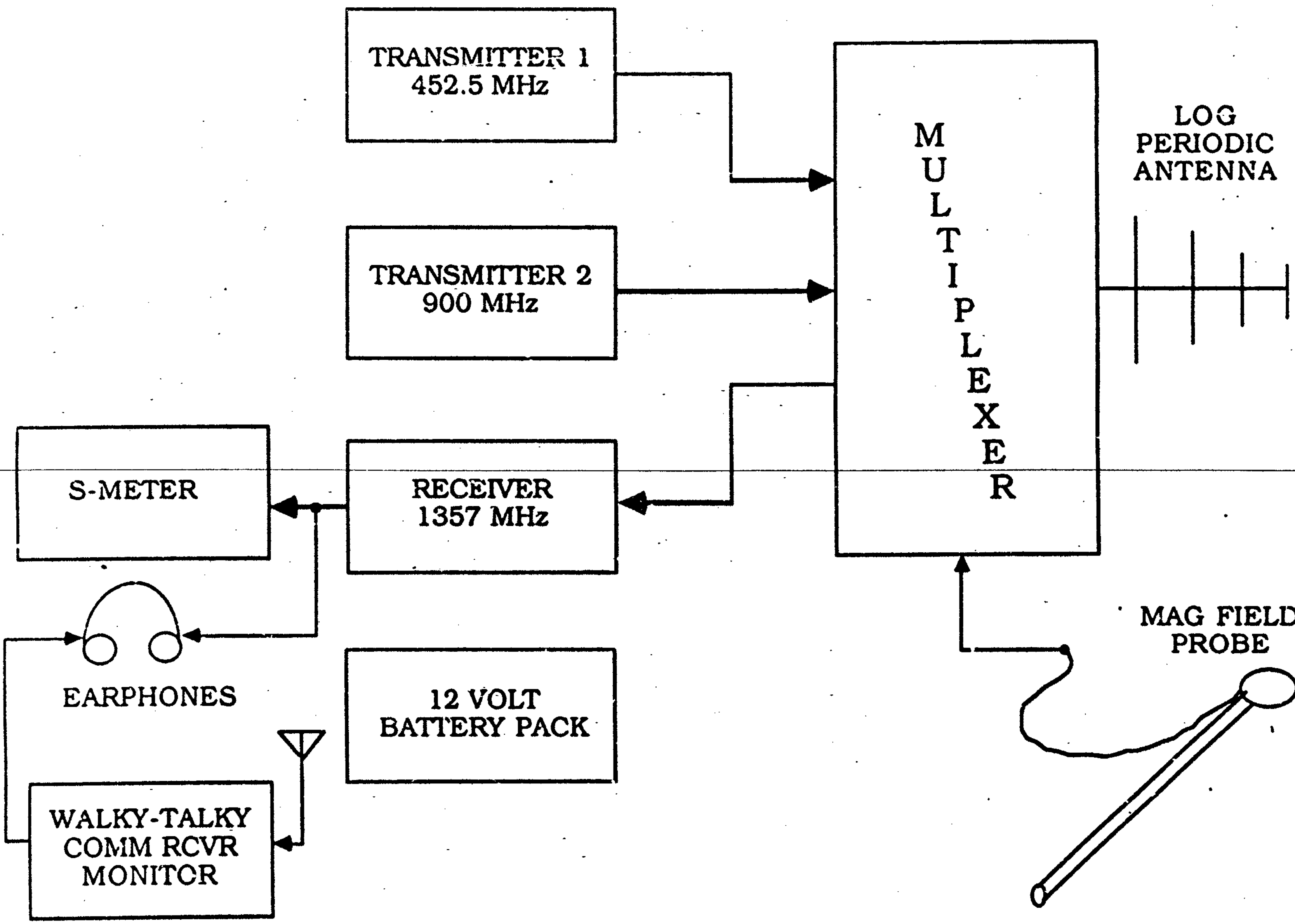

FIGURE 3 - RUSTY-BOLT RADAR BLOCK DIAGRAM

MODE	RANGE	RESOLUTION
SEARCH	30 FEET	10 FEET
LOCATION	12 INCHES	0.1 INCH

Table 1 - Range and Resolution Performance of Rusty-Bolt Locator

Fundamentals [MHz]		Intermodulation Product Orders in the HF Band [mHz]											
f1	f2	3rd	6th	9th	12th	15th	18th	21st	24th	27th	30th	33rd	36th
452.5	900	5	10	15	20	25	30						
451.25	900	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30

