

Linac, LTP, PTB and BTS Beam Position Monitors Cross Training

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Characteristics of BPM systems

- **Resolution - Ability to measure small displacements of the beam position (Affected by signal to noise, aperture size, sensitivity, A/D Quantization, EMI)**
- **Accuracy - Ability to resolve absolute beam position in vacuum chamber (Affected by mechanical alignment, tolerances in detector, cable offsets or reflections, electronics calibration and drift)**

Characteristics of BPM systems

- **Dynamic Range - Beam current range where useful position information can be obtained (Affected by LOG and Limiter errors, Operating offset)**
- **Bandwidth - Frequency range over which beam position can be measured (Affected by IF filtering LOG/Limiter response time)**

Linac Specification

Parameter	PC GUN	RF GUN
Dynamic range	0.1 – 2 nC	0.1 – 10 nC
S.S. resolution	15 μm rms	100 μm rms
Drift	15 μm rms	100 μm rms
Bunch length	< 5 ps	< 5 ps
Macropulse length	1 S-band bunch	2 - 20 ns
Position range	± 5 mm	± 5 mm



BPM Description Overview

- **13 Linac BPMs with 34 mm S-band stripline detectors, LOG ratio processing topology @ 2856 MHz IF frequency 3 MHz bandwidth**
- **4 Bunch Compressor BPMs with 34 mm S-band stripline detectors, new AM/PM processing topology @ 350 MHz IF frequency 3.5 MHz bandwidth**
- **8 LTP single plane BPMs with 4 blade combine for single plane detection, plan to upgrade 12/04 to LOG ratio processing topology @ 2856 MHz IF frequency 3 MHz bandwidth**



BPM Description Overview

- **8 Booster and PAR Bypass BPMs with 34 mm S-band stripline detectors, LOG ratio processing topology @ 2856 MHz IF frequency 3 MHz bandwidth**
- **9 PTB single plane BPMs with 70 mm stripline detectors , LOG ratio processing topology @ 350 MHz IF frequency 3 MHz bandwidth and 1 spare plane. 2 Direct injection BPMs with 34 mm S-band stripline detectors, LOG ratio processing topology @ 2856 MHz IF frequency 3 MHz bandwidth**
- **15 BTS single plane BPMs with 50 mm stripline detectors, LOG ratio processing topology @ 350 MHz IF frequency 3 MHz bandwidth and 1 spare plane**

Injector BPM Design Features

- **Universal BPM design**
- **Measures S-band position signals without the use of a down converter**
- **Provides both horizontal and vertical position information for each pass**
- **High resolution and dynamic range**
- **Built in test capabilities**
- **Simple low cost design with improved MTBF**
- **Designed to be upgraded as higher performance LOG Amplifiers become available**

