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Upgrade of Harry Diamond Laboratories Scale Model Facility:

I.—A 2-kV Repetitive Pulse Source with a 100-ps Risetime

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by

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Abstract

Harry Diamond Laboratories is currently upgrading its facility for electromagnetic scale modeling. This upgrade will include new pulse radiation sources, transducers, data couplers, instrumentation, and software. Each of these will be covered in a separate technical letter, as the items come on line. This first letter reports on the development of a repetitive (60 to 100 Hz) pulse source which has a risetime of about 100 ps (10 to 90 percent), and achieves a 2-kV amplitude. The source is a pressurized mercury reed switch, approximately 2 in. long, specially adapted in a coaxial housing. The housing has a self-contained coil for switch actuation and is configured to provide rapid and safe replacement of the modified mercury reeds. It is reasoned that faster and higher voltages may be achieved through research and development. Keywords: Electromagnetic, scale models, (CP) ←

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1. Electromagnetic Scale Model Facility

Harry Diamond Laboratories (HDL) conducts electromagnetic scale model experiments and tests to aid in the prediction of the responses of the external receptors of various Army systems to a simulated field that is representative, in scale, of that which results from a high-altitude nuclear explosion. This high-altitude electromagnetic pulse (HEMP) field simulation may be created by radiating a pulsed field from a biconical/dipole antenna. The resulting field induces currents on the receptors of the model under test, which are sensed and coupled to recording equipment housed in a shielded enclosure. Figure 1 shows how this was achieved in the past, without reflecting the upgrade now taking place.

The upgrade for these efforts will include a biconical/dipole antenna that is completely self-contained. That is, the antenna will act as the housing for the pulse source which will consist of batteries, high-voltage power supplies, high-voltage charge and delay lines, a shaping network, trigger circuitry, and the subject of this technical letter, a coaxially mounted mercury reed switch. The antenna will be operated remotely through a fiber-optic control system. The antenna will be more fully discussed in the next technical letter.

Figure 2 illustrates the mercury reed switch and coaxial housing. The mercury reed switch (MRS) was originally manufactured by C. P. Clare Co. of Chicago, IL, for use as a switching device in telephone relay stations; its model number was RP 18104. It is no longer a line

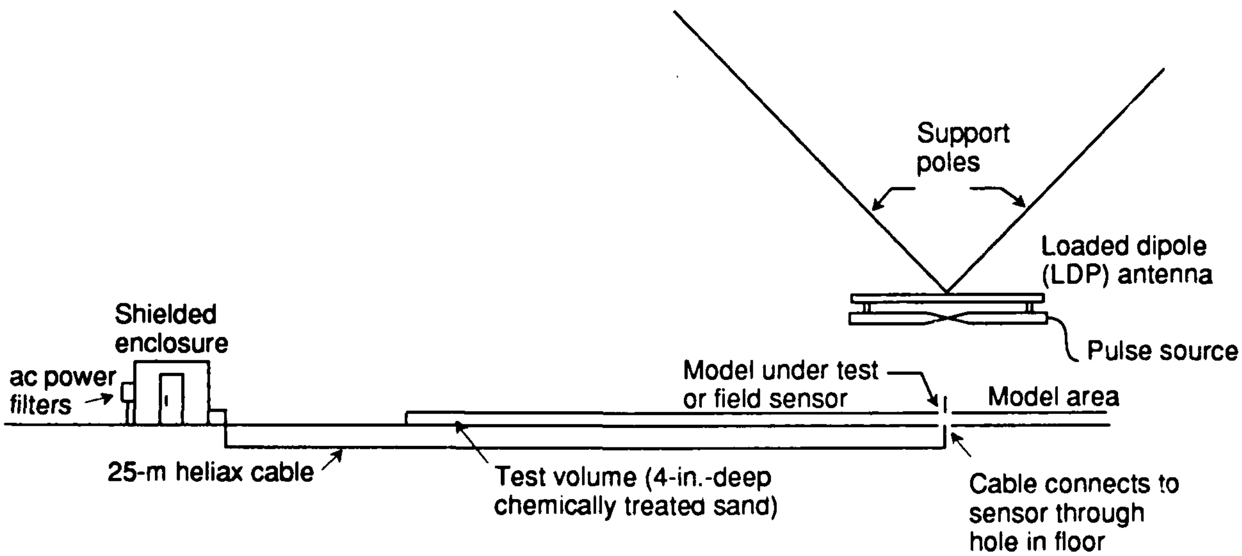
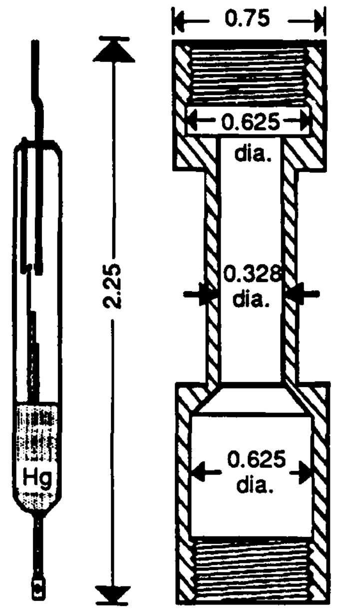


Figure 1. Scale model test volume and instrumentation enclosure.

