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CABLE DRIVER TECHNIQUES AND HARDWARE DEVELOPED DURING THE PERSHING CABLE/CONNECTOR PROGRAM

by

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ABSTRACT

Cable driver testing is a technique widely used in evaluating the shielding effectiveness of exterior cable shields. The cable driver is used to create a current on the exterior shield of the cable. Then, by comparing the ratio of the internal current to the external current with the current ratios obtained from other cables or test conditions, the relative shielding characteristics of a particular cable can be determined. To complete the PERSHING cable/connector program, new cable driver techniques and hardware had to be developed, including a portable driver applicable to test fielded cables.

The electrical characteristics and general design of all the drivers covered in this report are very similar. However, due to the physical differences in the test items and different sensitivity and resolution requirements in the instrumentation, no one driver setup could be used for all tests. Also, there was a natural refinement of the testing techniques as the program progressed. These modifications and improvements in the cable driver testing technique are described in this report.

Keywords: electromagnetic pulses, cable drivers, shielded cable test, shielding effectiveness transfer function, current injectors, spark gap pulsers

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FOREWORD

The investigation reported herein was conducted as part of the PERSHING Special Test Program, directed by the Secretary of the Army for the Secretary of Defense. The program plan was prepared by this organization and accepted by the Department of Defense Science Board, Director Defense Research and Engineering, and Army Materiel Command Research and Development Directorate.

The investigation was conducted with the assistance of George Gornak, Senior Project Engineer for the task; Joseph Capobianco and Robert A. Dyckson. Photos courtesy of John W. Beilfuss.

1. INTRODUCTION

1.1 Program Definition

This report defines the principles and developmental stages of the current-injection cable drivers which were used during the PERSHING cable/connector program. It was felt that the cable driver technique would be a valuable tool in determining cable/connector degradations.

1.2 Basic Cable Driver Concept

The basic idea behind the cable-driver technique is to inject a transient current of known waveform onto the external electrical shield of the cable and then to measure the current induced into the internal conductors. Then, by comparing the ratio of the internal current to the external current with the current ratios obtained from other cables or test conditions, the relative shielding characteristics of a particular cable can be determined. To determine if a cable/connector assembly has degraded, e.g. from use or improper manufacturing, its shielding characteristics have to be compared with those of known good cables (unused and carefully manufactured).

The electrical and general design characteristics of all of the drivers covered in this report are very similar. In each, a high-voltage storage capacitor is charged, then discharged into the item under test which has been made part of a transmission line. The shielding quality of the test item, be it an entire cable assembly or just one joint of a connector, is measured as the ratio of the internal energy to the external energy. However, due to the physical differences in the test items and different sensitivity and resolution requirements in the instrumentation, no one driver setup could be used for all tests. Also, there was a natural refinement of the testing techniques as the program progressed. These modifications and improvements in the cable driver testing technique are described in this report.

1.3 Purpose of the Report

The purpose of this report is to describe the operation and developmental stages of the current injection cable drivers which were used during the PERSHING cable/connector program. The very short time frame of the program compared with its objectives eliminated the possibility of conducting a complete feasibility study to determine which technique would yield the information required to perform the program. Therefore, most of the testing techniques initially investigated were performed throughout the program if they showed any promise of giving important results.

A list of the drivers and their test items is presented in Table I. They appear in the order in which they are described. Physical design details and specific electrical characteristics of each driver unit are also presented. Instrumentation, data collection, and preliminary reduction techniques that were used throughout the program are also given.

TABLE I

DRIVER UNIT	TEST ITEM
1020A Cable driver	All 40- to 50-foot-long cable/connector assemblies
Copper ground-plane (CGP) Cable driver	8-foot-long validation cables and the 100-foot and 500-foot-long cables
1020B Cable driver	Control-parameter tester and short-bulk-cable sections
1020C Cable driver	Replaced 1020A Driver at end of Program
Field Cable tester	Proposed tester for all cable/connector assemblies used in the field

2. THE OPEN TRANSMISSION LINE CABLE DRIVER (1020A)

Initially is was planned to use the balanced transmission line cable driver as developed by American Nucleonics Corporation (ANC) under contract,[1] because much data had been collected on the PERSHING TAM II cables, and use of the identical driver would allow direct correlation of the results.

In this cable driver the cable under test is made a part of a balanced three-wire transmission line that is terminated in its characteristic impedance to eliminate reflections in the external sheath current. The driving source is an energy-storage capacitor discharged through an adjustable spark gap. Figure 1a gives the design of the cable driver, and figure 1b is the equivalent-lumped-parameter-circuit representation of the cable driver. The inductance L is the summation of the inductances of the source, the driver leads, the spark gap and the balanced transmission line. (Note: Since the transmission line is terminated in its characteristic impedance it is normally taken to look like a pure resistor from the source end. However, it was found that minor perturbations in the line caused significant increases in the sheath-current risetime indicating an increase in the transmission line's inductance.)

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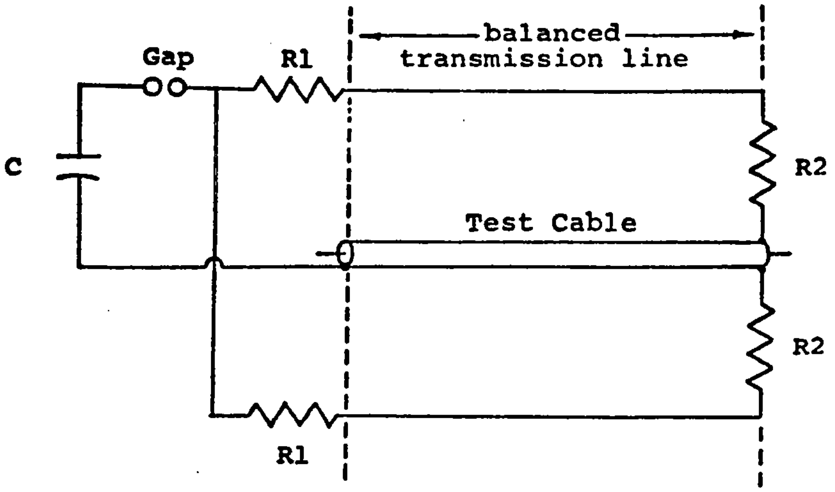
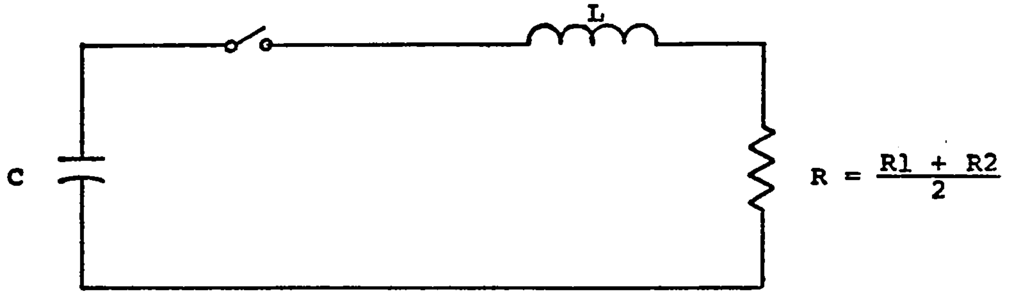
[1] Shkabara, P., Brown, G., Keith, R., "The ANC Cable Driver", ANC 30R-26, Contract DA44-009-AMC-1493, April 1970.