34 mm shorted quarter-wave stripline BPM

- **Stripline electrode**

$$V_s(t) = \phi L / 2\pi C * I_b(t) / \beta c - V_o$$

ϕ **Stripline width**

L **Stripline length**

C **Stripline capacitance**

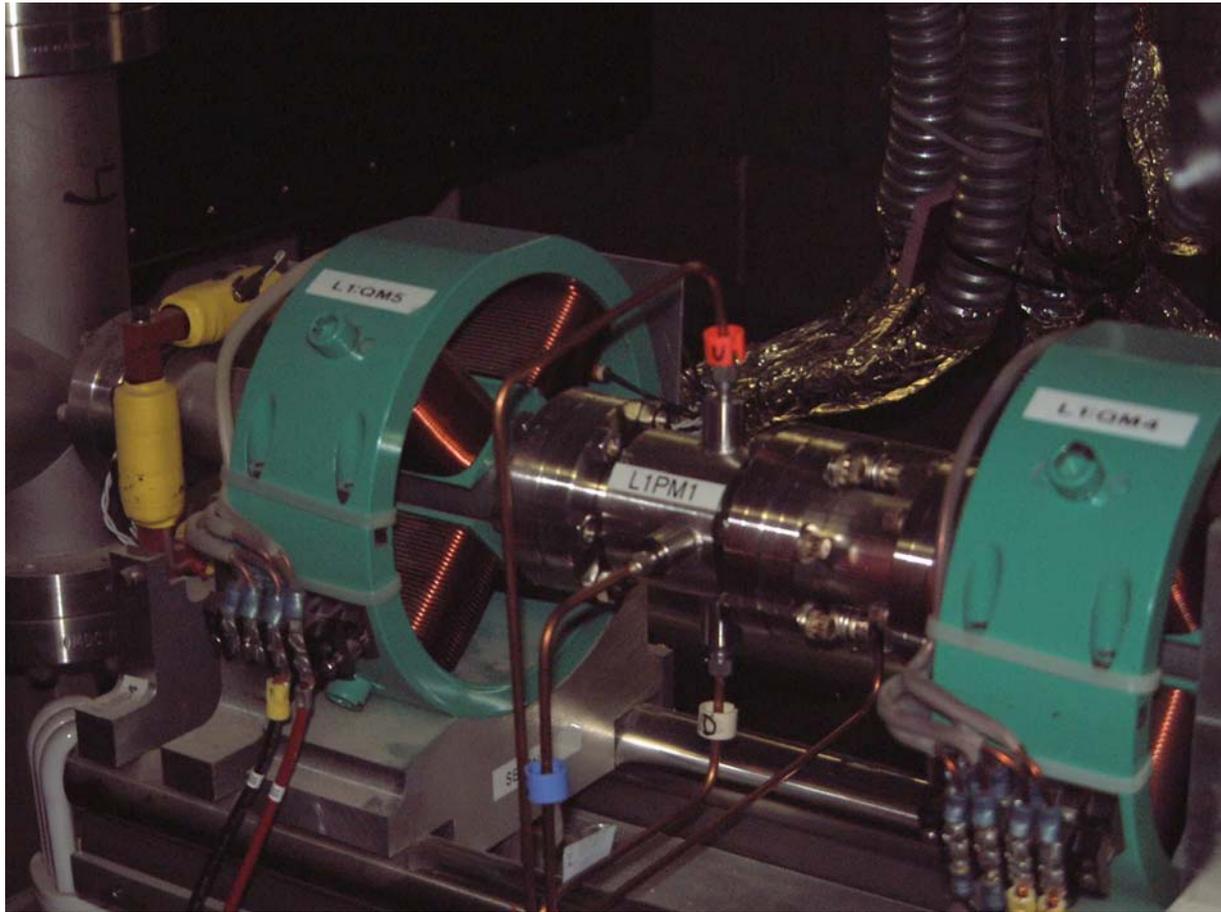
βc **Beam velocity**

V_o **Constant of integration**

$I_b(t)$ **Beam Current**

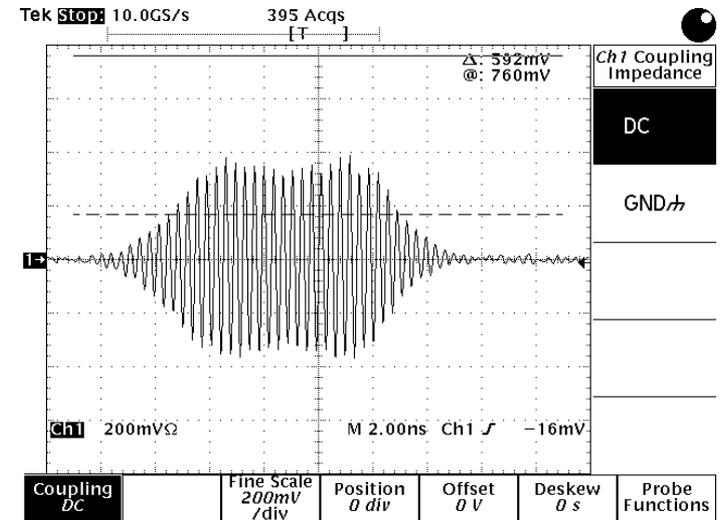


Linac Stripline L1P1

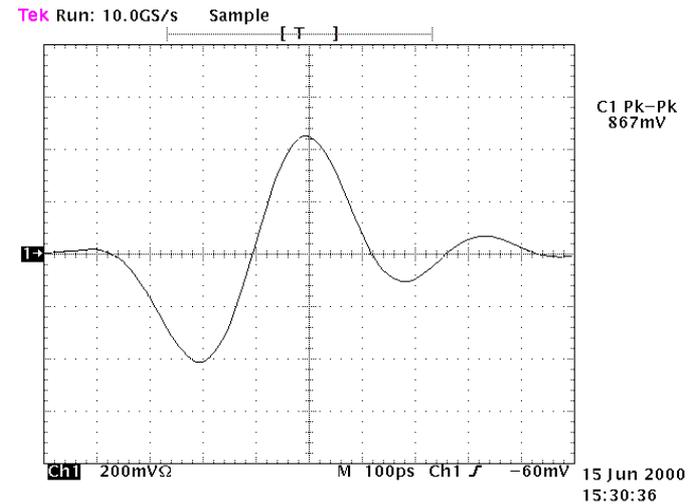