Figure 2. Mercury reed switch and coaxial housing.



item and must be specially ordered. The housing was designed* and fabricated by SOL Telecommunications Systems, Inc., under the direction of HDL.

The first recording of the output of this device may be seen in figure 3, where a 1.5-V battery was substituted for the power supply. The measurement system consisted of a Tektronix 7854 oscilloscope, with 7S12 and S-6 plug-ins. This system, when used with very high quality cables, has a risetime capability of approximately 40 ps. Unfortunately, the system's inability to provide an advanced trigger from the device or use random sampling required the use of a delay line. With a type 7M11 delay line, the measured net risetime of this system was 196 ps. As seen in figure 3, the recorded risetime from the device is 164 ps, which exceeds the measurement system's capability. The peak amplitude recorded is 600 mV (300 mV at the scope times two for the delay line). The peak should have been on the order of 750 mV, as a charged line pulser outputs half the charging voltage.

A considerably faster instrument was made available by Tektronix Inc. (Rockville, MD). The second recorded output of the coaxially housed MRS is seen in figure 4, while figure 5 illustrates the risetime capability of the measurement system, a Tektronix model 11802 transient digitizer with an SD-24 plug-in (net risetime capability of 70 ps). The coupling cables were two SMA types with extremely wide bandwidth.

**George Crowson of SOL Telecommunications Systems, Inc., was the designer.*

Figure 3. Risetime of mercury reed switch as recorded with Tektronix 7854 oscilloscope; 10–90% risetime = 164 ps.

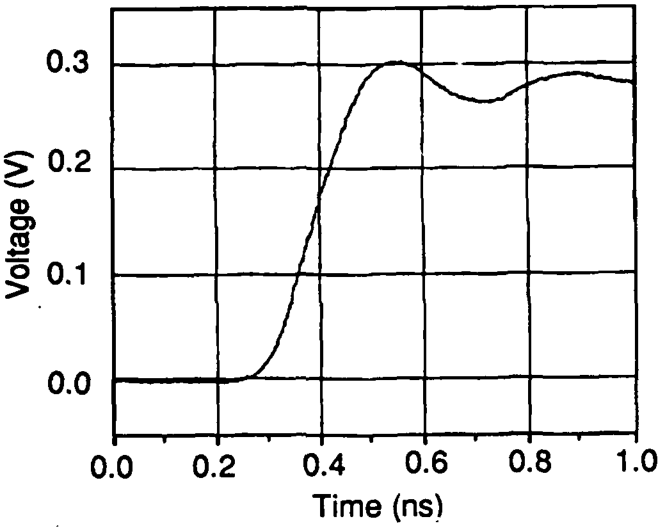


Figure 4. Risetime of mercury reed switch as recorded with Tektronix 11803 transient digitizer; 10–90% risetime = 124 ps. Estimating risetime: $[(124)^2 - (72)^2]^{1/2} = 101$ ps.