R1 = Shaping Resistor
R2 = Terminating Resistor

Figure 1a. Design of cable driver.



Equivalent Circuit

Figure 1b. Equivalent-lumped-parameter-circuit representation of the cable driver.

2.1 Electrical Characteristics

With the capacitor charged initially to V_o and the switch closed the Kirchhoff voltage equation for the series R-L-C circuit, shown in figure 1b, is:

$$L \frac{di}{dt} + Ri + \frac{1}{C} \int_{(T)} i dt = V_o \qquad (1)$$

which has the solution of:

$$i = \frac{V_o}{R\sqrt{D}} e^{-Kt} \left[e^{Kt\sqrt{D}} - e^{Kt\sqrt{D}} \right] \qquad (2)$$

where $K = R/2L$

$D = 1 - 4L/R^2C$

It can be seen that the current, i, could become oscillatory if

$4L/R^2C > 1$

Therefore, the value of the shaping resistor, R_1, is always kept large so that

$4L/R^2C < 1$

making the circuit overdamped.

For this case the time, t_1, in which the current reaches its peak value is:

$$t_1 = (2L \tanh^{-1} \sqrt{D})/R\sqrt{D} \qquad (3)$$

This equation (3) can be used to estimate the risetime of the current, providing the equivalent inductance, L, is known.

2.2 Design Details

The test cable is placed in a balanced, parallel-wire transmission line with the test cable being the center, low-potential conductor. The two outer, high-potential, conductors are the cores (center conductor and dielectric) of the RG17 high voltage coaxial cable. The external shield of the coaxial cable is stripped off and the dielectric core is left. This prevents arc-over between conductors and also reduces the high-voltage hazard to operating personnel. The instrumentation end of the transmission line is terminated in its characteristic impedance, R_2 to eliminate reflections.

The pulser unit of the 1020A cable driver is enclosed in a large (3 ft x 3 ft x 5 ft) RFI-tight cabinet. The large box is required because the storage capacitor used (Tobe-Deutschmann 0.02μf @ 100 kV, Type ESC-390), is approximately 4 ft high and 8 in. in diameter. The self inductance of the ESC-390 capacitor is less than 100 nH. A variable aluminum spark gap is used; one large aluminum ball is fitted over the top of the capacitor and another small movable ball is supported by a dielectric wafer fastened to the box. The small electrode of the gap is connected to the two outside cables of the transmission line through the two pulse shaping resistors. Figure 2 shows the cable driver pulser unit in its original configuration as developed by ANC.

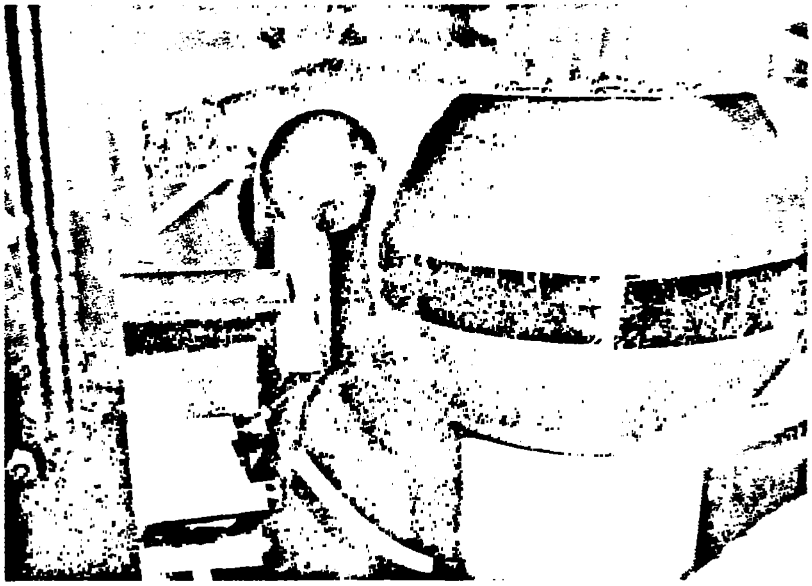


Figure 2. ANC driver pulser

2.3 Problems and Modifications of the Cable Driver

The 1020A cable-driver was rebuilt at HDL with the aid of ANC personnel. It was estimated that from the standpoint of instrumentation sensitivity an external sheath current of approximately 300 A was required. Therefore, the movable air gap was adjusted to about a 0.5-inch separation which gave a 300-A peak current at a 50-kV charging voltage, with a repetition rate of one to two pulses per second. A typical sheath-current waveform is shown in figure 3. The picture indicates that there are two undesirable characteristics in the original arrangement. First, the 10- to 90-percent risetime is only about 34 nsec which made the frequency range of investigation too narrow for this program. Second, the picture is of two consecutive pulses and shows that the waveform varies between shots. In addition to the problem of jitter from shot to shot, the repetition rate also varied.

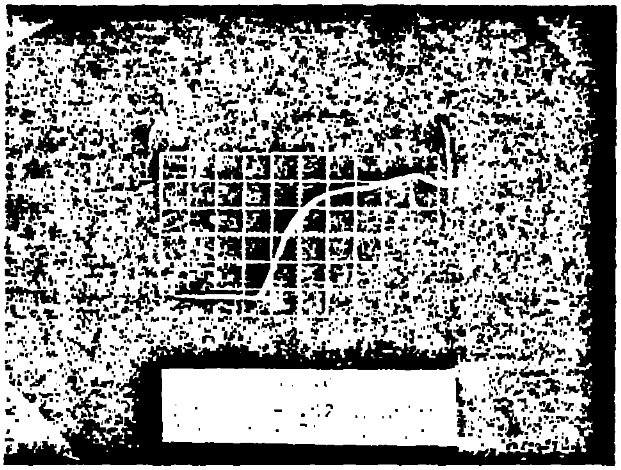


Figure 3. ANC driver sheath current.

It was felt that both the slow risetime and the jitter could be corrected by replacing the adjustable air gap with a fixed gap that could be pressurized with sulfur hexafluoride (SF_6) and also by rearranging the geometry of the driver components. Therefore, the modifications shown in figure 4 were made with the intention that they would lower the inductance of the driver unit and that the jitter would be eliminated by the more controlled arc path in the new gap. The pressurized gap had a nylon housing and two identical electrodes of one-inch diameter with inserts of Elkonite (Malleroy, Inc.).

