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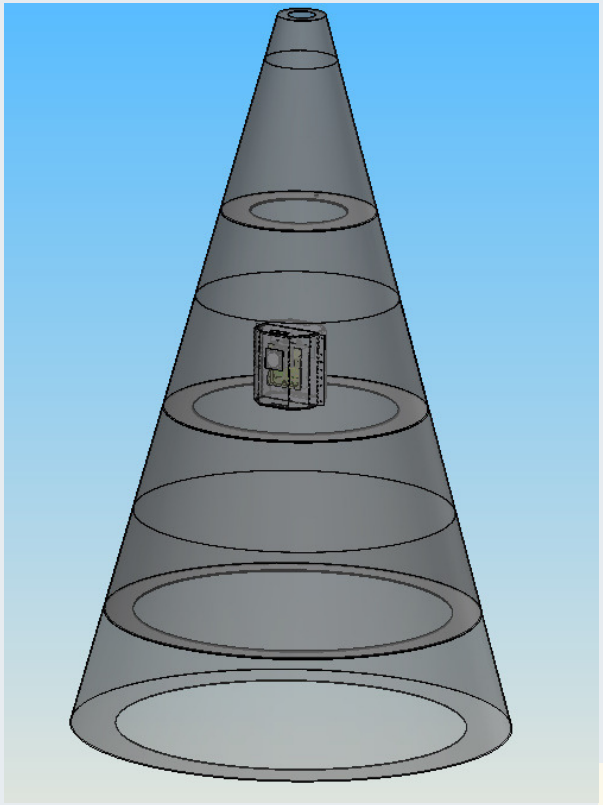
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

Curtin University



BIGHORNS Radiometric Receiver

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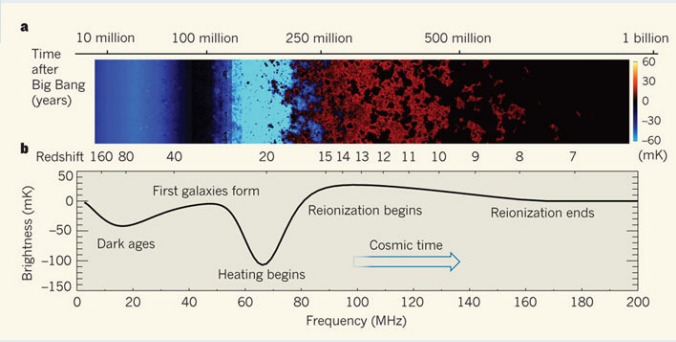
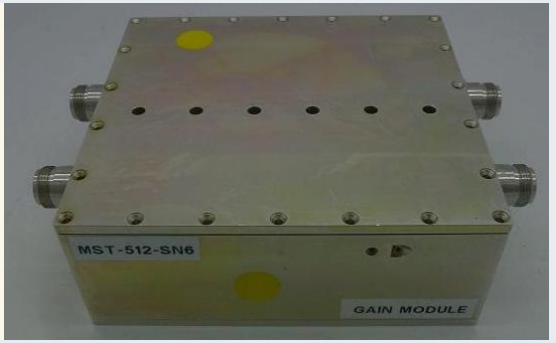
Curtin / CAASTRO

