Stripline Beam Position Monitor for the MIT-Bates South Hall Ring*

J. B. Flanz, R. Averill, E. Ihloff, K. D. Jacobs, D. Wang, and A. Zolfaghari
MIT-Bates Accelerator Center
P.O. Box 846, Middleton MA 01949 USA

I. INTRODUCTION

The MIT-Bates South Hall Ring (SHR) is an electron storage ring currently being commissioned. It is designed to operate at an rf frequency of 2856MHz with all the 1812 buckets filled and a circulating current of 80mA or greater. This leads to a small charge per bunch and the requirement for sensitive Beam Position Monitors (BPM). Since there will be 31 BPMs in the vacuum system, it is important to suppress trapped modes which may excite coupled bunch instabilities [1]. The stripline BPM built for the SHR is a stainless steel structure, designed to be manufactured using standard machining techniques and commercial feed-throughs. With proper 50 Ohm matching and a geometry derived by insight from MAFIA calculations the BPM was constructed having a nearly flat rf response up through 10 GHz over the range of measurement. The stripline electronics allows the measurements within 0.1mm resolution, maintains orbital harmonics information past the 10th harmonic, and operates over a dynamic range of 1ma to greater than 80ma of beam current.

II. COUPLING IMPEDANCE CALCULATIONS

Any device present in the ring may have unwanted resonant modes, which could lead to coupled bunch instabilities. This is particularly true for the SHR, since all 1812 of the 2856 MHz rf buckets contain electron. In an effort to minimize the possibility of the stripline monitors causing a harmful coupled bunch mode, a detailed numerical study of the resonant modes of the monitors was made using the MAFIA family of programs [2].

Figure 1 shows a sample result from a MAFIA stripline calculation. From such calculations, the frequency, shunt impedance and quality factor of each resonant mode were found. By studying the dependance of these parameters on the stripline design, it was possible to select an optimum design. The width and height of the metal filling the spaces between the strips were varied, as was the size of the gap between the ends of the strips and the beam pipe. In all cases, the inner radius of the strips was equal to that of the beam pipe. The space between the strips and the outer wall of the monitor was adjusted to maintain 50 Ohm impedance.

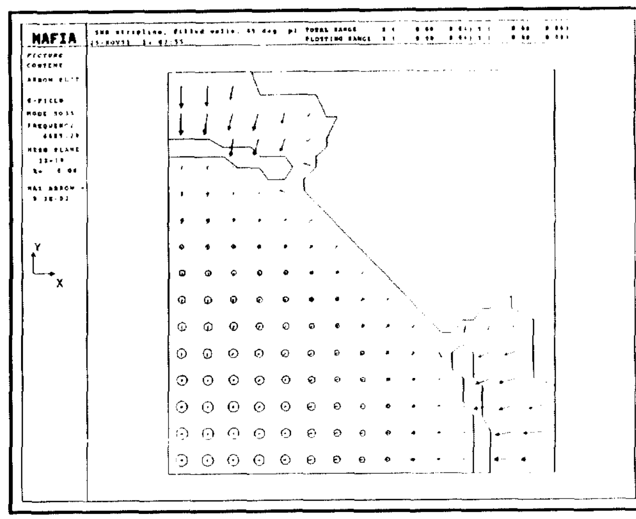

Figure 1. Cross section of a stripline monitor. Only one quarter of the monitor is shown. The arrows indicate the strength and direction of the electric field for the particular resonant mode shown.

The MAFIA calculations did not take into account the fact that the strips were terminated in 50 Ohms. This termination significantly altered the characteristics of many of the resonant modes. Nonetheless, the MAFIA calculations provided valuable guidance in the design of the monitors. We found that the best design had the wells between adjacent strips filled with metal, and had a small gap from the strip ends to the beam pipe. In the final design however, a compromise must be reached between the mode spectrum of the monitor, and its sensitivity.

III. Mechanical Design

The mechanical design of the stripline was chosen to ensure that the electrical center was close to the mechanical center, operate in Ultra High Vacuum, minimize Higher Order Mode losses, and have a minimum insertion length. The stripline monitor is made of four approximately 1/4 λ (24.7mm) long. The length of the strip is designed for the 2856MHz fundamental. Each of the strips subtends 42° of the 60 mm aperture. Each strip sits in a pocket spaced 3° away on from a solid spacer on either side. The strips ends are chamfered at 45° and the pin connectors are angled at 45° for impedance matching. Longitudinally, there is a 2mm space from the end of the strip to the body. Figure 2 shows a photo of the stripline unit and Figure 3 shows a design schematic drawing.