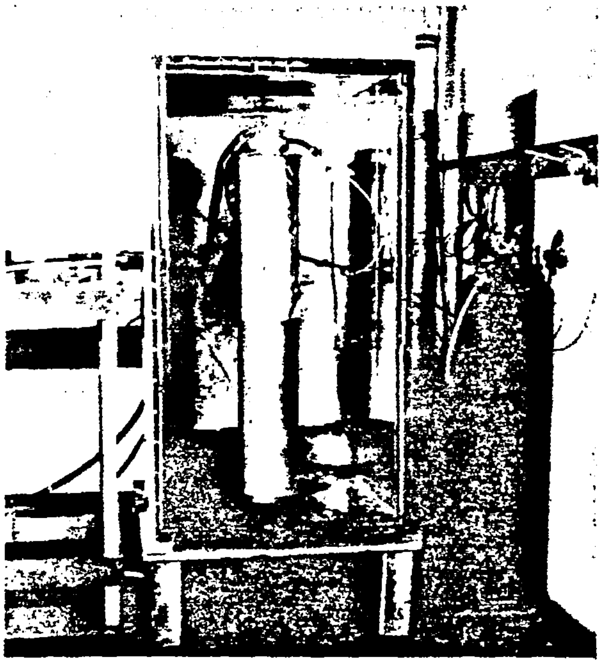


Figure 4. 1020A Driver driver pulser

These modifications did, in fact, decrease the risetime to 18 nsec (10-90 percent) but the jitter and erratic pulsing still persisted. Further experimentation has shown that a charging-time constant of approximately .2 (i.e. $RC \approx .2$) is necessary to have a good, consistent pulser. The reason for this is that the breakdown voltage of a gap is not only a function of the spacing and the dielectric between the electrodes, but also of the rate at which the voltage appears across the gap. With too small a time constant the charge rate of the capacitor becomes unstable and therefore the breakdown voltage of the gap varies, causing jitter. Therefore, when the charging resistor was replaced with two 100-watt, 15-megohm resistors in parallel, the jitter stopped, as indicated by the multipulse picture in figure 5. The repetition rate was steady. This, then, was the cable-driver configuration used throughout the PERSHING cable/connector program for the 40- to 50-foot-long cables. The instrumentation used will be discussed in Section 7.

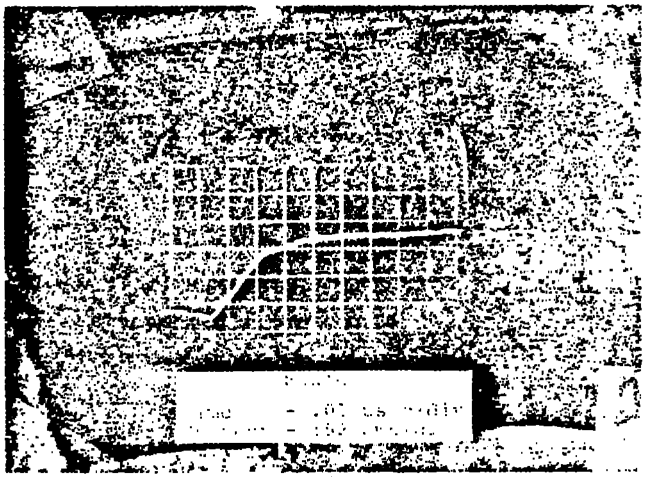


Figure 5. 1020A Driver sheath current.

3. THE COPPER-GROUND-PLANE (CGP) CABLE DRIVER

The principle behind this driver is identical to that of the long-cable driver, but the actual construction is different. The cable again is made part of a transmission line but in this case a 12-inch wide copper sheet is used instead of two inner cores of coaxial cable. The transmission line is terminated in its characteristic impedance to eliminate reflections.

The pulser unit uses a small coaxial disc capacitor. It is a .05 μf, 20 kV capacitor, Tobe-Deutschmann Type ESC-247F with a self-inductance of one nH. The spark gap used was a triggerable Type GP-17B (EG&G, Inc.). The gap was run at its own breakdown voltage of 12 kV instead of using a trigger pulse. With this driver setup, shown in figure 6, peak pulse currents of approximately 60 A were obtainable with risetimes of 10 nsec (10-90 percent) as shown in figure 7.

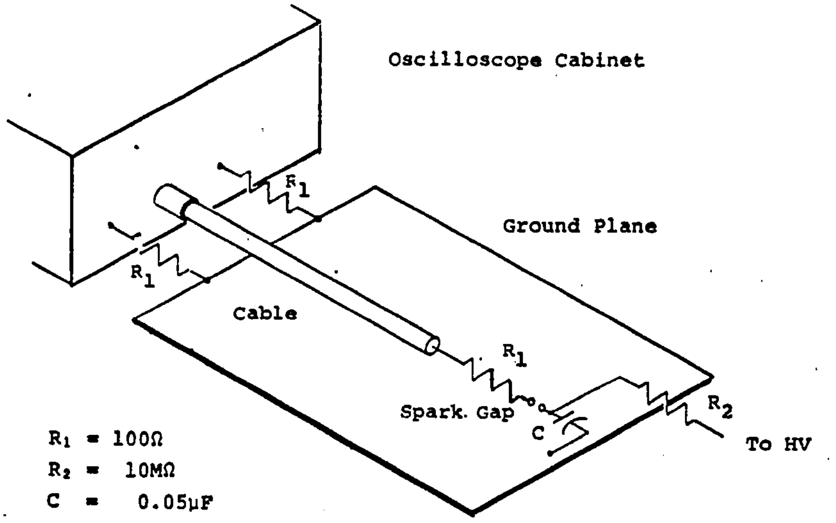


Figure 6. Copper-ground-plane(CGP) driver .

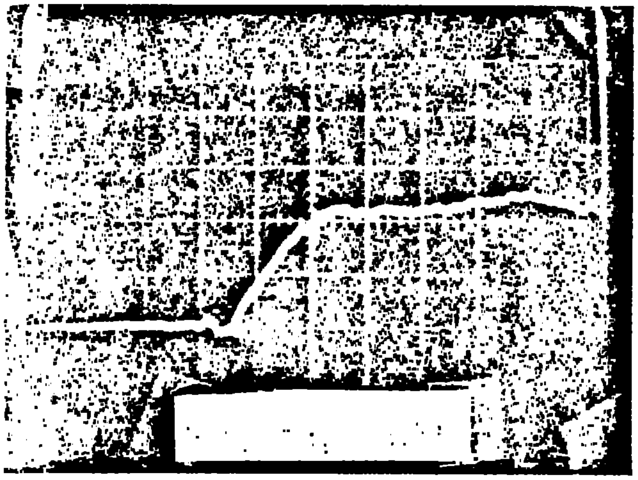


Figure 7a. Copper-ground-plane (CGP) driver sheath current at .01 μsec/div.

