EMMI Manual

I. General Description

The Pavia-Roma Electromagnetic Micrometer (EMMI) is a device to measuring the position of the wire in an MDT tube. It consists of:

o two V-blocks, each with two coils between which the MDT tube is placed;
o a signal generation board (SG) which sends an oscillating current to the tube wire;
o two readout boards (RO) which read out the signal induced on the coils.

The differential signal between the coils on the sides of a tube end is proportional to the wire position in the tube. Hence, this signal can be used to determine the wire position within the tube.

II. Description of the electronics

Signal Generation Board

o Oscillator SG-1-Y1 (SG-1-Y1 = Signal generator schematic page 1, circuit component Y1) generates a 3.6884 MHz signal which feeds into scaler SG-1-U1 from which a 450 Hz clock is extracted.

o The 450 Hz feeds into flipflops SG-1-U4:A,B which clock out at 225 Hz and feed into rotary switch SG-1-RSW1. The rotary switch permits selection of signal phase at 90 degree intervals (0, 90, 180, 270 degrees). A 225 Hz signal is used since 225 Hz is a multiple of neither the US or European standard power frequencies of 60/50 Hz respectively.
o The 225 Hz clock signal is sent in 2 different phases (0, 90) to the readout module via the front panel 9-pin D-SUB connector. The RO board uses these clock signals in the demodulation of the coils signals, discussed later.

o The 225 Hz clock signal is also fed to connector SG-1-J1, a front panel LEMO connector, to allow easy access to the clock signal for display on an oscilloscope.

o The signal then goes through a 225 Hz 2-pole bandpass filter (SG-1-U6) where the square wave clock signal is changed into a sine wave.

o The signal then goes through unity amplifier SG-1-U2:B which permits a continuous adjustment of the phase of the signal via trimpot SG-1-VR3 (on front panel).

o The signal then goes through buffer SG-2-U2:A which permits an amplitude adjustment of the signal via trimpot SG-2-VR4 (on front panel).

o The signal at this point can easily be monitored via connector SG-2-J2, a front panel LEMO connector, readout via buffer SG-2-U7:A.

o The signal then passes through SG-2-U7:B which is an offset null circuit to remove an DC component of the current signal. This adjustment is done via trimpot SG-2-VR6 during board manufacture and should not normally need to be reset.

o The signal then goes to current generator SG-2-U8 which generates a constant current to input to the tube wire.

o The output of the current generator has a toggle switch to allow shunting of the current when there is no tube installed to prevent the current source from instabilities and/or underheating due to missing load. When the shunt is on (toggle to left) the green LED on the front panel is illuminated. The current source is output to LEMO connector SG-2-J3 on the front panel. The current source is connected to the tube wire to provide a signal for the coils surrounding the tubes.

o Red LED indicate that power is on when illuminated.

Readout Board

o The coil signals are fed into the RO board via connectors RO-1-J1 & RO-1-J2. It is important that the coils signals are wired in an opposite way so that a differential signal is input so that signal is proportional to wire position projected in the coils plan.

o The coil signals then enter differential amplifier RO-1-U4 with gain 1000. The output of the amplifier is typically quite noisy due to the small size of the differential voltage present at coil ends.

o The signal is then put through the three stage (6-pole) bandpass filter RO-1-U1, RO-1-U2, RO-1-U3 to extract the 225 Hz signal.

o The signal is then passed through unity-gain amplifier RO-2-U6:A and buffer RO-2-U6:B which permit phase and gain adjustment via front panel trimpots RO-2-VR6 and RO-2-VR5, respectively.

o The signal is then amplified by 10 by amplifier RO-2-U7.

o There are also 2 standalone buffer readout circuits (RO-2-U5:A,B) which are accessible via front panel inputs RO-2-J5 & RO-2-J6 and outputs RO-2-J3 & RO-2-J4 respectively. These are not used in the circuit, but can be used in circuit debugging to readout signals which are routed through these circuits via jumpers. The buffer gives better impedance matching to examine signals on an oscilloscope.

o The signal then goes to two different demodulator circults, one for 0 degree phase and one for 90 degree phase. These circuits are identical so only the 0 degree phase will be discussed. Both 0 and 90 degree demodulation has been provided to allow the use of a phase-lock amplifier, however, this technique has been found to have no greater sensitivity than just the straight signal readout. Therefore, only one phase need be read out, and the other just provided a redundant signal.

