Fermi National Accelerator Laboratory

FERMILAB-TM-1852

Linac BPM Cable Phase Matching

Jeffrey Arthur

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

August 1993

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

Disclaimer

Fermi National Accelerator Laboratory

TM-1852

Linac BPM Cable Phase Matching

Jeffrey Arthur
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, Illinois 60510

August 6, 1993

Operated by Universities Research Association Inc. under contract with the United States Department of Energy

Linac BPM Cable Matching

J. Arthur
8/5/93

Introduction

This report explains the method chosen to phase match cables, it's accuracy and the effects of mismatched cables on the position output of the Linac Beam Position Module.

Beam Position Module and Cable Phase Match

The Linac Beam Position Module receives the incoming signals from the detector plates in the beam line through phase matched 1/2" Heliax cables. The BPM lowpass filters the signal at 215 Mhz and then incorporates amplitude modulation to phase modulation (AM/PM) normalization similar to that of the existing MR/Tev & Booster beam position modules. The signals are then sent through phase matched limiter sections to provide a constant amplitude signal to the phase detector. Through this process the measured position is as follows:

NOTE: *Linac Beam Detector Sensitivity is 1.8 db/mm*

for cable phase error ϕ

$$position = \frac{20}{{}^{db}\!/_{mm} \ln(10)} \left\{ \frac{\pi}{2} - \tan^{-1} \frac{\cos\phi}{{}^{a}\!/_{b} - \sin\phi} - \tan^{-1} \frac{\cos\phi}{{}^{a}\!/_{b} + \sin\phi} \right\}$$

The High Energy Linac has 29 BPM's, requiring 58 pairs of matched cables. These 1/2" Heliax cables were phase matched with the same system that was used to phase match Tev, Booster, and P-Bar cables for their BPM systems. This system uses a HP 8405A Vector Voltmeter and a Fermi-Lab built module (The Red Box) that uses directional couplers and two frequency sources to measure the relative phase of the reflected signals through the cables to be matched. The lower frequency (6 Mhz) is used to rough cut and the higher frequency (53 Mhz) is used to cut to the final length. Technicians typically were able to match pairs to within +/- .2° or better at 53 Mhz which corresponds to the smallest cut one can make with a hacksaw. Due to this matching procedure that looks at reflected signals a 1° match on the Vector Voltmeter is a .5° match of the cables at 53 Mhz. On the other hand, a 1° error at 53 Mhz is a 4° error at 200 Mhz. The following charts show the effects of mismatched cables on the position output of the Beam Position Modules.

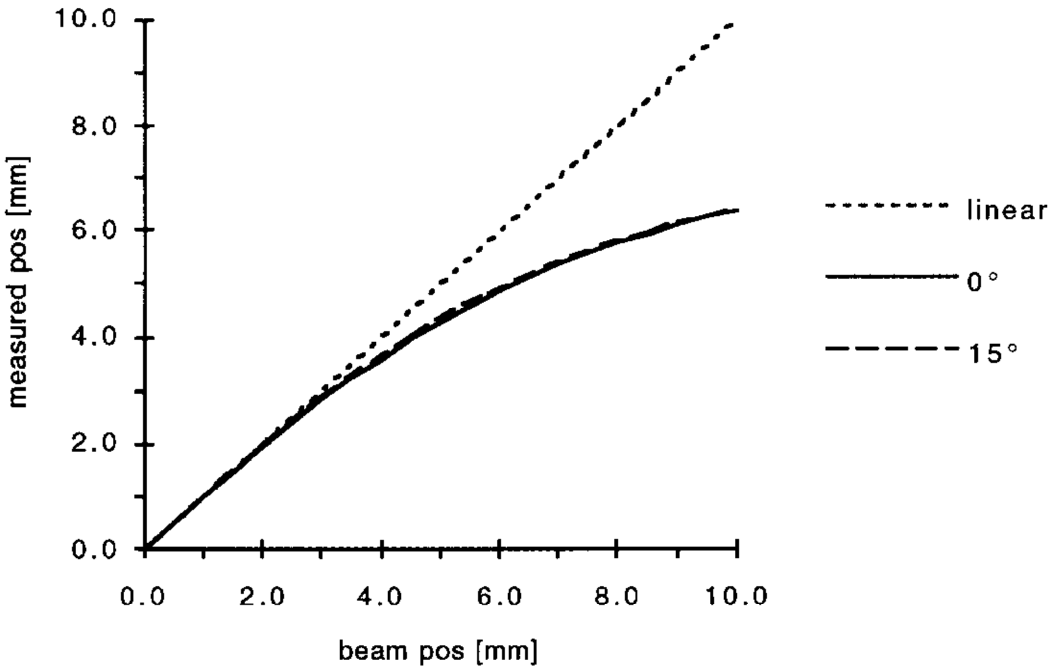

Figure 1 - Position output with cables that have 0° and 15° error.