EoR Global Signal Workshop
19-21 Nov 2012

ICRAR
International Centre for Radio Astronomy Research





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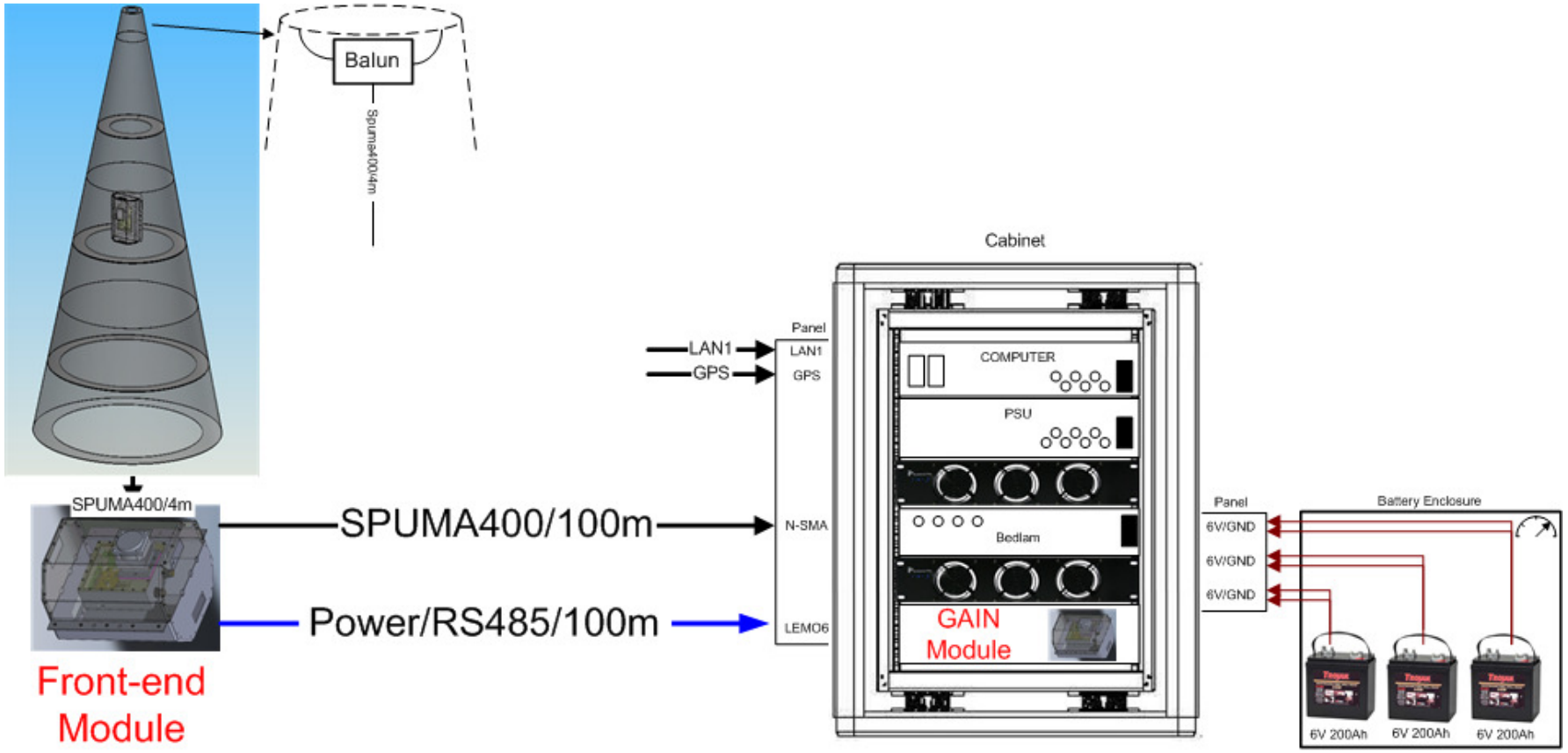
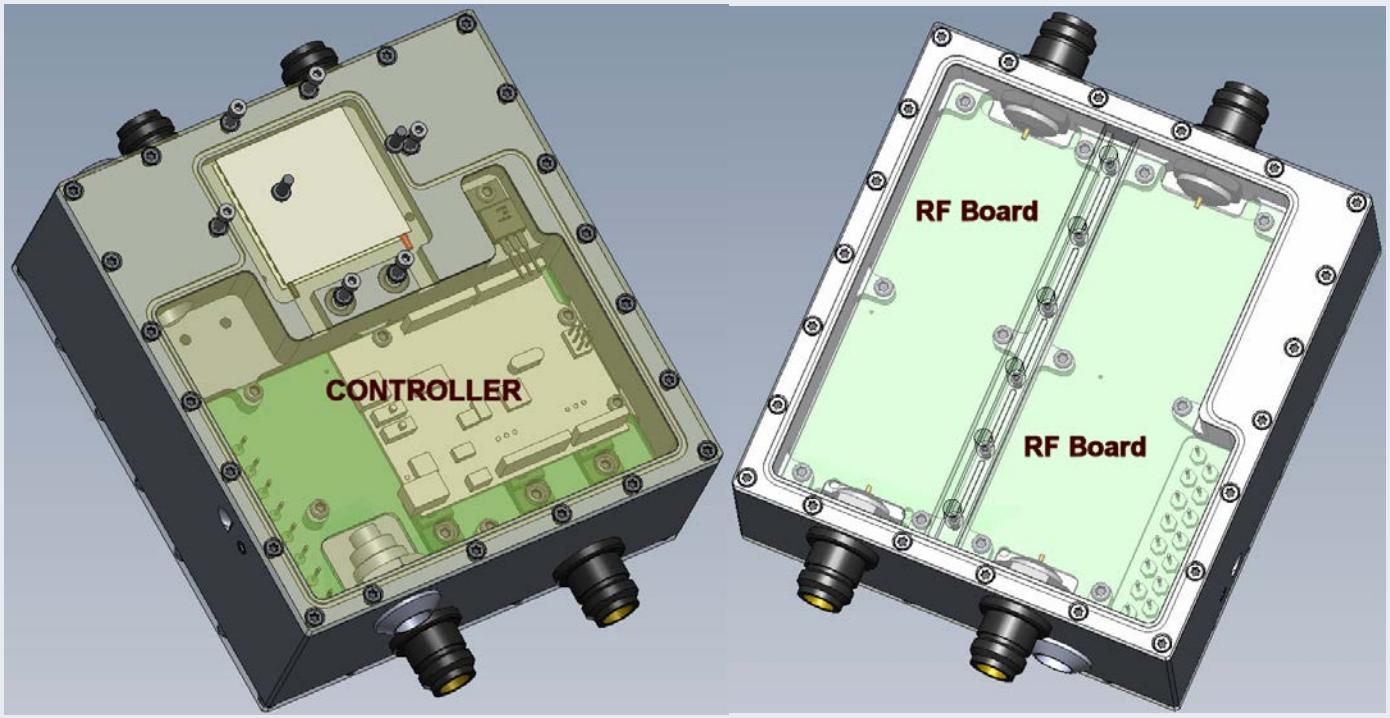
BIGHORNS Field Layout