o The demodulator circuit RO-3-U10 combines the clock signal and the coil signal to produce a demodulated output. The demodulator has a gain of -2 when the clock signal is positive, and a gain of +2 when the clock signal is negative. If the clock signal and coil signal are in phase then the demodulator acts like a rectifier (times a factor -2). However, the phase between the clock and coil signals can be adjusted to allow for cancellation of the constant term in the output signal as is explained in section "EMMI Phase Cancellation Calibration" below.

o The demodulator output goes through a 2 stage (4-pole) low pass filter RO-3-U8 & RO-3-U9 which effectively integrates the demodulated signal. Hence, a DC output is obtained which is proportional to the projected wire displacement.

o The output signal combined with a DC offset via summer amplifier RO-3-U16:A which sums the signals from the coils with (twice) a constant offset between -5 and 5 V provided by RO-3-U11:B and controlled with front panel trimpot RO-3-VR7. The offset adjustment is provided to match the output range of the EMMI to the input ranges of a DAQ device such as a scaling ADC.

o The output signal is available on front panel LEMO connector SG-3-J8 (0 degree), and SG-4-J9 (90 degree).

o Red LED indicate that power is on when illuminated.

o Note that both the SG and RO boards are equipped with a number of jumpers which permit disconnecting parts of the circuit from each other for the circuit testing/calibration. The boards also have a few disconnected circuits which are used during testing/calbration to adjust amplifier gains, etc. These parts of the circuit are only used during construction and calibration.

III. Description of the V-blocks

The main features of the V-blocks are:

o Two coils between which the tube is placed. The coils have small banana connectors for the readout cables.

o A V-block on which the tube is held via a spring-loaded clamp.

o Copper strips in which the threaded brass post of the MDT endplug is inserted in order to provide an electrical contact to the wire. The copper strips are connected to a LEMO connector to supply the oscillating current to the wire.

o The vblocks are mounted on a movable stage which permits the movement of the coils with respect to the tube via a micrometer.

IV. Instructions for using the EMMI

SG = *Signal Generation board.*
RO = *Read out board, one for each end of the tube.*

A. **Wire Connections**

1) Connect the 9-pin D-SUB connectors from the SG to each RO board. This cable provides power and 225 Hz clock signal to the RO boards.

2) Move toggle switch on SG to left. This shunts current source to ground when a tube is not connected to the current source to avoid instabilities of the power op-amp. The green LED is turned on indicating the STAND-BY status.

3) Connect current source (LEMO-SG/J3) to tube wire. Connect the return line at the other end of the tube. Each site will have to provide this wiring. One simple method to do this is to use the central conductor of a LEMO cable for the signal, and to make a junction box which joins the wires coming from the tube ends together, putting the return line on the ground of the LEMO cable connecting to J3. These wires should be routed in a secure manner, since wire movements will cause large changes in the output of the RO circuit.

4) Connect 0 degree output from each RO (LEMO-RO/J8) to a DC voltmeter. Equivalently one could use the 90 degree output.

5) Connect coil readout wires to each coil. For one coil connect red-red and black-black, and on the other connect red-black and black-red. The point here is that the 2 coils should be connected in an opposite polarity so that the difference of the coil EMFs is made by the RO board.

6) Plug in main power with transformer set to 110/220V as appropriate. Two red LEDs on each SG and RO board should light, indicating power on. The green LED on the SG will also be on which indicates that the current source is being shunted.

The EMMI is now ready for measurements.

B. **Measurements**

1) Insert a tube into the vblocks and hold down with the spring-loaded clamp. Remove brass caps (which may be installed to protect the wire crimping tube) so that the threaded brass post on the endplug can be placed between the copper electrodes to make the electrical connection to the tube wire.
Make sure tube is seated correctly so that it does not easily move.

2) Move the toggle switch to the right which turns off the green LED and sends current through the tube wire.

3) Set the tube orientation with the fixture on the tube mount block.
Take 4 readings at 0, 90, 180, and 270 degrees.

4) Determine the micron/mV conversion factor, K, by moving the coils by 100 microns and noting the change in mV reading. A more significant result may be obtained by a linearity scan (for example, 20 points over a full range of +/- 100 microns around the central position).