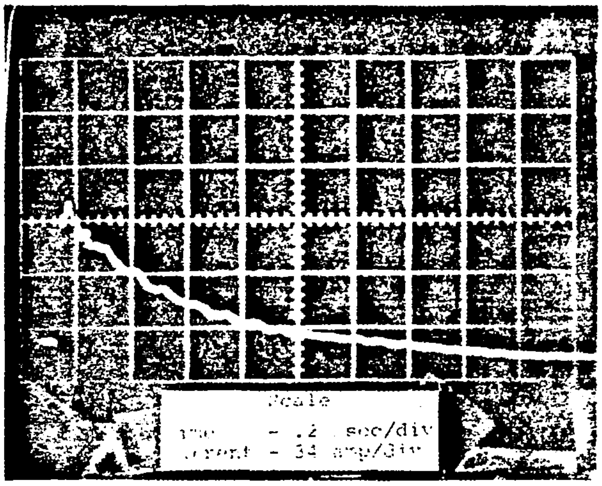


Figure 7b. Copper-ground-plane (CGP) driver sheath current at .2 μsec/div.

3.1 Validation Tests on Short Cables

As part of the PERSHING cable/connector program, eight cables were assembled by Martin Marietta Corporation of Orlando, Florida, for validation tests, using the assembly specifications developed by Electromagnetic Effects Laboratory personnel. These cables were about 8 ft long, with a connector on one end only. The other end of the cable was formed into a shorted inner bundle (all inner connectors were soldered together). The external shield then was soldered to the inner bundle and a large lug was fastened to the end to permit easy attachment of the cable.

These cables were subjected to several environments with shielding-effectiveness tests conducted on the cables before and after each exposure in order to validate the new production specifications. The results of these tests are the subject of another report.

3.2 Long-Cable Tests

The CGP driver was also tried to test longer cables, 100 ft and 500 ft. It was obvious that the cables were too long to attempt to drive them over their entire length. Therefore, the short cable driver was modified to drive only about eight foot lengths of the cable. This was done by reversing the driver so that the pulser unit was at the same end as the instrumentation box and then trying to terminate the cable shield to the ground plane with a three-foot-long capacitive collar of copper around the cable. A schematic representation of the driver in this configuration is given in figure 8. Although the capacitive collar was intended to couple the sheath current on the cable to the ground plane, later experimentation indicated that it is only possible to couple the very high frequencies. The low-frequency current coupling onto the inner bundle is, therefore, exaggerated compared to the low-frequency-current coupling produced with full length drivers.

This reduces the sensitivity of the test method to something less than the sensitivity of an overall shield resistance measurement made with a volt-ohm meter. The problems of this test method were overcome, though, and the solutions are described in a later section on the cable/connector field tester development.

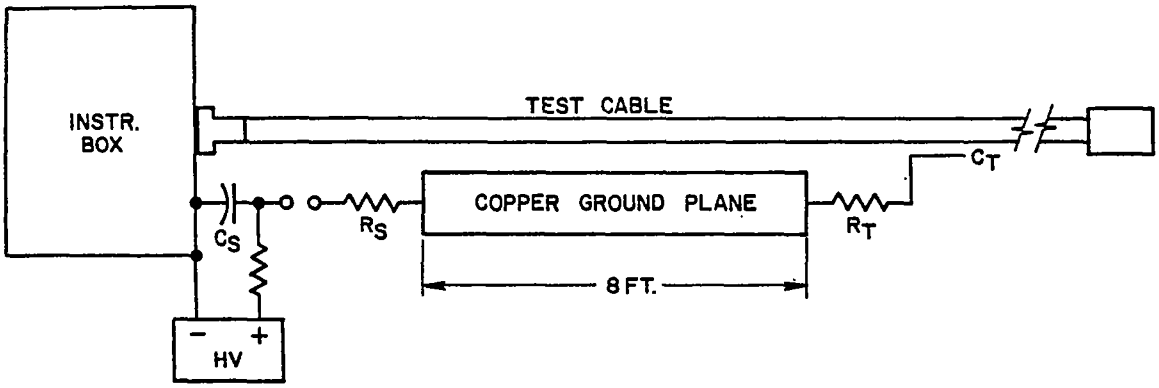


Figure 8. Schematic of copper-ground-plane (CGP) driver for long cables.

4. TYPE 1020B DRIVERS

There are two different configurations for the Type 1020B driver. The pulser unit is the same but the test items, and therefore the transmission line sections, are different. The most significant feature of the 1020B driver is that it marked the change from open drivers (parallel lines and lines over a ground plane) to completely enclosed coaxial drivers. The primary benefits of these coaxial drivers are faster risetime and reduced noise problems because the energy is almost completely contained within the driver.

4.1 Pulser Design

The pulser unit is completely contained in a brass cylinder approximately four inches in diameter and six inches long. The capacitor used is a 2.5-nF, 40-kV doorknob capacitor manufactured by Sprague Electric. The capacitor is discharged through an adjustable, pressurized spark gap designed at the Electromagnetic Effects Laboratory. The electrodes are .5 inches in diameter and machined from 410 stainless steel. The spark-gap housing was machined from a solid block of plexiglass. The output of the pulser is a short section of 50-Ω air line with a separation of .4 inches between the conductors.

The total risetime of the 1020B pulser output is about 5 nsec and the peak amplitude is continuously variable up to approximately 60 A. A cutaway view of the pulser and the short bulk cable driver is shown in figure 9.

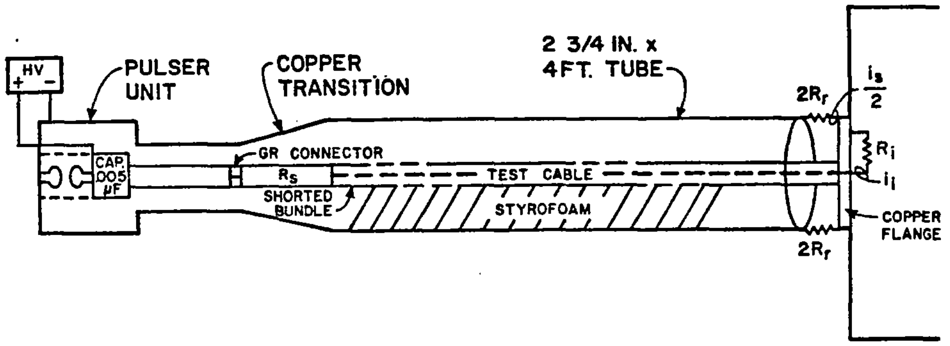


Figure 9. 1020B cable driver.