34 mm stripline BPM Response

- Stripline BPM response to RF 2



- Stripline BPM response to Photo Cathode PC gun



Waveguide Bandpass Filter Installations

- Linac L2 installation

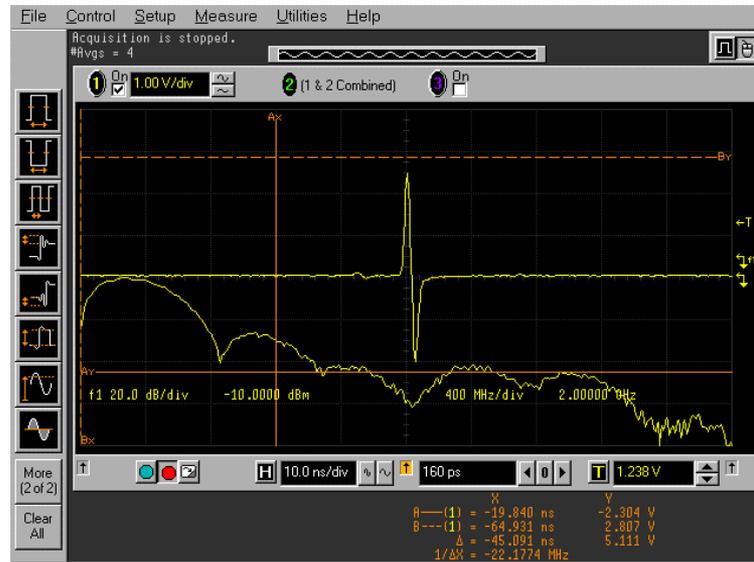


- PTB direct injection installation



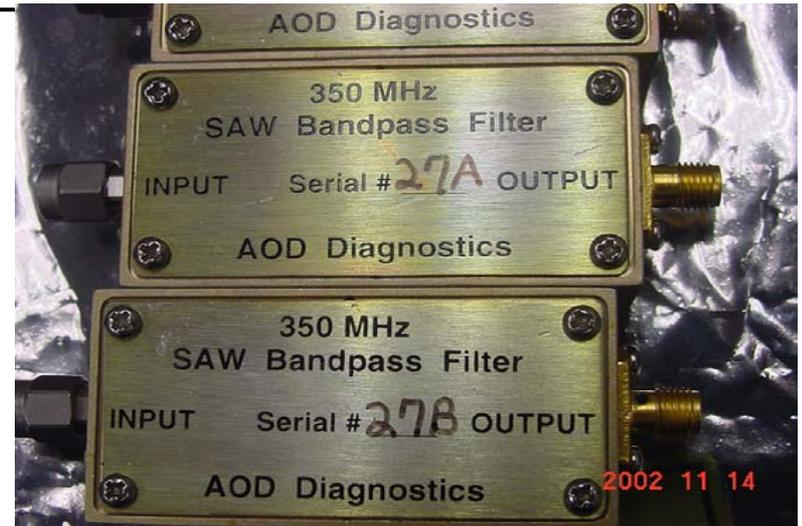
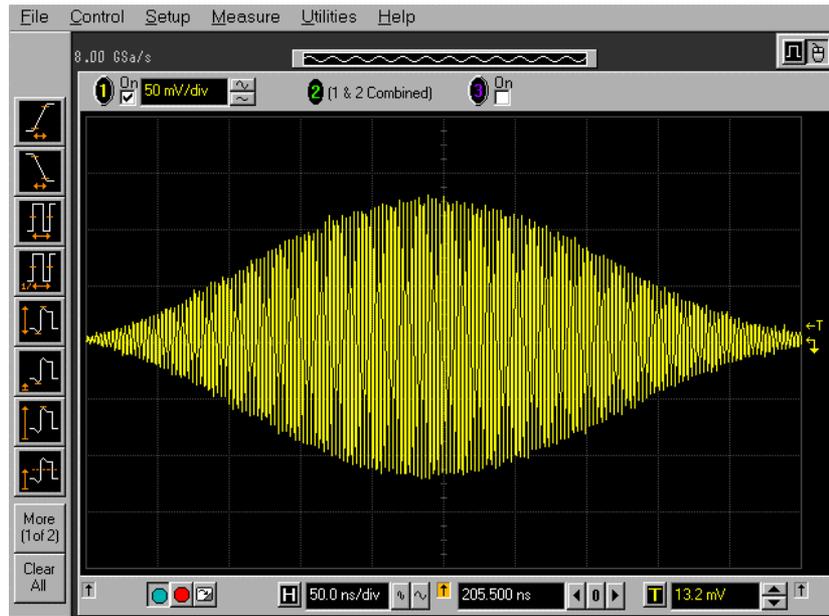
PTB 350 MHz, 70 mm shorted quarter-wave stripline BPM

