Main Injector Note #0226A
MI BPM RF Module Test Results
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A series of measurements were conducted on the BPM RF modules that were removed from the Main Ring for use in the Main Injector. This was done to determine what average performance could be expected from these modules as part of the BPM system. The modules were first tuned and aligned using the Beam Position Module Test Unit (Fermi DWG #1680.00-EC-158143). The procedure followed was the *Beam Position System - RF Module Inspection, DC Test and Checklist* . After alignment, the modules were measured using a Labview based test system. The system was configured with a 53 MHz signal source, an RF amplifier, a NIM programmable attenuator, a GPIB DVM and the Quadra 700 computer running Labview. The RF input to the module under test was varied in 2dB steps through 40dB of intensity range (max. approx. 10e10 ppb) and $\pm$15 dB of A/B range (approx. $\pm$25 mm of horizontal position for the Main Injector).

The data generated for the 228 modules tested was compared to the RF module mathmatical model:

$$V= -2.3168+2.9499*ATAN\{e^{[(A/B)dB/-7.6192)]}\}$$

This model is simply an algebraic rearrangement of the model found in BPM Design Note #4 (Equation 2):

$$(A/B)dB=[-20/(F*\ln 10)]*\ln\tan[F*C_1*(V-V_O)-\pi/4]$$
$$F=1.14,\ C_1=\pi/10,\ V_O=0.0$$

The Mean Square Error (MSE) for each RF module relative to the above model was calculated. The square root of the MSE (SQRT MSE) was taken to yield an average error term for each module expressed in mm. Analysis of the set of SQRT MSE terms for all 228 modules yielded the following:

Position Range	$\pm$25 mm	$\pm$10 mm
Mean (SQRT MSE)	0.5969 mm	0.3724 mm
Standard Deviation	0.2154 mm	0.2345 mm
Sample Variance	0.0464 mm	0.0550 mm

We then varied the voltage offset term (V_O) and compared it with the measured data and found a minimum Mean (SQRT MSE) of 0.5690 mm at V_O=0.017v. As this difference is about 1/4 of an LSB in position for the system, no change in the model is suggested. We also compared the data to a 5th order polynomial based on average coefficients from fits to the individual modules, finding a Mean (SQRT MSE) of 0.502 mm. Again, the difference amounts to less than 1 LSB and a change to this model is not suggested.

This set of tests indicate that a beam position measurement made using the Main Ring/ Tevatron style RF modules will have an RMS uncertainty of approximately 0.6 mm over a range of $\pm$25 mm and an uncertainty of about 0.4 mm over the range $\pm$10 mm (horizontal).