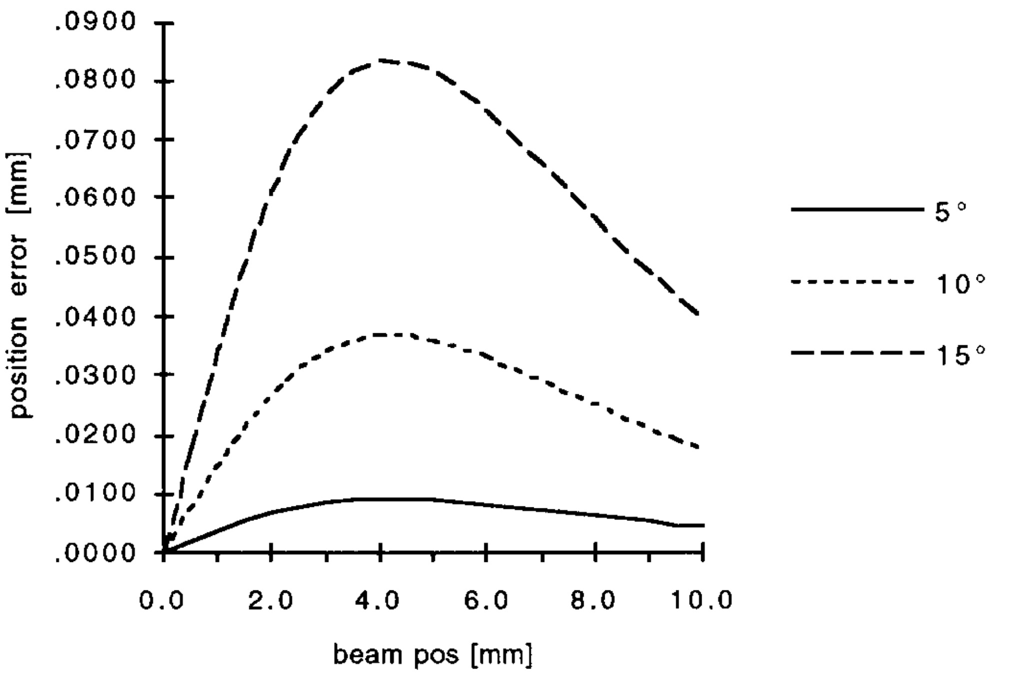

Figure 2 - Position error of 5°, 10°, and 15° mismatch of cables vs. expected beam position

Technicians checked selected cables that had been phase matched with this "Red Box" method using an HP model 8753B Network Analyzer for fo = 201.25 Mhz, Span 25 Mhz and confirmed that the cables were matched to within +/- .5° throughout that range. Given the accuracy and relative ease of the "Red Box" phase match method and the calculations of position error vs. expected position, this method of phase matching is entirely satisfactory. Attached is the Calibration and Phase Match Measurement Procedure.

Conclusion

The method of phase matching cables that has been used for previous beam position systems at Fermi-Lab that operate at lower frequencies is more than adequate for this system that processes signals at near 200 Mhz. Technicians typically can with this method phase match cables to within +/- .2° at 53 Mhz on the VVM which translates to approximately < +/- .5° at 200 Mhz. The calculations show that an 10° mismatch at 200 Mhz adds only a small position error of less than 1%.

Acknowledgments

I would like to thank Jim Crisp for the great help with calculations of phase errors and of the general understanding of these effects as they pertain to the Linac Beam Position system. I would also like to thank Elliott McCrory for his input, and the Linac technicians for their attention to detail required to complete this procedure.

CALIBRATION AND PHASE MATCH MEASUREMENT PROCEDURE

Jeff Arthur June 1993

EQUIPMENT

1. Hewlett Packard 8405A Vector Voltmeter
2. Fermi-Lab built "Red Box"

CALIBRATION

Calibrate the system by using the following procedure:

1. Short Red Box ports with shorting caps.
2. Switch Red Box frequency to 53Mhz.
3. Switch the VVM Frequency Range Switch to the correct range, so that the APC light goes out. (APC LOCKED).
4. Phase Meter Sensitivity to +/- 6 Range.
5. Meter Offset to +180 Deg.
6. Vector Voltmeter probes to the correct ports on the Red Box.
7. Zero Phase Meter with Zero Adjust on Vector Voltmeter.

MEASUREMENT AND MATCHING PROCEDURE

1. Check Cables to be Phase Matched for Shorts.
2. Connect Cables to be Phase Matched to Red Box.
3. Set Red Box frequency to 6 Mhz.
4. Switch the VVM Frequency Range Switch to the correct range, so that the APC light goes out. (APC LOCKED).
5. Measure Phase difference. *NOTE: BE CAREFUL WHEN CHANGING THE PHASE RANGE ON THE VVM. BE CERTAIN NOT TO CHANGE THE ZERO ADJUSTMENT.*
6. Cut appropriate cable to within +/- 4 Deg. at 6 Mhz.
   IF B LAGS - CUT B *IF B LEADS - CUT A*
7. Set Red Box frequency to 53 Mhz.
8. Switch the VVM Frequency Range Switch to the correct range, so that the APC light goes out. (APC LOCKED).
9. Measure Phase difference. *NOTE.: USE +/- 6 RANGE FOR FINAL CUT.*
10. Cut appropriate cable to within +/- .2 Deg. at 53 Mhz.
    IF B LAGS - CUT B *IF B LEADS - CUT A*

NOTE : CALIBRATION PROCEDURE SHOULD BE DONE FREQUENTLY TO ASSURE VALID MEASUREMENTS.