- PTB stripline time and frequency response

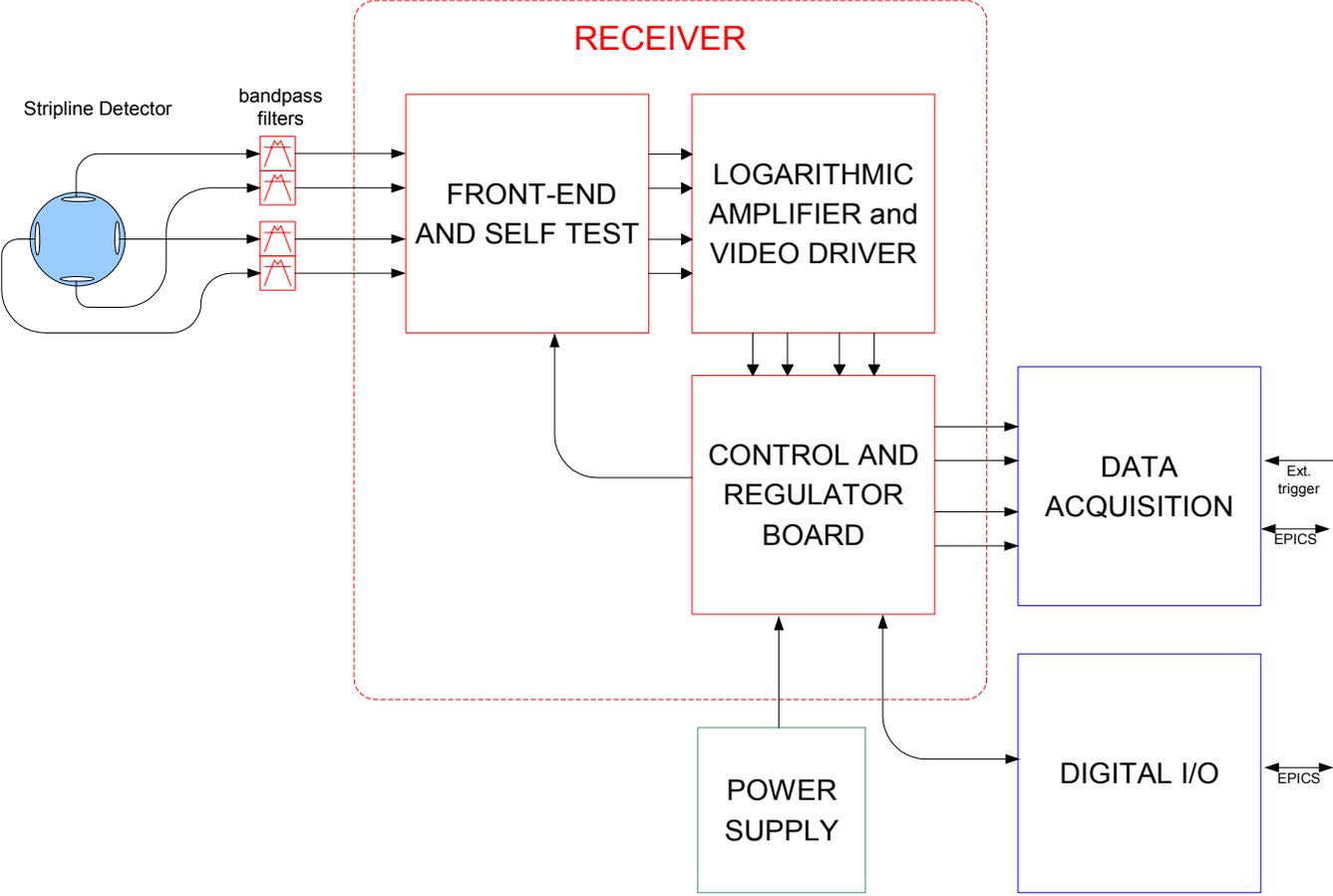


350 MHz Surface Acoustic Wave (SAW) 3 MHz –3 dB bandwidth filters

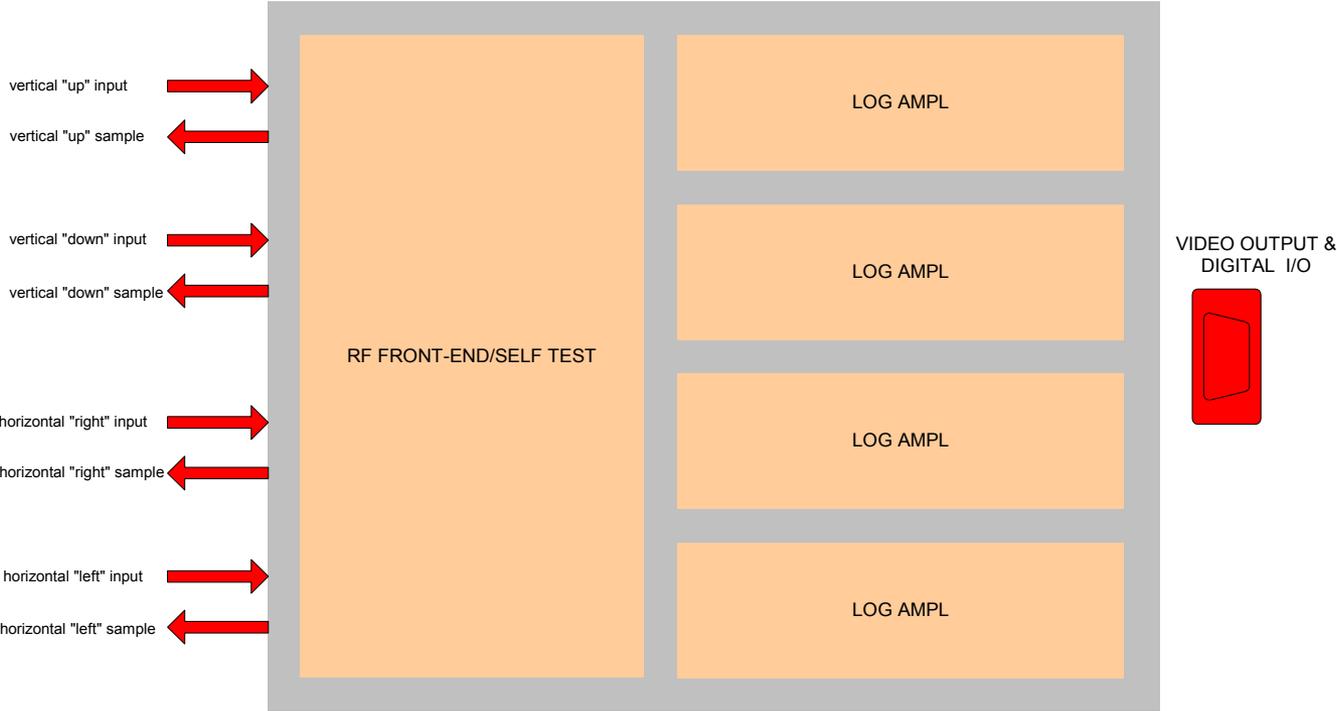
- RFM standard part (\$7)
SF1073A
- Matched filter sets
- Build and tested over 100 filters



