TITLE WIDE-BANDWIDTH TEST FIXTURE FOR ELECTROMAGNETIC-BEAM SENSORS

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Summary

The Fusion Materials Irradiation Test (FMIT) accelerator will provide an intense deuteron beam 35 MeV (R = 0.19). The beam, following a stripping reaction on a lithium target, will supply the neutron flux required for studying materials that may be used in a fusion environment. The diagnostic measurement instrumentation, which will characterize the accelerator beam, must be noninterceptive because of the beam's power density. Instrumentation also must be fully functional for start up of the FMIT accelerator.

To this end, a test facility was needed to examine signals from diagnostic probes that sense electromagnetic fields emanating from the charged particle beam. The test facility also will help evaluate the probes' corresponding measurement systems before final assembly into the beam line. Three types of test facility were proposed: (1) a low-energy electron accelerator, (2) a large "electron-gun assembly," and (3) a coaxial structure that produces electromagnetic fields similar to that of the proposed FMIT accelerator. The third type was chosen because the design and fabrication could be done at Los Alamos and Types (1) and (2) would be more costly.

The coaxial structure can carry the impulse currents required but cannot model the FMIT accelerator charged-particle-bunch velocities accurately. However, one may introduce a highly resistive dielectric material into the coaxial test fixture so that its electromagnetic-wave velocities match those of the accelerator's particle-bunch velocities.

This paper describes the design and some experimental results of the coaxial test fixture.

Test-Fixture Design

To validate the coaxial test fixture as an electromagnetic field model for the accelerator beam, several assumptions were made. The electric and magnetic fields of the coaxial line should be similar to those of the beam. If the beam is thought of simply as a line current, one could then supply this line with a fast current pulse capable of producing a field similar to that of the charged-particle bunch. With the proper dielectric material in the coaxial test fixture, the velocity of the test-fixture fields matches that of the accelerator's particle bunch and therefore the fields have similar longitudinal and transverse electromagnetic fields. Because the cross-sectional fields of both the beam and the coaxial line are dependent on the transverse location of charge with respect to the longitudinal axis, the proposed accelerator beam and the coaxial test fixture were equated by considering the FWHM beam diameter into the characteristic coaxial impedance formula. The beam impedance and the characteristic coaxial test-fixture impedance were calculated to be 101 to 106 Ω.

Most electronic test equipment has 50-Ω input and output impedances. The test fixture must be able to transform 50 Ω to 106 Ω then back to 50 Ω, with minimum signal loss. To achieve this, a tapered impedance transformer was designed so the test fixture would have a low VSWR and a wide bandwidth.

The time-varying signals expected from the diagnostic probes in the FMIT accelerator will have a broad spectrum. The lowest spectral component is that of the proposed 80-MHz beam bunch period and the highest spectral component (1000 MHz) may be the frequency corresponding to the expected FMIT bunch width (~1 ns). Therefore, the test fixture was designed with a 80- to 1000-MHz minimum bandwidth.

The type of construction material and the material's surface roughness also affect the test fixture's high-frequency capabilities. Hard-drawn copper and aluminum were chosen for their machinable properties and their high conductivity. Copper and aluminum have respective skin depths of 83 and 105.3 microinches at 1000-MHz; therefore, an overall surface roughness of 83 microinches was chosen. Finally, all test-fixture components were interconnected with either a silver solder, a tungsten inert gas (TIG) braze, or an O-ring leak-tight connection that will allow future use of liquid or powdered dielectric materials.

Essentially, the Assembly A form of the test fixture consists of two sets of three coaxial components, shown in Fig. 1: an N-connector to a 3.125-in. 50-Ω adapter, a 3.125- to 4.815-in. 50-Ω adapter, and a 50- to 106-Ω impedance transformer. The N-to-3.125-in. adapter was purchased from Phelps Dodge to reduce the fixture's design and fabrication costs. The 3.125- to 4.815-in. adapter was designed to maintain the 50-Ω impedance over its full length. The impedance transformer's coaxial taper span 1.5 wavelengths at 1 GHz (~17.72 in.). The VSWR for this section should be 1.1 or less for frequencies below 1 GHz.

Figure 2 shows the test fixture (Assembly B) with the box containing a single capacitive pickup.
Fig. 2. Assembly B is composed of the Assembly-A components with a capacitive pickup probe and box inserted into the center of the test fixture.