Table 2 - Sample of Intermodulation Product Orders that can be generated in the HF band by the choice of the fundamental frequencies

A commercially available rusty-bolt locator has been found and evaluated for its ability to satisfy the requirements for location of shipboard rusty-bolts. The candidate device is manufactured by MICROLAB Inc. and is sold as an anti-eavsdropping device which is marketed to governments and industry so they can detect and find "bugs." Although this device is capable of locating rusty-bolts it does not possess 1) the capability of generating intermodulation products in the HF band for the "assessment" feature or 2) generating other intermodulation frequencies in the HF band.

NSRDC Hardware Evaluation Report

The Naval Ship Research and Development Center (NSRDC) in Annapolis Md. has developed a corrosion protection coating for marine hardware (nuts and bolts). Preliminary data indicated that these coatings could suppress the generation of IMI on currents flowing through the hardware. IMI and conductivity tests were performed on samples of this hardware which had been subjected to extensive salt environments. This data was analyzed, correlated and a test report prepared and issued to NSRDC.

EMI Gasket Adhesive

A EMI gasket adhesive is being developed at NRL to solve a F/A-18 EMI shielding problem wherein the existing EMI gasket adhesive causes severe corrosion to the aluminum frames. Two formulations have been developed and tested. Initial testing was done on the IMI test set-up and subsequent testing has employed the HP4192A Impedance Analyzer and a salt spray test jig designed by Chomerics Inc.

The F/A-18 structures to be bonded are graphite epoxy 'skin' panels which are seated against aluminum frames. To determine what could take place where aluminum comes in contact with graphite, a physical junction of these two materials was made and it was determined that this junction was non-linear. This led to making just a graphite to graphite junction, which was also determined to be non-linear. The IMI spectrum generated and the IV curves are shown in Figures 4 & 5. Two types of graphite materials were mated, one a small sample to the actual graphite-epoxy composite aircraft 'skin' and the second being a "hank" of the graphite fibers which are woven to make up the actual graphite epoxy composite structure. Figure 4a shows the IV curves and the IMI spectrum for an aluminum to graphite epoxy junction and Figure 4b shows the IV curves and the IMI spectrum for just a section of graphite epoxy composite. Figure 5a shows the IV curve and IMI spectrum generated by RF being mixed in 3 inches of carbon fiber bundles and Figures 5b shows the results of mixing action in a very short section of this same carbon fiber bundle. The higher DC resistance associated with the long (3 inch) current path tends to swamp out some of the non-linearity and consequently the magnitude of the resulting IMI is reduced.

Other IMI Test and Evaluation

IMI test and evaluation was also performed on the following:

Comercial water-based conductive paints
CBA Greases
Many special CBA's
Gasket adhesive's
Superconductive materials