Injector BPM Block Diagram



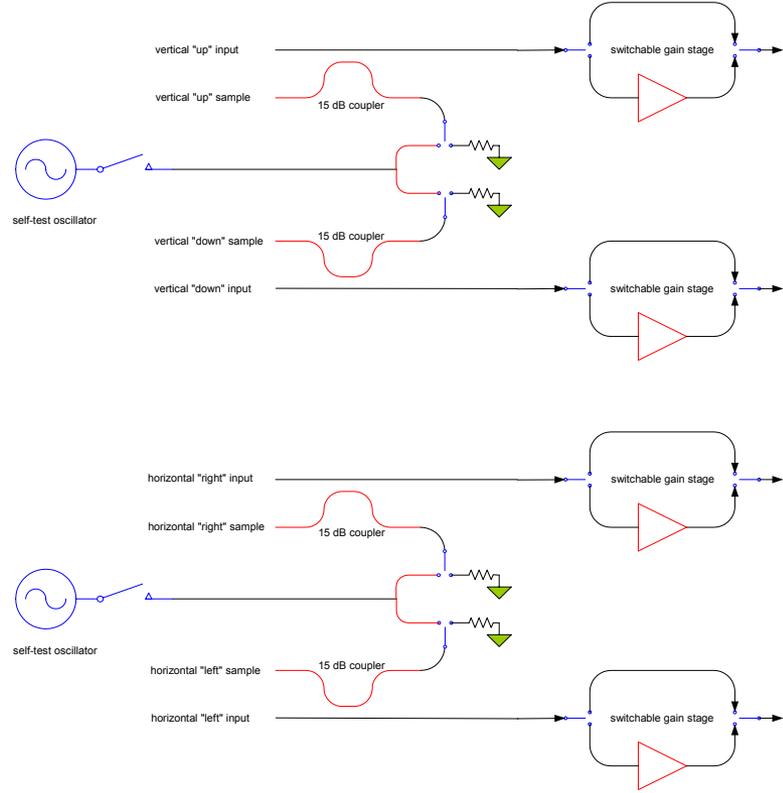
Receiver Design



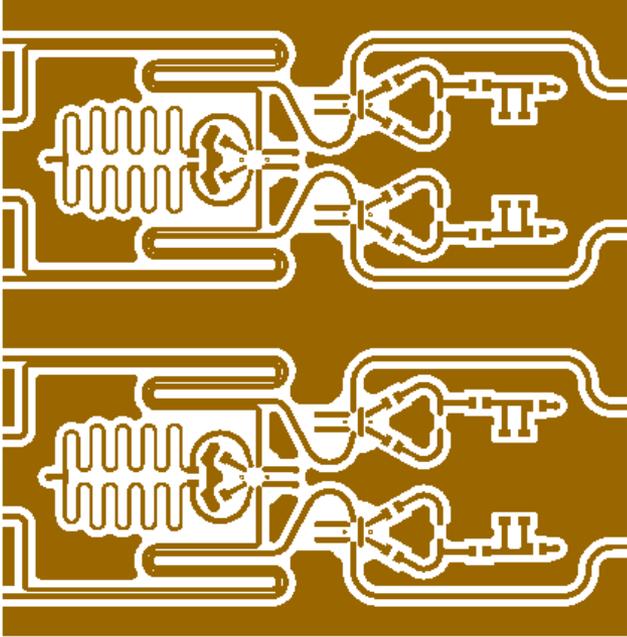
In-house receiver housing machining



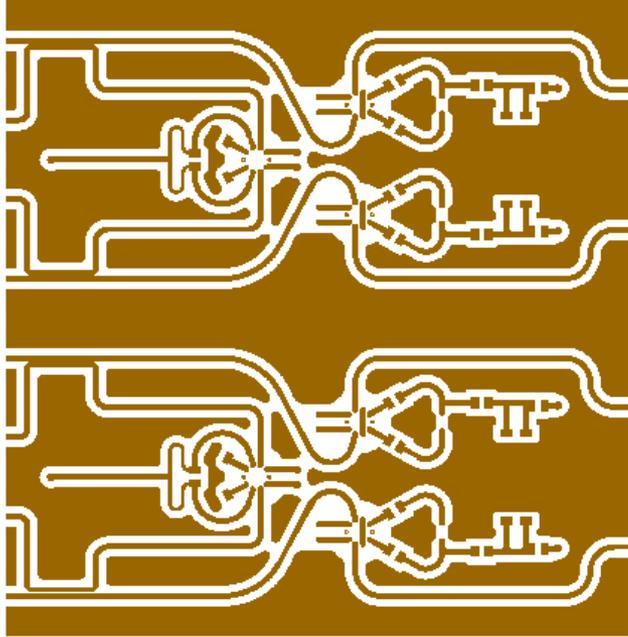
RF Board Block Diagram



RF Board on Roger's 3006 25 mil core, Dk 6.15



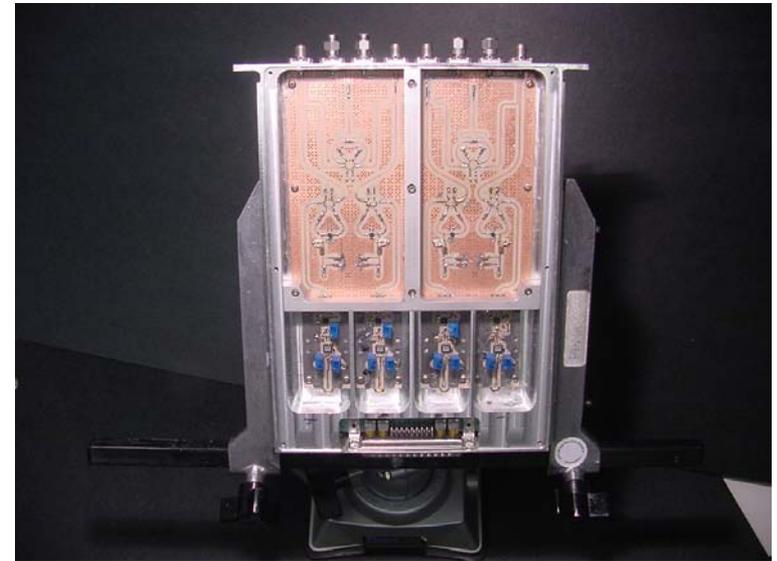
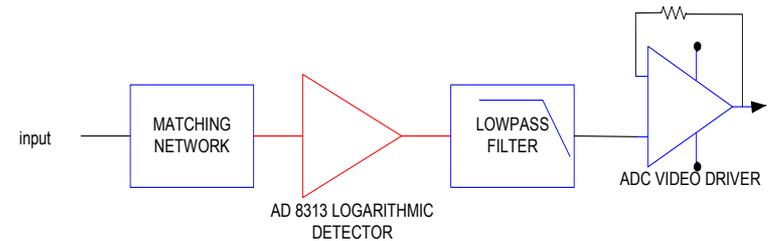
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31-002856

Receiver Design Features

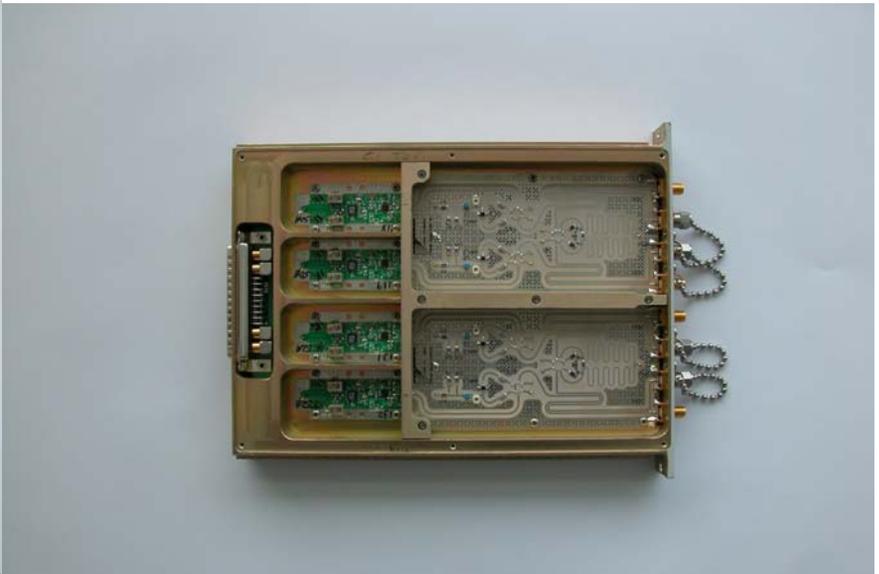
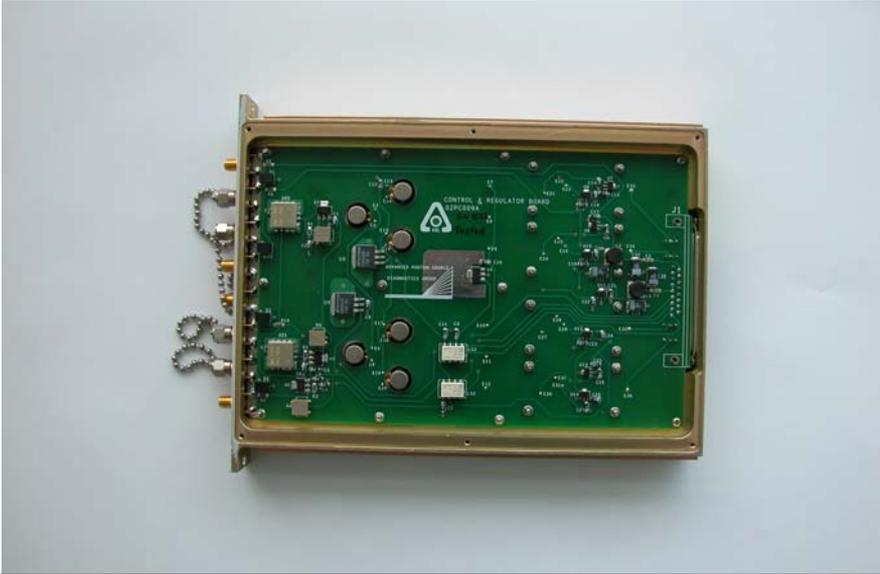
- **The AD8313 RF logarithmic detector**
- **Capable of accurately converting a modulated RF signal to an equivalent decibel-scaled value at its dc output**
- **The dynamic range is up to 70 dB with ± 3 dB accuracy, or 62 dB to ± 1 dB**