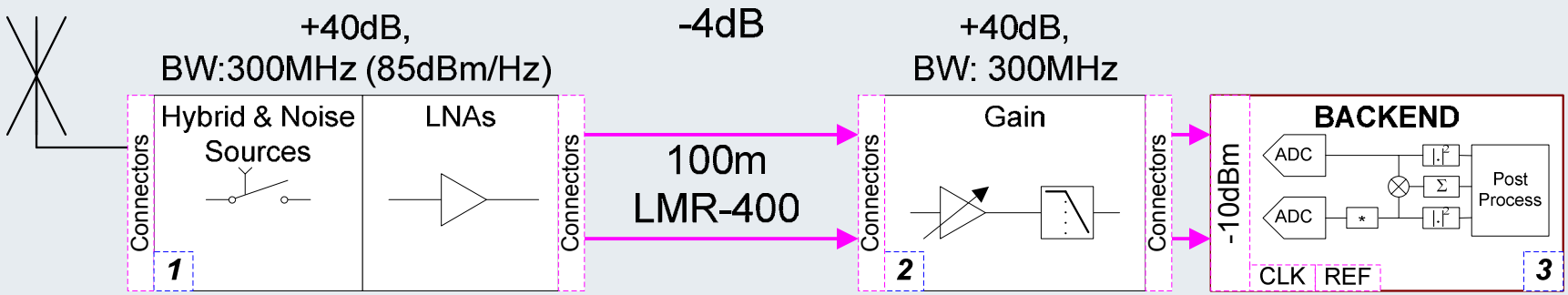
BIGHORNS Receiver

- The receiver consists of :
- 1) A Front End Module (RF & Controller PCBs)
- 2) At least a Gain Module (RF & Controller PCBs)
- separated by a 100m of SPUMA-400 cable for RF & a Beldon 2-pair double shielded cable for DC Power & RS485.