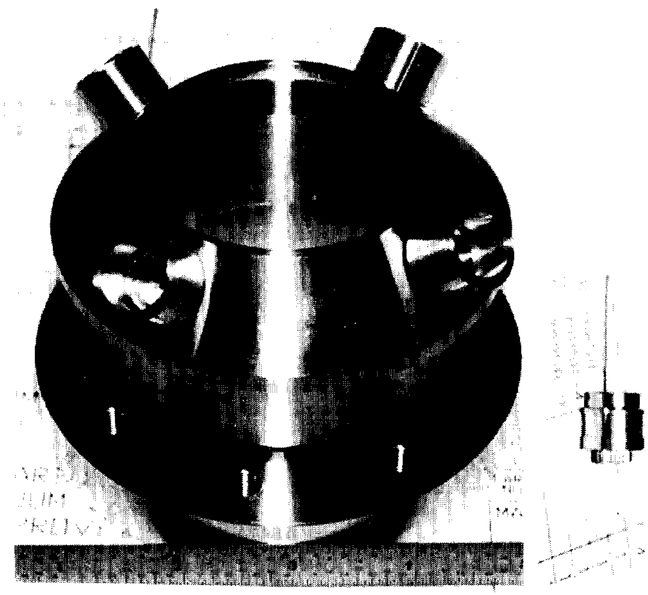

Figure 2. Photo of stripline BPM.

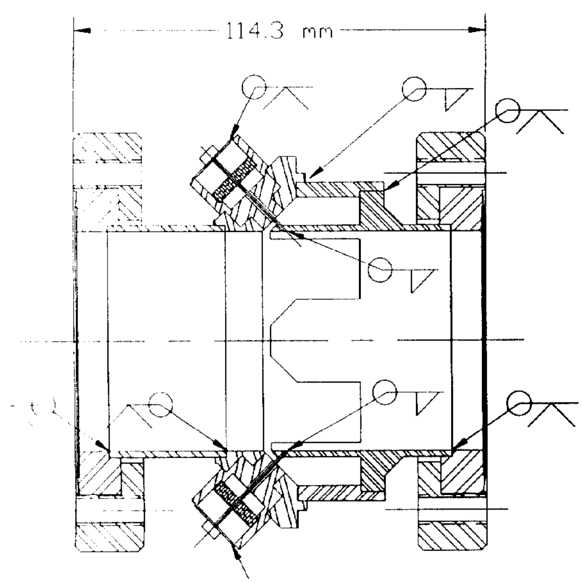

Figure 3. Stripline BPM Design.

The body is made by conventional machining methods from a 3.25" by 0.75" wall stabilized 316L seamless stainless steel tubing. After machining and cleaning, it is TIG welded and leak checked. The connectors are not demountable and are welded into the strips and body. Replacement requires machining. By the use of close tolerances and centering on machined surfaces, the electrical centers are reproducible within $\pm$ 0.025mm. These tolerances were checked after welding. The stripline monitors reach pressures of 5×10^{-10} torr unbaked. They are designed to be baked to $150^{\circ}C$.

IV. Impedance Measurements

The transmission core coefficient [S21] was measured for a pulse transmitted through the BPM on a bead loaded 50 Ω coaxial line. coefficient approximates the longitudinal coupling impedance of the device undergoing such tests. The measurement was performed using a network analyzer HP-8510 to obtain data in the frequency domain, which were FFT transformed to determine the two port S-parameters of the BPM. Tapered input and output sections with level response over a 10 GHz frequency range were designed and employed to minimize reflections at the BPM ports. Measurements were made with and without the transition section, higher order mode damper spacer inserts, and with and without a 50 Ω output load line. Some results are shown in figure 4.

To investigate the impedance matching of the junctions of the feed-through and the stripline, time domain measurements were conducted using the network analyzer including the TDR option.

V. Stripline BPM Electronics

The Signal processing of the transducer signals is conducted in two stages, RF processing at 2856 MHz and an IF stage at 50 MHz. The RF stage consists of feeding the outputs of opposite strips into a 90° hybrid where the amplitude information is converted into phase information. As long as the difference in electrical lengths of the cables feeding the hybrids are small, no significant errors are introduced. The output of the hybrids goes through a phase matching section and possibly a circulator or attenuator, then into a mixer section, heterodyning the signals to 50 MHz. These signals are summed with the other two strips to get a signal proportional to the beam current. The phase detector has an amplifier and analog multiplier, then a gain converting amplifier and line driver. These signals are then digitized by a flash ADC converter for signal processing. The bandwidth of the IF signal processing stage is 15 MHz.