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Receiver Design



Calibration Factors

- The stripline sensitivity and system calibration factor can be calculated by the following equations

$$S \approx \frac{80}{\ln(10)} \times \frac{1}{b} \quad X(mm) \approx \frac{1}{S \times G_{system}} \times V_{out}$$

Where S = Stripline Sensitivity (dB/mm) and b = Half Aperture (mm)

X(mm) = Normalized Position (mm)

S= System Gain, which is set to 33mV/dB

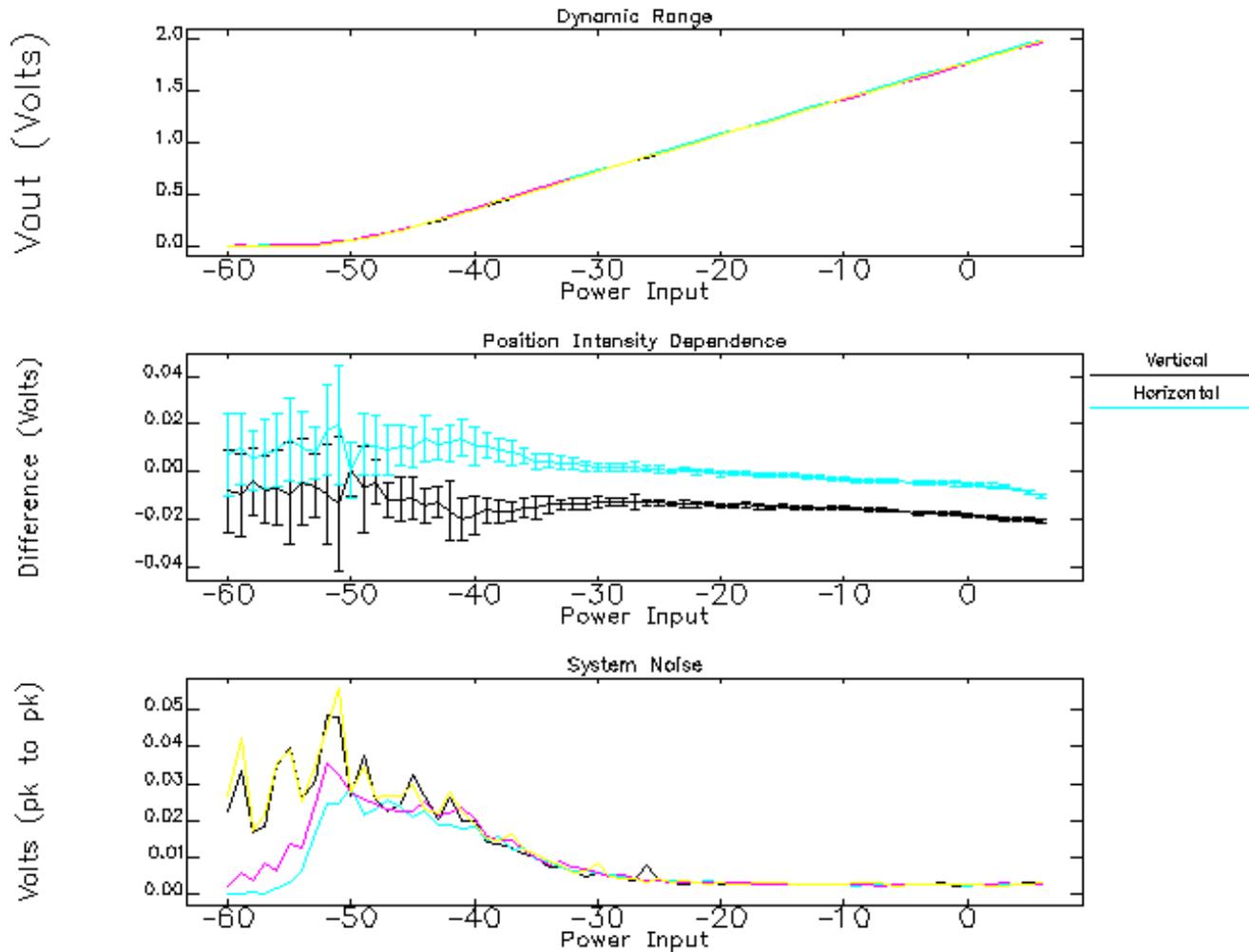
Vout= Log Amplifier Module Output (mV)

Log-Ratio BPM

$$Np = [(\log(A) - \log(B))] = \log(A / B) = \tanh^{-1} \left[\frac{(A - B)}{(A + B)} \right]$$
$$\approx 2 \frac{A - B}{A + B}$$

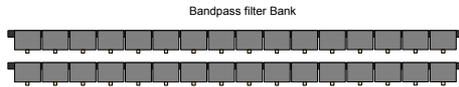
Where Np is the normalized Position and A and B are the induced voltages on the stripline pick-up.