Receiver Noise Budget

- If the required input to 8-bit data acquisition is approx -10dBm.
- Assuming a min of 40dB gain in the Front-end & Gain Module
- 200-300MHz of bandwidth
- Low loss SPUMA RF Cable with return loss of >27dB (Γ<0.04)
- Then:
- Min detection would be ~ -171dBm/Hz
- And 2 to 3 dB of noise figure



- 171 dBm/Hz + 85dBm/Hz + 40dB - 4dB + 40dB = - 10dBm

Receiver Characteristics

- Frequency Range 50-250MHz (27<z<5)
- Noise Figure < 2.2dB (180±20K)
- RF & Controller PCB in a H-sec Al Enclosure
- RFI Tight & Hermetically Sealed Enclosure
- Temperature sensors on PCBs (Rref, NS)
- Humidity sensor on RF PCB
- Voltage and Current Monitors
- Temperature Compensation
- Can be Temperature Controlled
- Approx. 2kg
- Dimensions of 145x135x55mm

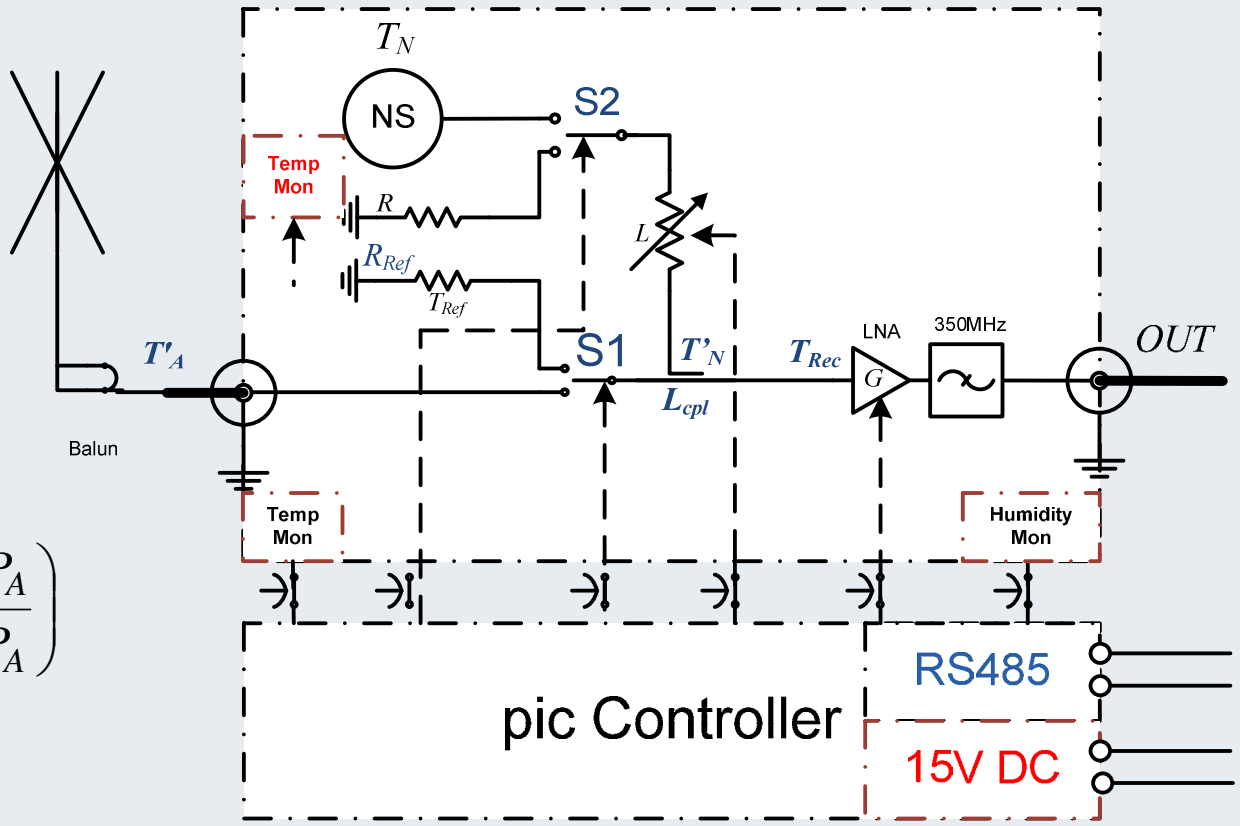
Front End Module

- Noise Adding Radiometer (S2)
- With an addition of a Comparison (Dicke) Switch (S1)
- Four switch positions:
  - $P_A = (T'_A + T_{Rec})\kappa BG$
  - $P_{AN} = (T'_A + T'_N + T_{Rec})\kappa BG$
  - $P_{Ref} = (T_{Ref} + T_{Rec})\kappa BG$
  - $P_{Cal} = (T_{Ref} + T'_N + T_{Rec})\kappa BG$
  - *Therefore:*