5) To determine the wire position, R, use the following formula:

A = (S_180 - S_0)/2
B = (S_270 - S_90)/2

R = SQRT(A*A + B*B)*K*FF (in microns)

where
S_0, S_90, S_180, S_270 =
signal readings (mV) at 0, 90, 180, 270 degrees, respectively.
K = micron/mV conversion factor
FF = Correction factor from comparison to microscope measurements (constant factor for a given coil setup), typically 1.065.

6) To do the next tube, move the toggle switch to the left (to shunt constant current) supply, and replace tube.

7) If the EMMI is being readout by a scanning ADC which requires a particular range of input voltages, one can adjust trimpots VR7 (0 degree output), and VR8 (90 degree output) to provide a DC offset between -5V to 5V.

V. EMMI Phase Cancellation Calibration

Before the EMMI can be used the system must have the phase adjusted to cancel the constant term in the signal. Such a term seems largely generated by asymmetries in the signal detection.

1) Set the demodulator to self-reference by adjusting jumper RO-3-S1.
This change causes the demodulator to use the input signal as the modulation

reference, resulting in a output of the demodulator which is just the rectified input signal.

2) Next adjust the position of the coils to minimize the output signal from the coils. At minimization the tube wire is at the "electrical" zero between middle of the coils due to small differences between the coils. The exact position of the zero is not important since the computation of the wire displacement is found by taking the difference of signals at 180 degrees offset in orientation, so the center position cancels out.

3) After the electrical zero position is found switch the demodulator to external reference by adjusting jumper RO/S1.

4) Make sure the output signal has no offset introduced by RO-3-VR7 (0 degree output) or RO-4-VR8 (90 degree output):

a) Set the jumpers RO-3-JP20 & RO-3-JP21 (RO-4-JP24 & RO-4-JP25 for the 90 degree output) to short the input to summer chip U16 to ground: JP20 (JP24) open, JP21 (JP25) closed to ground. Now the output will read just the DC offset.

b) Zero DC offset with RO-3-VR7 (0 degree output) or RO-4-VR8 (90 degree output).

c) Replace the jumper at JP20 (JP24) and JP21 (JP25).

Such offset nulling operation may be avoided by taking directly the output signal from JP20 (JP24). A buffer output (J3 or J4) may be used for comfortable connection. Try anyway to avoid ground loops as they may introduce instabilities.

5) Now adjust the phase of the wire current which zeroes the output signal. The phase can be adjusted in three different locations: (i) rotary switch SG-1-RSW1 [this adjusted the phase in 90 degree steps: 0, 90, 180, 270]; (ii) trimpot SG-1-VR3 [continuous adjustment]; (iii) trimpot RO-2-VR6 [continuous adjustment]. Locations (i) and (ii) adjust the wire current phase, and thus affect the phase for both readout boards, whereas RO-2-VR6 adjusts the phase on signal readout, and thus is separately adjusted for both RO boards. In general, it is more convenient to use (iii) so as to easily accommodate a separate phase for each RO board.

6) Once the phase is adjusted the trimpot should be locked into position. Now the EMMI should give linear readout based on the wire position. Maintaining the coils at the exact electrical zero position is not critical since there is a wide region of linearity about the electrical zero position.

Pavia, June 1999

Manual Author:

Edward Diehl
Assistant Research Scientist
271 West Hall — Office: 734-936-9662
University of Michigan — Fax: 734-936-6529
500 E. University Ave — Sec'y: 734-764-4442
Ann Arbor, MI 48109-1120 — Email: diehl@umich.edu

Contact Persone in Pavia:

Roberto Ferrari
I.N.F.N. Researcher
Sezione I.N.F.N. Pavia
Via A. Bassi 6
I 27100 Pavia — Office: +39 0382 507 631
Italy — e-mail: roberto.ferrari@cern.ch

Agostino Lanza
I.N.F.N. Researcher
Sezione I.N.F.N. Pavia
Via A. Bassi 6
I 27100 Pavia — Office: +39 0382 507 414
Italy — e-mail: agostino.lanza@pv.infn.it

Michele Prata
Ph.D. Student
Dipartimento di Fisica Nucleare e Teorica
Via A. Bassi 6
I 27100 Pavia — Office: +39 0382 507 234
Italy — e-mail: michele.prata@pv.infn.it

Gabriella Gaudio
Ph.D. Student
Dipartimento di Fisica Nucleare e Teorica
Via A. Bassi 6
I 27100 Pavia — Office: +39 0382 507 324
Italy — e-mail: gabriella.gaudio@pv.infn.it