The probe, the first to be assembled into the test fixture, will be used for the time-of-flight energy measurement in the FMIT accelerator. The capacitive pickup senses the electric fields from a beam bunch passing through its two concentric rings. The resultant bipolar, time-varying signals of two probes, separated by a known distance on the beamline, trigger their respective discriminators. The interval between these two discriminated events will be timed to calculate the velocity and energy of a particular particle beam bunch.

Test Results

Any transverse discontinuity in the test fixture will increase its VSWR and, in turn, decrease its bandwidth. To ensure that few discontinuities existed, a surge impedance test was performed. The test used a high-resolution time-domain reflectometer (TDR) capable of resolving impedance discontinuities within 0.2 in. along the longitudinal axis. The Tektronix 7512 TDR with the S-52 pulsing head and S-6 sampling head has a 45-ps system rise time, with a corresponding frequency well above the test fixture's designed bandwidth. Therefore, the surge impedance test also allowed verification of the impedance transformer mechanical design.

The trace in Fig. 3 has been smoothed to show the overall impedance characteristics of the test fixture (Assembly A). The TDR's smoothing filter distorts the transient peaks; thus, Fig. 4 shows Assembly B's TDR trace without this smoothing function. Figure 4 also shows the large discontinuity reflections from the probe and box in the left half of the trace. Table I summarizes reflection coefficients, VSWR, and impedance data from the TDR measurements of the test fixture. As can be seen from Figs. 3 and 4 and Table I, the Teflon supports and 3.125- to 4.015-in. adapter have a lower VSWR than the purchased Phelps Dodge adapter.

Lower frequency VSWR measurements were acquired by connecting an 80-MHz oscillator and directional power meter to the inputs of 50-ohm terminated test fixture Assemblies A and B. Table II summarizes this data. Because Assembly A actually is two sets of the components pictured in Fig. 1 plus a Teflon support, one may use the data of both Tables I and II to estimate the overall VSWR at 80 MHz of the impedance transformer. The calculated VSWR of the impedance transformer is 1.03, which is well below the designed VSWR of 1.1.

Fig. 3. The TDR trace of Assembly A shows the high-frequency reflection coefficient change with respect to the z-axis, which correlates to an impedance transformation of 50 to 106 Ω.

Fig. 4. The TDR trace of Assembly B shows the reflection introduced into the test fixture from the Phelps Dodge connector and the capacitive pickup and box.
TABLE I

<table>
<thead>
<tr>
<th>Component</th>
<th>Fixture Assembly</th>
<th>Reflection Coefficient</th>
<th>VSWR</th>
<th>Impedance (Q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teflon bead</td>
<td>A</td>
<td>0.02</td>
<td>1.04</td>
<td>-</td>
</tr>
<tr>
<td>or support</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phelps Dodge</td>
<td>A, B</td>
<td>0.15</td>
<td>1.35</td>
<td>-</td>
</tr>
<tr>
<td>3.125-in.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>adapter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The 3.125-</td>
<td>A, B</td>
<td>0.36</td>
<td>2.13</td>
<td>50 to 106</td>
</tr>
<tr>
<td>to 4.805-in.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>adapter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE II

<table>
<thead>
<tr>
<th>Component</th>
<th>Fixture Assembly</th>
<th>Reflection Coefficient</th>
<th>VSWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>A</td>
<td>0.414</td>
<td>2.414</td>
</tr>
<tr>
<td>All</td>
<td>B</td>
<td>0.458</td>
<td>2.698</td>
</tr>
</tbody>
</table>

The frequency-response curves, shown in Figs. 5 and 6, are for Assemblies A and B with an air dielectric inside the fixture. Both Assemblies A and B display the TE_{11} mode being excited within the coaxial line at 660 MHz. It also is believed that the low-power spectra ~740 MHz in Fig. 6 display the TE_{22} or TM_{11} mode, which consumes power within the capacitive pickup box. The key point is that even with a large capacitive pickup box in the test fixture, the frequency response between 60 and 1000 MHz is flat within ±3 dBm.

**Conclusion**

The test fixture has the desired bandwidth and a minimal VSWR that preserves the desired signal.

**References**

3. Rigid Coaxial Transmission Lines and FM Broadcast Antennas (Published by Phelps Dodge Communications Co., Rt. 79, Marlboro, NJ 07746) Catalog No. 778, p. 5.
4. Beam Diagnostic and High Vacuum Components Specifications (Published by HTG, 6460 Gelnhausen 3 Haller, West Germany), Vol. 2, p. 46.
5. Supplement to Sampling Systems and Applications, Application 5 (Published by Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077).