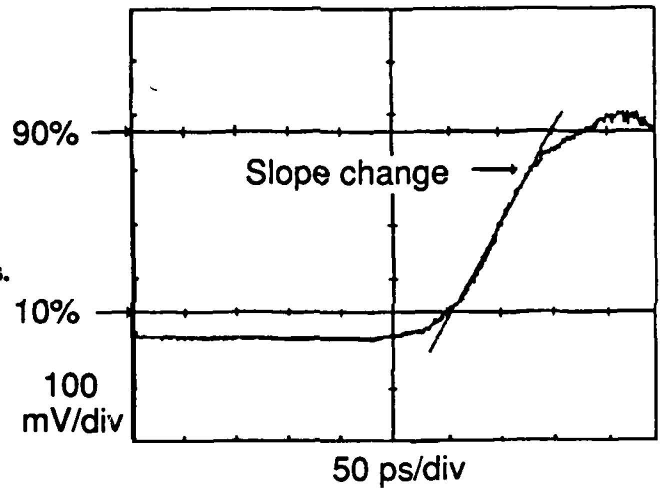
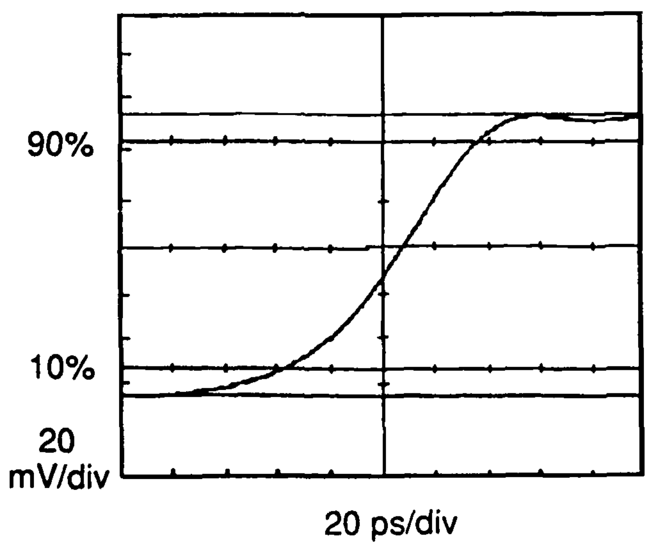


Figure 5. Risetime capability of 11803 transient digitizer system: system risetime = 72 ps.



The measured risetime of the MRS (10 to 90 percent) was 124 ps. The ratio of the risetimes of the measurement system to the measured signal being small (less than two), the actual risetime is estimated by the square root of the difference of the squares of the risetimes. This may be seen in figure 4 to have a value of approximately 101 ps.

In figure 4, a linearly sloping line has been superimposed on the leading edge of the recording. This line illustrates a slope change in the risetime which is generated in the MRS or by an impedance mismatch within the switch housing. If this slope change can be removed by changing the internal geometry of the switch housing, the output risetime should decrease to approximately 80 ps.

The switch output (fig. 4) was recorded directly at the switch output port using a short SMA-type cable as the voltage storage line, charged by a 1.5-V battery. While this setup would only be practical for low-voltage applications, other tests conducted on this device provide strong technical confidence that this risetime may be achieved at the 2-kV level.

Several aspects of this effort may be of interest to other researchers. These include how the switch is configured, alternative practical configurations, triggering problems, and future development.

2. Switch Configurations

2.1 Basic Configuration

Note: These switches contain high-pressure nitrogen gas (~90 psi) and are easily exploded.

In the configuration used within the coaxial housing, the two short (normally closed) output leads are cut off near the glass housing. It was originally reasoned that for mechanical stability and minimal inductance, both of the output leads could be electrically tied together to form a single output lead in a coaxial configuration. There is a subtle but important reason why this should not be done. When the switch is closed magnetically, both of these leads make contact with the actual reed. The problem is that in the picosecond regime, one must take into account that physically, one lead will be contacted before the other. While the difference in contact time was not measured, the effect was seen as a change in the slope of the risetime of the output when the switch was observed in a dual-output-lead configuration. It is reasoned that the lack of precision in the physical closure caused the current flowing on the "closed" lead to flow back toward the "open" lead about to be closed. When the second lead makes contact, the current it provides must first overcome the back-flow from the first.

2.2 A Second Configuration

Workers in this field are probably familiar with a device known as a stripline adapter. Such devices provide a means to apply coaxially coupled signals to a microwave stripline. Typically, these devices are about 4 in. long with various coaxial adapters at both ends, attached to the stripline over a ground plane. It is not difficult to modify such a device to hold the MRS. Experiments here have shown that this method may provide pulse risetimes even faster than the coaxial configuration.

3. Triggering Problems

The MRS switch risetime measurement was not made in the fastest possible configuration because of the need to use a delay line. Since the MRS is closed by a relatively slow-rising field as provided by the coil and switch closure jitter time is significant (because of mechanical aspects of the switch), it is not, as yet, feasible to provide a reliable external trigger source for the digitizer. HDL is presently addressing this problem.

4. Future Development

Since we can achieve a 100-ps risetime at the 2-kV level, using a device *not* designed for this purpose, we believe that this technology has not been fully exploited. What is needed is an MRS specifically designed for coaxial (or stripline) application. While new ultrafast devices such as bulk avalanche semiconductors are now coming on line, they are quite expensive and have not yet been proven reliable. After the initial research, design, and startup costs are covered, MRS high-voltage picosecond-regime pulse generation could prove highly reliable and inexpensive.

The author would appreciate and welcome any comments on this note and would be glad to share (when possible) his latest observations with any interested researcher.