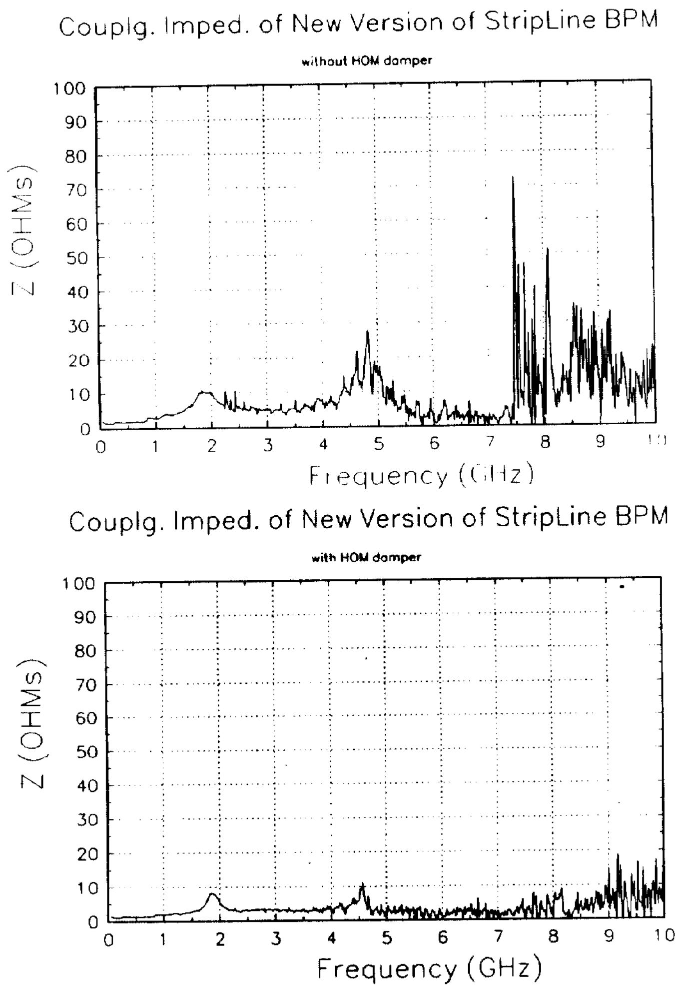

Figure 4. Stripline BPM Impedance measurements with and without spacer insert.

Calculations and measurements of noise levels show that the signal to noise ratio is high enough to get the .1mm resolution at 1ma of beam current. There are some problems with mismatches in the RF section, causing reflections which can introduce a large offsets in the output. Solutions to this problem will be the addition of attenuators or preferably circulators after the hybrids to kill the reflections.

V. Operation

Tests with beam have been conducted both in the beam switchyard beam line and the SHR. Figure 5 shows the beam position at a location in the SHR for several turns. The figure shows the beam current and beam position with betatron oscillation resulting from the beam trajectory being different from that of the closed orbit. (That is also the reason for the decreasing current.) At about 0.5mA the signal disappears. Measurements to 40 mA have been made with good results. The gains of the monitor electronics differ by as much as 5% from BPM to BPM, however they are measured and recorded in the computer data acquisition system. The BPMs and ancillary systems are designed for data acquisition in several modes [3].

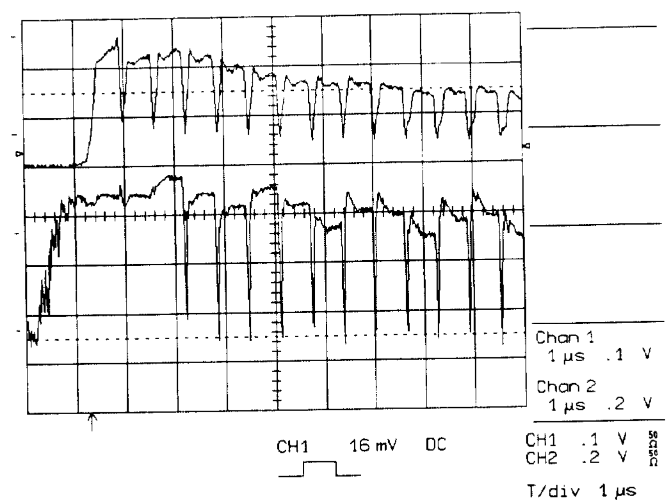

Figure 5. Beam Position Output from Stripline BPM.

VI. References

* Work Supported by the U.S. Department of Energy

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