Typical Performance Data



L2 Linac Gallery BPMs

LINAC BPM UPGRADE L2 AREA CABINET ELEVATION

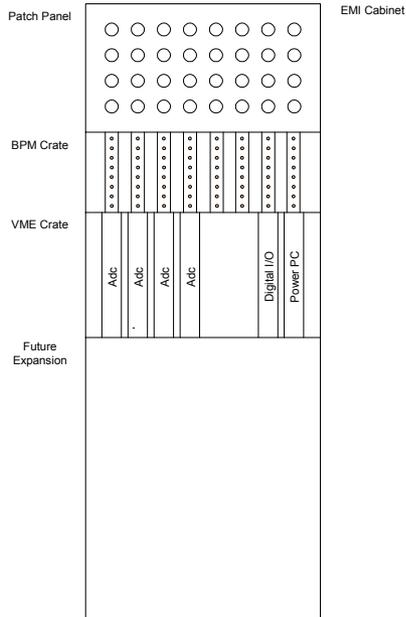


L2 Area

- L1:PG1
- L1:PM0
- L1:PM1
- L1:PM2
- L2:PM1
- L2:PM2
- L2:PM3

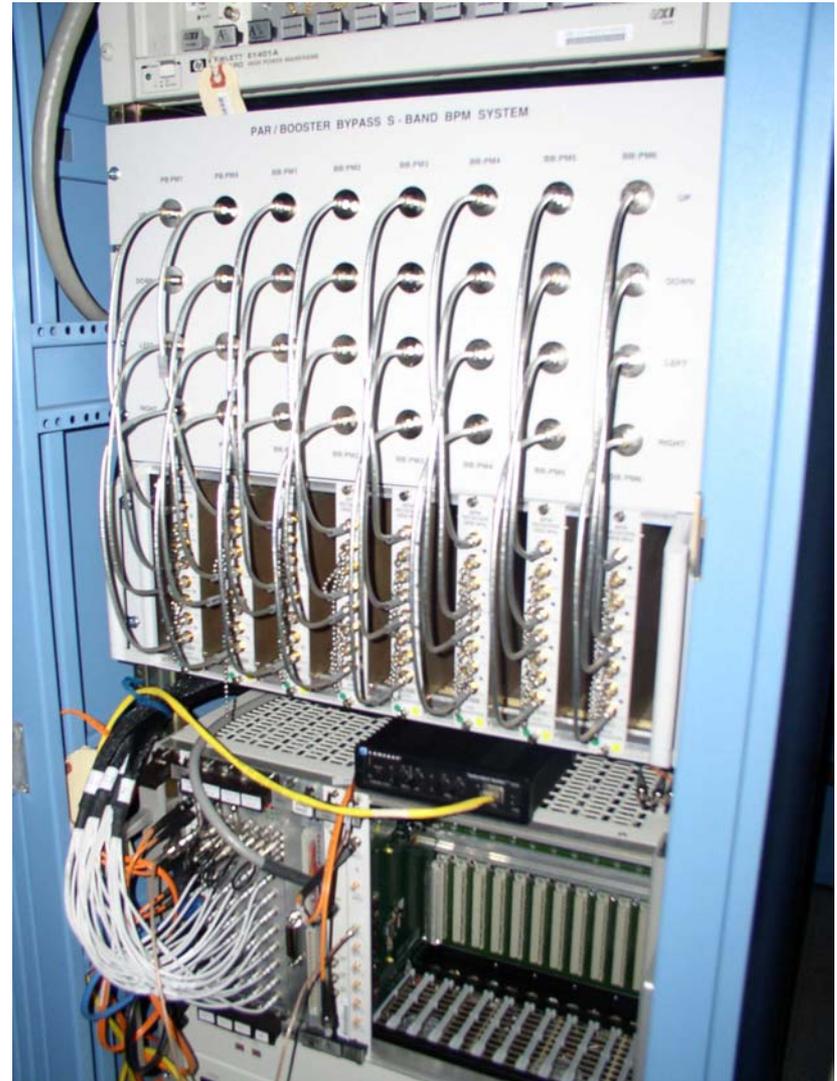
**Phase Detection
Kylstron
1&2**

- L1:PD1
- L2:PD1



Booster and PAR Bypass Installation

- **Installed in room B102 cabinet # 10**
- **8-2856 MHz dual plane position operational.**



