DC Current Transformer (DCCT)

Calibration Talk
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Introduction

• Beam monitors are designed to sense the electric field, magnetic field, or some combination.
• Beam current monitors are generally devices that interact with the beam’s magnetic field to measure beam current, charge, and/or pulse shape.
• Beam current monitors are based on transformer circuit theory.
Basics of Classical Transformer

- Current in any $N$ turn winding $k$ produces a magnetic flux in the core.
- The voltage appearing across each winding is proportional to the time rate change of the total flux.
- In the beam current model, the voltage generator is replaced by a current generator.
- For $R_{\text{beam}} \gg R_s$, the secondary current is very close to $1/N_s$ times the beam current.

\[ \Phi = \Phi_T = \frac{L_p \cdot i_p}{N_p} - \frac{L_s \cdot i_s}{N_s} \]
\[ i_s = \frac{s \cdot \Phi_T \cdot N_s}{R_e} \]
\[ V_g = i_p \cdot R_g + s \cdot \Phi_T \cdot N_p \]
DCCT Intensity Monitor System

- The pickup consists of 2 sets of cores, which are excited in opposite senses with the beam signal acting as the primary turn.
- Placing these toroidal transformers in the feedback loop creates an active current transformer, extending the system’s useful bandwidth.
- Any magnetic flux change in the active beam transformer core is handled with the addition of a magnetic modulator and control loop.
  - A particle beam in the aperture of the toroids will introduce asymmetry and give an output of even harmonics at the modulation frequency. The 2\textsuperscript{nd} harmonic component of the output signal is proportional to the primary current and its phase is determined by the direction of the beam.
  - A synchronous demodulator detects this 2\textsuperscript{nd} harmonic signal synchronous with input.
  - Using that signal in a closed feedback loop, a feedback current is produced to null out the magnetic imbalance – maintaining 0-average flux.
  - A stable, precision resistor in the feedback path yields a voltage output.
DCCT Output Signals

- DCCT Receiver has 3 different buffered outputs to provide more useful scaling: The “S” is for small intensities, “M” for medium, and “B” for big.
- The “B” output is simply a buffered output of the signal received.
- “M” output has amplification and a low-pass filter. (e.g. 500 Hz anti-aliasing LP Filter for MI DCCT).
- “S” output has additional notch filtering to remove parasitic resonant 1st and 3rd harmonic frequency components (e.g. 200 Hz & 600Hz Filter for MI DCCT). It also has gain.
- “B” is used to provide inputs to digitizing front-end. As a result, an intermediate filter module is used to mimic filtering schemes in “M” and “S”. This allows the digitizing front-end to keep similar responses the old MADC readings over the full range of beam intensities.
MI DCCT Calibration Test Setup

- Current source is typically a precision voltage supply.
- Known DC currents are sent through calibration winding of detector.
- Test currents are determined by measuring voltage drop across calibration resistor as current source is stepped from 0 to full-scale.
- ACNET readings are compared to calculated intensities for a given current range under test.
- Calibration setups for other DCCTs (e.g. RR, TEV, PBAR) are similar.
### Example of DCCT Calibration Calculations

**Electron Charge** = 1.60E-19  
**RF Frequency (8GeV/150GeV)** = 52958000  
**Burden Resistor (Ohms)** = 10.12

<table>
<thead>
<tr>
<th>VIN</th>
<th>Amps</th>
<th>Watts</th>
<th>Calculated</th>
<th>ACNET Measured</th>
<th>Voltage Reading</th>
<th>LSF CORRECTED (E12)</th>
<th>Errors With Correction</th>
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<tbody>
<tr>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.142</td>
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<td>-0.047</td>
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<td>0.832</td>
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<td>0.068</td>
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<td>1.537</td>
<td>0.152</td>
<td>0.233</td>
<td>10.522</td>
<td>9.490</td>
<td>2.536</td>
<td>10.534</td>
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<td>2.167</td>
<td>0.214</td>
<td>0.464</td>
<td>14.841</td>
<td>13.360</td>
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<td>2.873</td>
<td>0.284</td>
<td>0.816</td>
<td>19.675</td>
<td>17.610</td>
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<tr>
<td>3.547</td>
<td>0.350</td>
<td>1.243</td>
<td>24.269</td>
<td>21.670</td>
<td>5.793</td>
<td>24.320</td>
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<td>4.275</td>
<td>0.422</td>
<td>1.806</td>
<td>29.275</td>
<td>26.040</td>
<td>6.961</td>
<td>29.266</td>
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<td>5.003</td>
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<td>2.473</td>
<td>34.261</td>
<td>30.390</td>
<td>8.124</td>
<td>34.189</td>
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**Gain**

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<th>Offset</th>
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<tr>
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<tr>
<td>Old</td>
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<td>0.006</td>
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<tr>
<td>New</td>
<td>4.233041629</td>
<td>-0.200441224</td>
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**I:BEAM**

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<tr>
<td>Δ in Gain</td>
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<tr>
<td>Δ in Offset</td>
<td>-0.21</td>
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