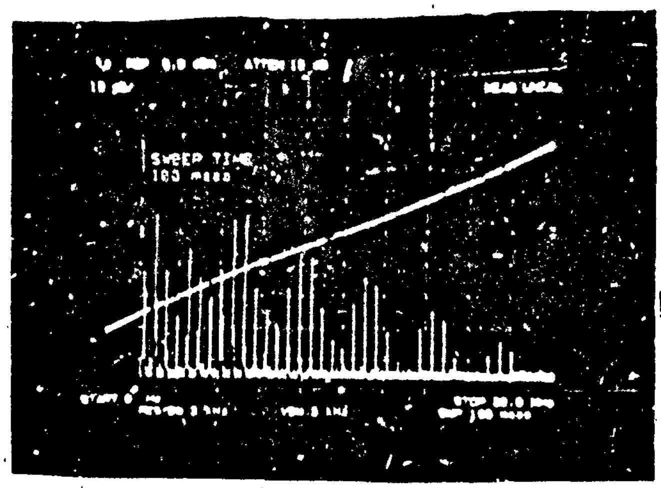

Figure 4 a - Aluminum to Graphite Junction

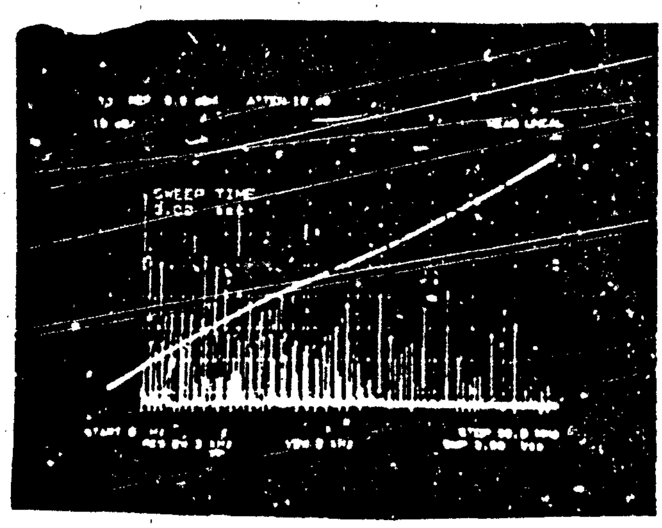

Figure 4 b - Graphite to Graphite Junction

Figure 4 Dual exposure showing RF Spectrum and IV curves super-imposed. The RF Spectrum is the IMI generated by an Aluminim to graphite and a graphite to graphite non linearity.

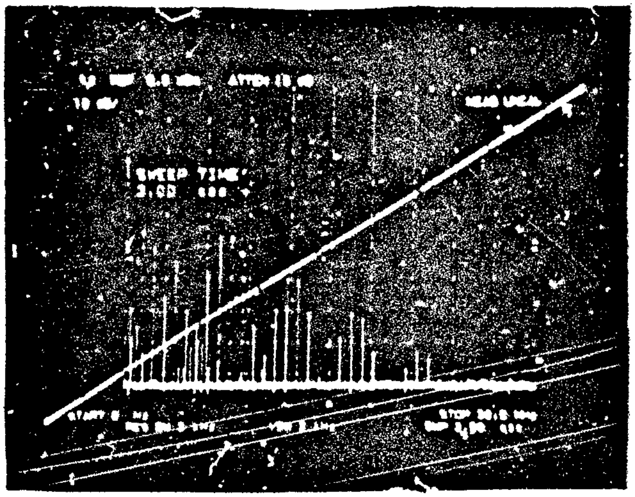

Figure 5 a - Carbon Fiber bundle, 3 inches long.

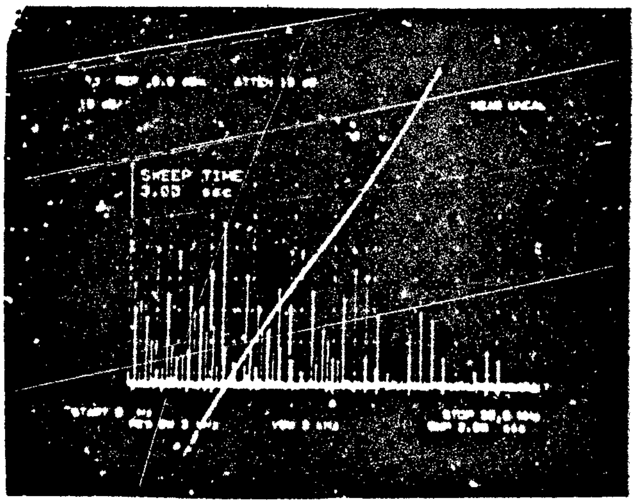

Figure 5 b - Carbon Fiber bundle, 0.25 inches

Figure 5 - Dual exposure showing RF Spectrum and IV curves super-imposed. The RF Spectrum is the IMI generated by 2 tones mixed by this graphite fiber non linearity.