4.2 Short Bulk Cable Sections Tests

The short-bulk-cable tester was used to drive 4 1/2-ft-long sections of each type of shielded cable used on the PERSHING system. In this way, the characteristics of each cable type could be determined for a higher frequency range because the shorter length cable has a much higher resonant frequency. This investigation made possible the development of a resistive-inductive model for the shielded cables which clearly identifies the important cable parameters from a shielding standpoint.

The bulk cables were prepared for testing as follows:

(a) The internal wires and shields were stripped and soldered at each end to form a shorted internal bundle.

(b) At the driver end of the cable, the external shield was soldered to the internal bundle, forming a short circuit. A copper lug was soldered to the shield.

(c) At the instrumentation end a data pin was soldered to the internal shorted bundle and the external shield was fastened with panduit straps to a tube/flange which mounts to the instrumentation box.

Then the short section of the cable was centered inside of a 2 3/4-inch aluminum tube of the same length forming a coaxial transmission line for driving. The external sheath current is measured by placing a current probe around one of the two termination resistors. The internal current was measured for two different values of terminating impedance. This is required to fully develop the cable model.

4.3 Control Parameter Tests

The other transmission line section which the 1020B pulser unit was used with is the control parameter tester. The purpose of the control parameter tests was to determine the maximum shielding conditions for each connector parameter. This tester allows one cable/connector parameter to be varied while the other parameters are kept constant. In this way a set of optimum assembly specifications for the existing connector hardware could be developed.

The control parameter tester, figure 10, is about 5 ft in overall length. It is made up of two concentric coaxial transmission lines. The interior coaxial line was for the most part a 50-Ω air line with a solid shield that was used to increase the sensitivity of the unit by eliminating the inductance of a braided sheath. At the end of this line any one of the connector parts could be inserted separately. Therefore, the shielding effectiveness variations for each parameter could be determined exactly becuase the parameter under study was the prime contributor to the internal signal.

The outer coaxial line, consisting of a solid outer shield of the inner line and another solid conductor placed around it, was driven by the 1020B pulser unit. The outer conductor of this line was split diagonally and hinged to allow easy access to the interior coaxial line to perform other tests and make configuration changes. The sheath current pulse risetime and duration for this line was comparable with those obtained with the 4 1/2-ft long cables.

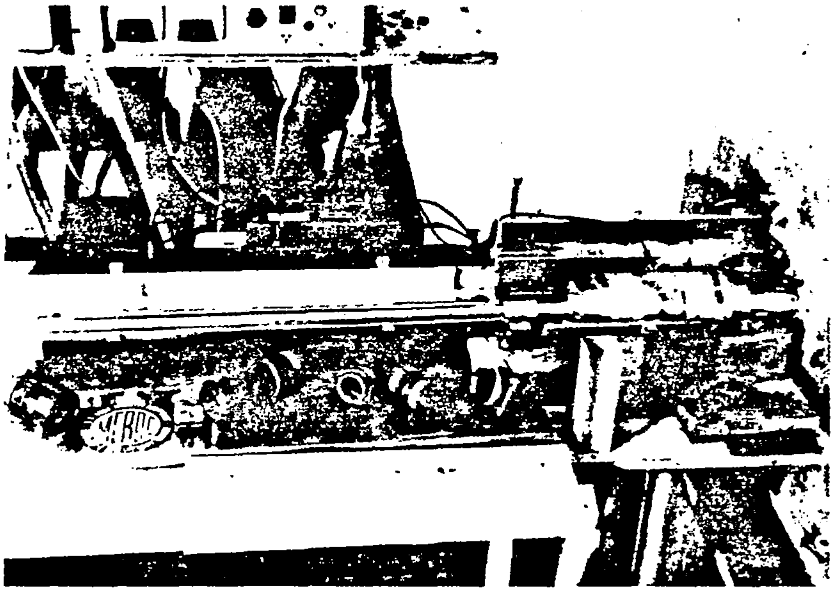


Figure 10. Control parameter tester.

5. TYPE 1020B DRIVER

Due to the superior performance demonstrated by the type 1020B coaxial drivers over the open transmission line type cable drivers, it was decided that a larger coaxial driver should be designed and fabricated to replace the 1020A cable driver. Unfortunately, this new driver (1020C coaxial cable driver) could not be developed until the major part of the cable/connector program was completed. However, the 1020C driver is now functional and has been used to drive cable/connector assemblies not tested previously in the program.

5.1 Design Details

The design of the pulser unit is very similar to the 1020B pulser unit except that the 1020C pulser housing can be pressurized. This was done to eliminate high voltage arc-over since this unit will be operated at much higher voltages. Four Sprague doorknob capacitors are used in parallel in order to get durations comparable with the 1020A driver. The shaping resistor is formed from four carbon resistors in parallel to minimize the inductance. The total inductance of the unit should be greatly reduced from that of the 1020A unit because the outside dimensions of the 1020C pulser are only 7 in x 18 in, a great size reduction. The gap used in the new pulser is the same one used in the 1020A pulser. The 1020C pulser unit is shown in figure 11.

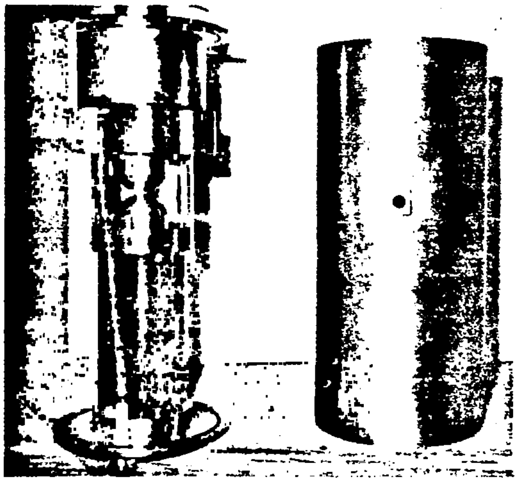


Figure 11. 1020C pulser unit and cover.

The design of the coaxial transmission line is fairly straight forward. The outside conductor is made from 4-in outside diameter 1/16-in thick aluminum tubing which is split in half and hinged. The test cable is supported inside the outer conductor by styrofoam blocks spaced one foot apart. The overall line length is adjusted by using different-length sections of the outside conductor. The coaxial line shown in figure 12a is terminated by three carbon resistors spaced around a circular flange of diameter large enough to permit the attachment of external sheath-current probes around the cable connector, figure 12b.