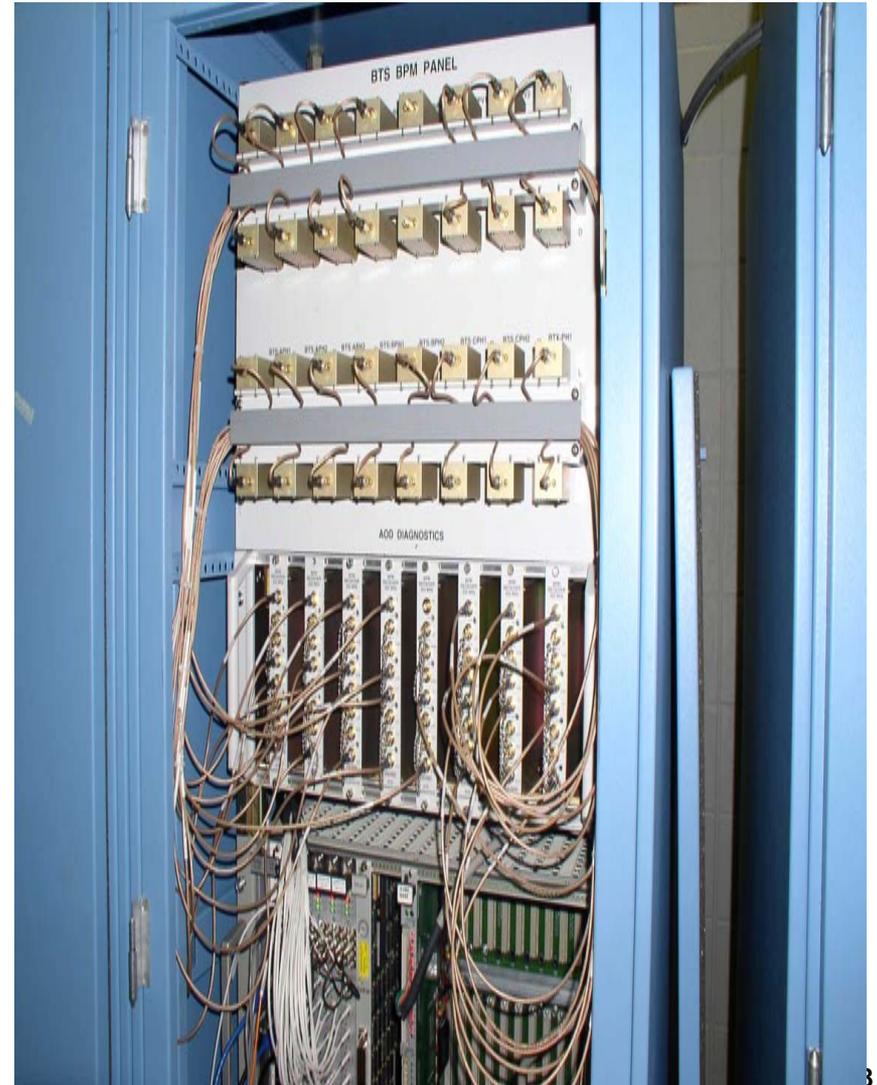
PTB Installation

- **Installed in room B107 cabinet # 4**
- **10-350 MHz single plane position operational and 1 spare.**
- **2-2856 MHz dual plane operation and 1 presently being added.**



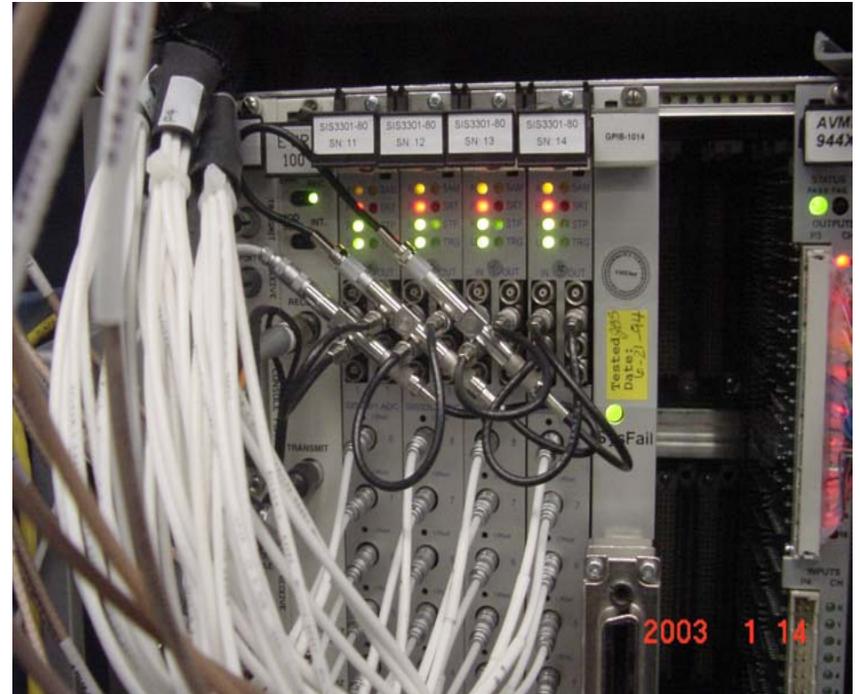
BTS Installation

- **Installed in room A013 cabinet #13**
- **15 single plane position operational and 1 spare.**

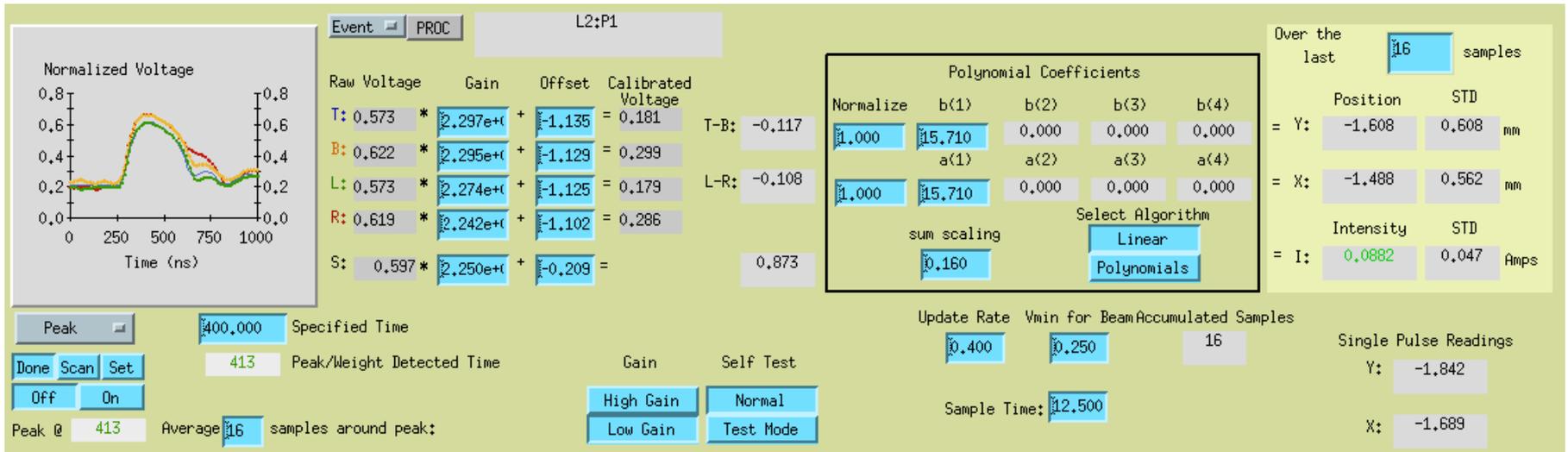


Struck 3301-80 ADC

- 8 channels (2 BPMs) per VME card
- 80 MSPS (12.5 ns interval) based on AD 6645 ADC
- 14 BIT resolution
- 40 MHz analog BW



MEDM Screen



Spare Parts

- **Spare Receivers, Boards, Components**
- **Stored in AOD-DIA cabinet # 14**