B–1–1

THE TRANSIENT MEASUREMENT FACILITY* FOR BROADBAND ELECTROMAGNETICS

F. J. Deadrick, R. M. Bevensee,
E. K. Miller, A. J. Poggio
Lawrence Livermore Laboratory

INTRODUCTION

The state of sub-nanosecond pulse technology is at a point where scale model time domain electromagnetic pulse measurements can be performed in the laboratory. Electromagnetic phenomena can now be measured over instantaneous bandwidths of 100:1, thus enabling broadband determination of quantities such as input impedance, effective height, surface current and charge density, and radar cross-section. The Lawrence Livermore Laboratory has developed such a facility. This paper will discuss the operation and design of the transient facility and, in particular, will consider the types of measurements and applications of the facility. Throughout, we will emphasize how this facility is an inexpensive, cost-effective alternate to anechoic chambers.

OPERATION AND DESIGN OF THE TRANSIENT FACILITY

The operation of the transient range is conceptually very simple. A very narrow electrical pulse is used to drive a wide-bandwidth EM radiator which radiates an electromagnetic pulse that propagates outward from the source and illuminates the target under test. The target, in turn, responds to the incident EM pulse, and the induced currents and charges are measured by sensors mounted on the target. The outputs from the sensors are fed to a high-speed recording device such as a sampling oscilloscope, which records the transient response of the target. These results may be displayed in the time domain or transformed to the frequency domain.

Figure 1 is a schematic of the system and follows the design of Nicolson et al [1]. Measurements are made over a 8.5 m x 8.5 m aluminum ground plane and the EM pulse is launched by a monocone antenna of 4.3 m length. A minicomputer controls the operation of the equipment and handles the data logging tasks. The nature of the sampling oscilloscope is such that many pulses must be radiated by the source to provide a complete time history waveform. The computer controls the oscilloscope and, in the process, obtains 512 equally spaced samples of the waveform. This transient data is then plotted on an on-line plotter and then written onto magnetic tape for later off-line data processing.

Two factors determine the working bandwidth of the transient measurement system. At the low frequency end, the range clear time, or time it takes unwanted reflections from the walls and surrounding environment to reach the target area, establishes a

* Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under contract number W-7405-ENG-48.

lower limit. For the LLL range the clear time is approximately 20 nanoseconds, which corresponds to a minimum useful frequency of 50 MHz. At the high frequency end the limits are a complex combination of many factors including the rise-time of the exciting pulse, rise-time of the oscilloscope, and losses in the cables, delay lines, and connectors. Our measurements indicate that the maximum frequency is in excess of 5 GHz, depending on the pulse generator used to drive the antenna and the quality of the cables and delay lines used.

USES FOR THE TRANSIENT MEASUREMENT FACILITY

The LLL transient electromagnetic facility can be used to determine the time domain transient responses of various structures by operation as indicated in Figure 1. The surface current or charge densities on a body or the voltage induced at the terminals of an antenna can be simply probed. Note that from a single measurement of a transient response one can ultimately obtain the spectral response over a bandwidth defined by clear time, pulser characteristics, and equipment limitations.

The transient range can also be used for time domain reflectometry (TDR) measurements thus allowing a determination of the input impedance of a structure as a function of frequency. This feature is also included in Figure 1 (dashed line) where the impulse generator excites the target through a power divider. The reflected signal then passes through the power divider in the reverse direction to the sampling oscilloscope. The voltage waveforms for both an open circuit and with the structure connected are transformed to obtain the reflection coefficient

$$\rho(f) = -\frac{V_{load}(f)}{V_{open}(f)}$$

Using the reflection coefficient, the input impedance is computed using

$$Z_{in}(f) = \frac{1 - \rho(f)}{1 + \rho(f)} Z_o$$

where Z_o is the coaxial cable characteristic impedance.

The range is often used to obtain the equivalent circuits of structures as indicated in Figure 2. The effective height h_{eff} is determined by a transient scattering experiment, while the input impedance is obtained using TDR, as mentioned. In this case, a measurement of the received voltage $V_L(t)$ at the structure terminals is required and the effective height is given by

$$h_{eff}(f) = \frac{(Z_I(f) + Z_L)\, V_L(f)}{Z_L\, E^{inc}(f)}$$

where Z_I is the structure input impedance, Z_L is the load impedance, and $E^{inc}(t)$ is the product of the pulser voltage and a field calibration factor $e^{inc}(f)$ which is related to the pulser output voltage and transmitting antenna characteristics.