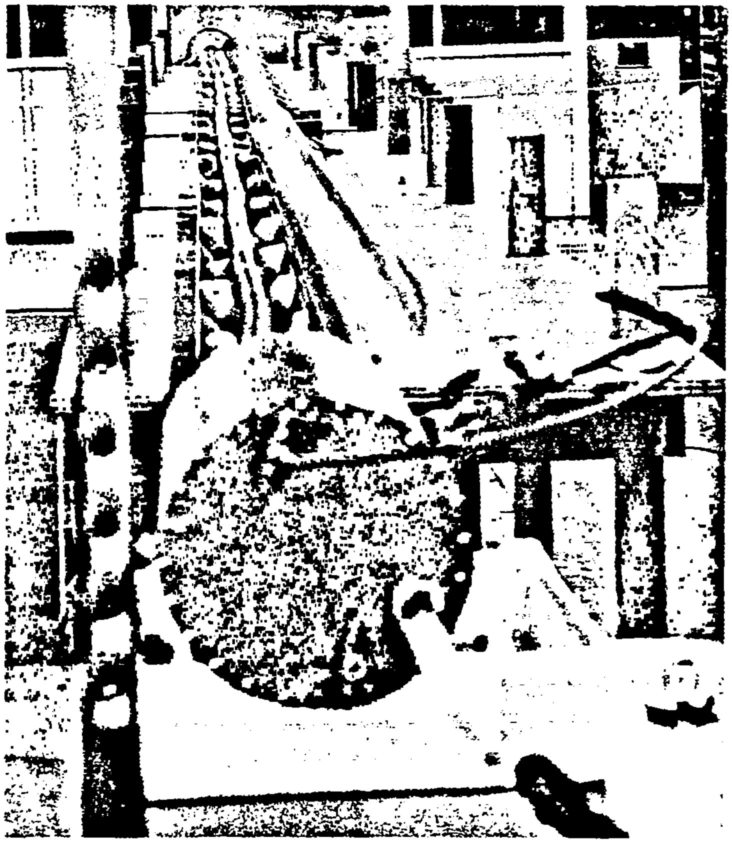


Figure 12a. 1020C cable driver showing cable driver transmission line and source.

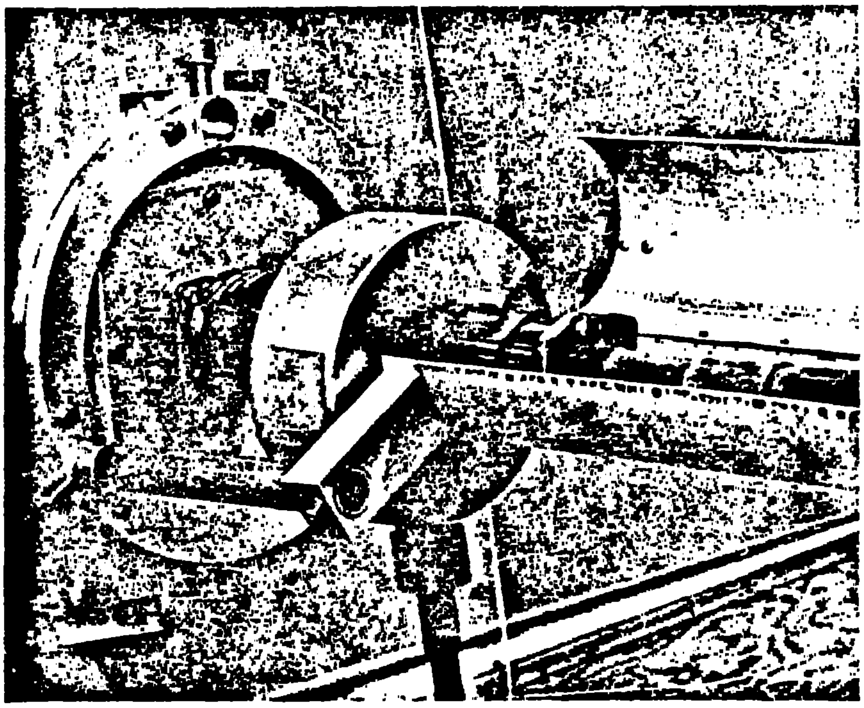


Figure 12b. 1020C cable driver showing driver termination.

5.2 Electrical Capability

The increased performance of the 1020C driver over the 1020A driver is indicated by the sheath-current risetime, as shown in figure 13. The total risetime of the 1020C unit is about 5 nsec (~2 nsec 10-90%), which is about four times as fast as the 1020A driver. This decrease in risetime has increased the investigation frequency bandwidth by about a factor of two. Also, the new driver is more reliable because the housing pressurization eliminates parts failure due to arcing. The peak voltage breakdown is adjustable up to 80 kV and the peak current output is load-dependent.

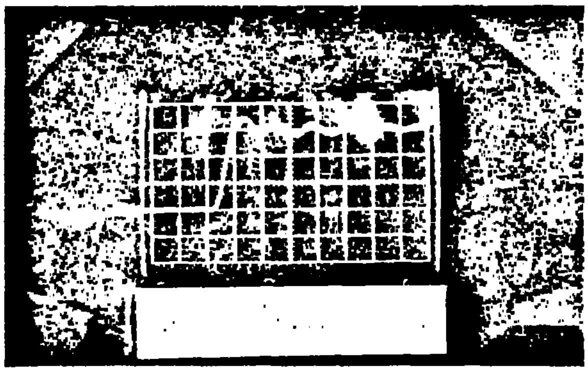


Figure 13. 1020C driver sheath current at 0.05 μsec/div.

6. FIELD TESTER

The last driver to be discussed is the "portable/cable/connector hardness evaluator" developed by HDL to evaluate fielded cables. This device was necessary to increase the confidence in the fielded cable/connector assemblies that they had not deteriorated from the shielding effectiveness data base of newly manufactured cables. It was decided that the portable tester had to involve a cable-driver type technique since none of the other techniques evaluated throughout the program indicated that they could independently identify all possible forms of shielding degradation incurred in the PERSHING TAM II cables.

6.1 Design Considerations

In order to make the testing of cables in the field feasible, the test equipment had to be reasonably compact. This restriction immediately eliminated the use of a full-sized cable driver such as the 1020A or C units. Therefore, it was decided to use a capacitively coupled driver similar to that used earlier on the very long cables. However, when the shielding-effectiveness transfer functions of the shorter, 40-50 ft long cables were derived with this driver, they were totally different from the transfer functions obtained with the 1020A cable driver. The low-frequency characteristics were distorted and made it impossible to detect any shielding faults other than an open circuit in the shield. This problem was not detected earlier with the long cables because no other reference for their transfer functions existed.

After much experimentation in the laboratory, the problem was finally isolated and a solution developed. The problem can best be explained by examining a low frequency, purely resistive model of the 1020A cable driver. Figure 14a gives the low frequency schematic of the 1020A driver and it can be seen that the shield acts as a current divider.

From this schematic, the ratio of internal to external current is:

$$i_i/i_s = r_s/(R_{t_1} + R_{t_2} + r_i) \qquad (4)$$

However, the low-frequency schematic for the capacitor-collar driver given in figure 14b indicates that the internal and external currents are equal at low frequencies. This is so because the impedance of the capacitor collar is very large for frequencies below about 1 MHz. For this reason there is no return path for the sheath current and it is coupled directly into the internal bundle. The source, i_e, is an equivalent source placed in the sheath circuit to represent the high-frequency pulse coupled in by the capacitor but due to its propagation along the cable, it appears as the low frequency source. The solution to this problem was to provide a low-frequency return to the pulser source for the sheath current by looping back the free end of the cable to the source. Although this return loop is very inductive, causing some alterations in the cable's transfer function, it is adequate enough to provide the sensitivity needed to identify all possible cable/connector faults. A prototype of the Hardness Evaluator was built and several cables with known faults were tested on it and compared with known good cables. The portable driver gave the same results as the 1020A driver.

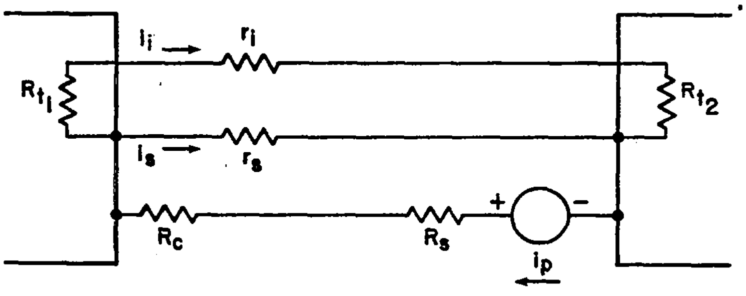


Figure 14a. Low-frequency model of 1020A cable driver.

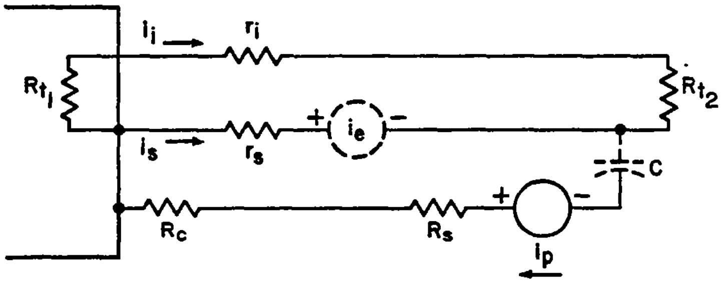


Figure 14b. Low-frequency model of capacitive driver.

Legend for figures 14a and 14b.

R_{t_1} & R_{t_2} - Internal terminations

R_s - Shaping resistor

R_c - External termination

r_s - External shield resistance

r_i - Internal bundle resistance

i_s - External current

i_i - Internal current

i_p - Pulser current

i_e - Equivalent current source

C - Capacitor collar

6.2 Measurement Technique

A preproduction model of the hardness evaluator was designed and fabricated. The high-frequency transmission line is only 12-ft long and the outside conductor is identical in construction to the one used in the 1020C Cable Driver. The high frequency coupling capacitor is one half of a 1 1/8-in inside diameter tube 4-ft long and is supported inside the outer driver conductor by three methyl methacrylate standoffs. There are two small aluminum boxes; one houses the pulser unit and the other will house all of the instrumentation. Both boxes have all eight types of PERSHING connectors mounted on them with the 50 Ω terminations from the shorted inner bundle to ground. One end of the transmission line is terminated to the instrumentation box and the other end is driven by a reed relay pulser via a short length of cable. The sheath current is monitored with a Tektronix CT-2 current probe at the pulse input and the internal current is measured with one of eight Tektronix CT1 current probes placed inside the instrumentation box. Figure 15 gives the layout of the portable hardness evaluator. The exact instrumentation package for the field tester is still under development, but it will use the same technique as the other drivers.

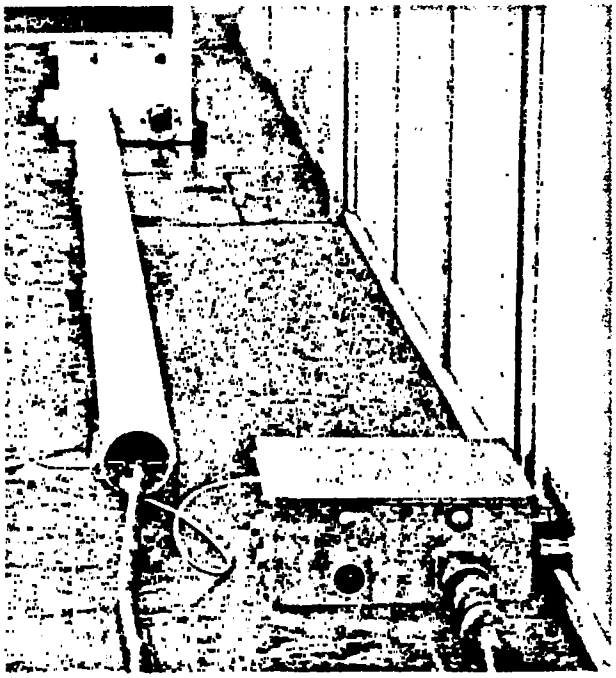


Figure 15. Portable hardness evaluator

7. INSTRUMENTATION

Throughout the tests both time-domain and frequency-domain data were collected. All of the instrumentation was housed inside a large shielded enclosure (see figure 16). AC power was supplied via two 10-A rf-power line filters.

Figure 16. Instrumentation housing.

7.1 Time-Domain Measurements

The time-domain data were recorded on 10,000 ASA speed polaroid film with a Tektronix C-31 camera mounted on a Tektronix 454 oscilloscope which has a 150-MHz bandwidth. The external sheath current was measured with either a clamp on Stoddard BR11 probe or a Tektronix CT-2 fixed current probe depending on the peak current and duration expected. Both of these probes have useful bandwidths from at least 100 kHz to about 100 MHz (see figure 17). The internal currents were measured with either a Tektronix CT-1 or CT-2 probe with a balanced 50-Ω load, made from low inductance precision resistors, attached to it (see figure 18).

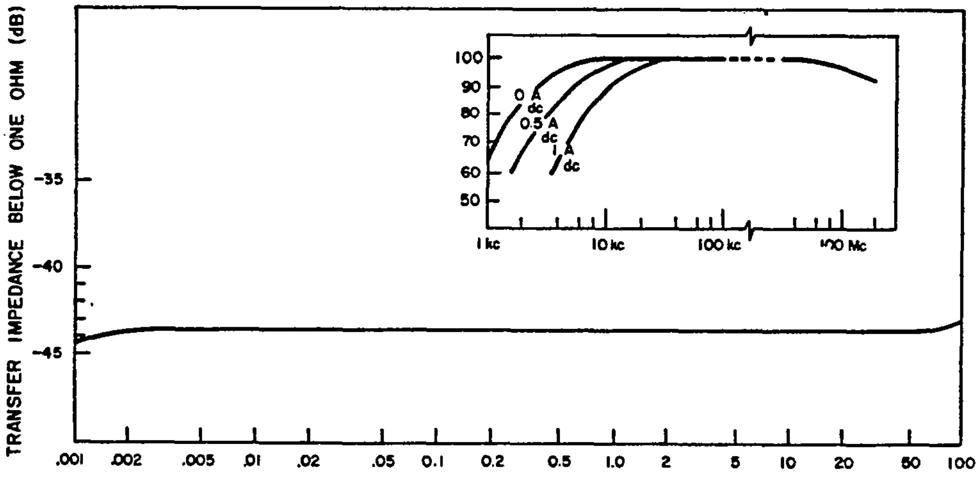


Figure 17. BR11 frequency response curve.
(Insert) CT2 frequency response curve.