In order to enhance the accuracy and reliability of the range measurements, extensive studies have been made of systematic and statistical errors. The errors or difficulties due to cables (impedance and attenuation) components (couplers, attenuators, power dividers), and sensors have been investigated. Also, considerable effort has been expended in studying the effects of pulser amplitude fluctuations, pulser time base jitter, an system noise. The details of the calibration and error studies are included in reports [2, 3].

APPLICATIONS OF THE TRANSIENT EM FACILITY

The transient electromagnetics range has been applied to a large number of problems, many more than space will allow to describe. The TDR technique has been used to determine input impedance of antennas such as monopoles in various and complex environments. The range has been used to obtain transient responses such as surface current and charge densities on scale model Boeing 747 aircraft and transient voltage on communication antennas aboard ships. Of course, the post measurement data processing provides spectral information regarding the responses so that with a single measurement we have available broadband spectrum information.

The LLL transient range has also been useful in transmission experiments. As examples, we have used it for the evaluation of the fields penetrating a screened enclosure, the energy and fields transmitted through an aperture, and the effectiveness of disks for suppressing transient currents on transmission lines.

SYNOPSIS

The range of problems to which the transient range has been applied is very large. It will be shown how the range is routinely used for the evaluation of transient and spectral responses and equivalent circuits. Also, a large number of examples will be provided to prove its utility and accuracy. We will show how the range is a very cost effective way for making scale model measurements. For those interested in the details of the facility and its calibration and errors, we will discuss its operation and the impact of certain range variables on the results.

REFERENCES

1. A. M. Nicolson, L. L. Bennett, D. Lamensdorff, and L. Sussman, "Applications of Time-Domain Metrology to the Automation of Broad-Band Microwave Measurements," IEEE Trans..Microwave Theory and Techniques, MTT-20, 3-9 (1972).

2. F. J. Deadrick, E. K. Miller, H. G. Hudson, "The LLL Transient Electromagnetics Measurement Facility," Lawrence Livermore Laboratory Report UCRL-51933, October, 1975.

3. R. M. Bevensee, F. J. Deadrick, E. K. Miller, J. T. Okada, "Validation and Calibration of the LLL Transient Electromagnetic Measurement Facility," Lawrence Livermore Laboratory Report UCRL 52225, March. 1977.

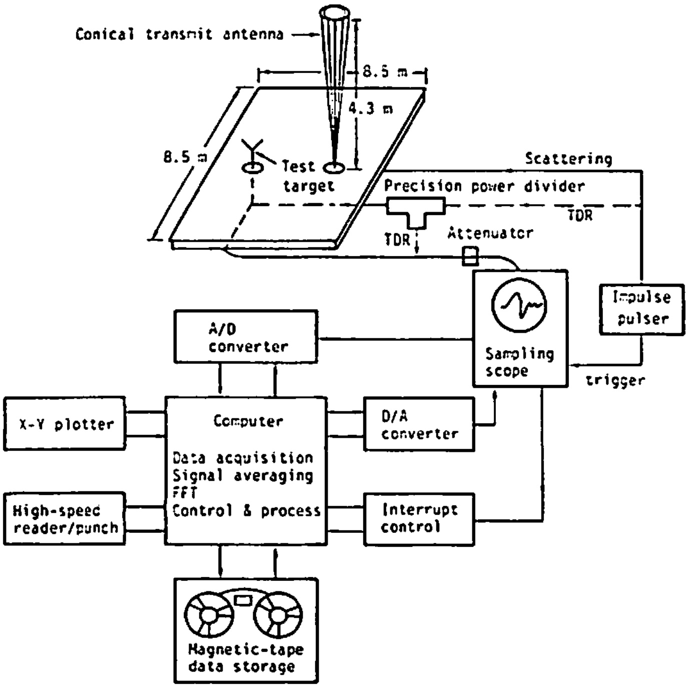

Fig. 1. Schematic diagram of the measurement facility, Range.

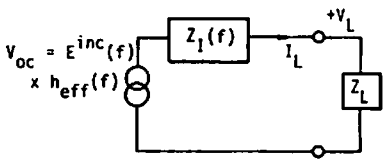

Fig. 2. The scattering equivalent circuit