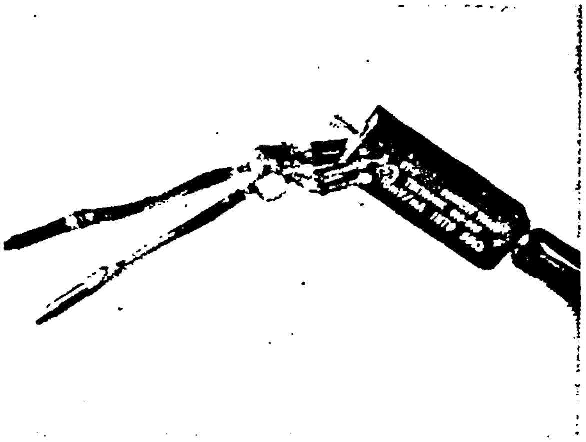


Figure 18. CT-1 current probe with 50 Ω balanced termination

A typical transfer function for one of these probes is given in figure 19. Female connector pins were soldered to the probe leads to allow data points (male pins) to be changed quickly. For some of the pin-to-pin measurements the common mode-to-signal ratio was too large for the balanced termination and a different technique had to be used. For these measurements, two probes were used back to back and their signals subtracted with the oscilloscope. Although this only gives a common mode rejection ratio of about 10:1 at 50 MHz, this was still sufficient to produce reasonable probe reversals for all points. The reduction techniques used for the time domain data will be covered in another report.

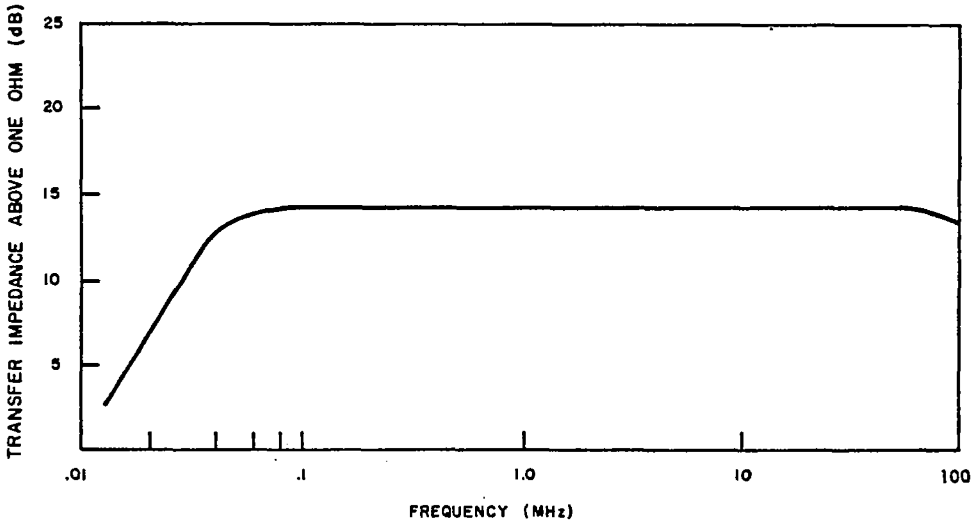


Figure 19. Frequency response of Ct-1 probe
with 50 Ω balanced termination.

7.2 Frequency-Domain Measurements

The frequency-domain data were obtained with a Hewlett Packard spectrum analyzer. The data were recorded on 3000 ASA speed film with a Tektronix C30A camera.

The same current probes as used for the time-domain data were used for the frequency domain data. The frequency spectrum of both the internal and the external current are taken over the frequency range of .1 MHz to 100 MHz in three separate intervals (.1 MHz to 1.1 MHz; 0 to 10 MHz; 0 to 100 MHz).

The driver pulser is adjusted to give about two pulses per second, and the analyzer is set at its slowest sweep rate of 10 sec per division which gives a frequency resolution of about 1 percent of the center frequency. Care must be taken to ensure that the if section of the spectrum analyzer is not saturated. This is done by increasing the input attenuation until linear reductions of the spectrum are observed.

These data are then reduced to obtain the shielding-effectiveness transfer function of the cable, $SE_{(\omega)}$, which is defined as:

$$\begin{aligned} SE_{(\omega)} &= 20\log_{10} \left|F_{(\omega)} \, (i_i/i_s)\right| \\ &= 20\log_{10} \left|F_{(\omega)} \, (i_i/i_r)\right| - 20\log_{10}\left| F_{(\omega)} \, (i_s/i_R)\right| + K \\ &= Q_{i_{(\omega)}} - Q_{s_{(\omega)}} + K \end{aligned} \tag{5}$$

where i_i is the internal current

i_s is the external current

i_R is the standard-reference current used in the H. P. Spectrum Analyzer

K is the scale factor in db for both current probes and the quantities $Q_{i_{(\omega)}}$ and $Q_{s_{(\omega)}}$ represent the Fourier spectra (in dB) of both the internal and the external current respectively as measured with the spectrum analyzer.

The shielding-effectiveness transfer function of the cable has proved to be an extremely useful technique in determining the relative shielding provided by cable shields. This technique has been used to resolve as little as 2-db-across-the-band increases in shielding effectiveness in controlled parameter tests.

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13. ABSTRACT

Cable Driver Testing is a technique widely used in the evaluation of the shielding effectiveness of exterior cable shields. The cable driver is used to create a current on the exterior shield of the cable. Then, by comparing the ratio of the internal current to the external current with the current ratios obtained from other cables or test conditions, the relative shielding characteristics of a particular cable can be determined. In order to complete the Pershing cable/connecto program, new cable driver techniques and hardware had to be developed including a portable driver which could be used to test fielded cables.

The electrical charateristics and general design of all the drivers covered in this report are very similar. However, due to the physical differences in the test items and different sensitivity and resolution requirements in the instrumentation, no one driver setup could be used for all tests. Also, there was a natural refinement of the testing techniques as the program progressed. These modifications and improvements in the cable driver testing technique are described in this report.

DD FORM 1 JAN 64 1473

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Cable Drivers; Shielded Cable Tests; Shielding Effectiveness Transfer Function; Current Injectors; Spark Gap Pulsers						

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