$$T'_A = T_{Ref} - C_{NIR}\frac{T_N}{L.L_{cpl}}$$

  - *Radiometer Observable:* $C_{NIR} = \left(\frac{P_{Ref} - P_A}{P_{AN} - P_A}\right)$
  - *And Gain*

$$G = \left(P_{Cal} - P_{Ref}\right)\frac{L.L_{cpl}}{kBT_N}$$



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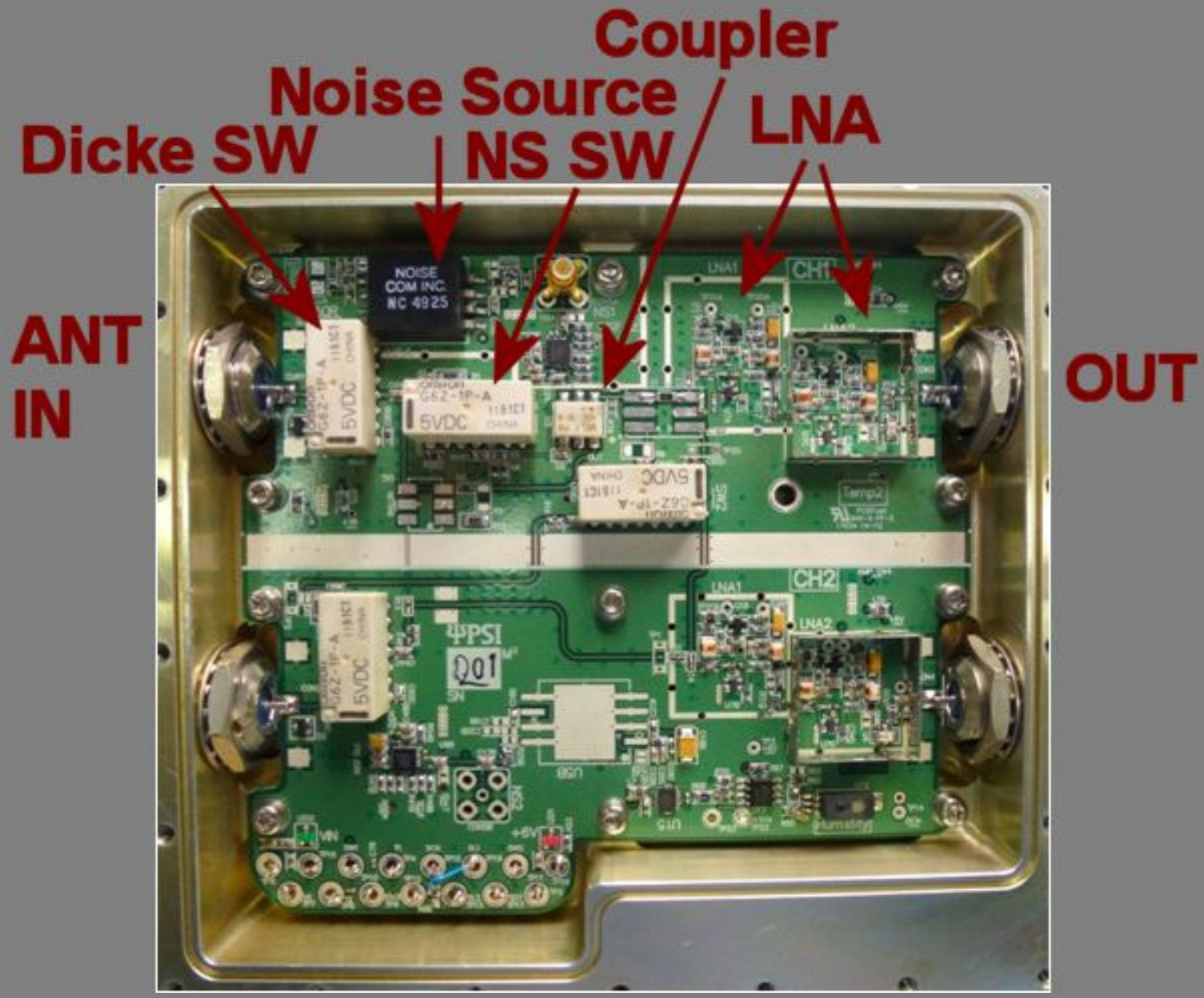
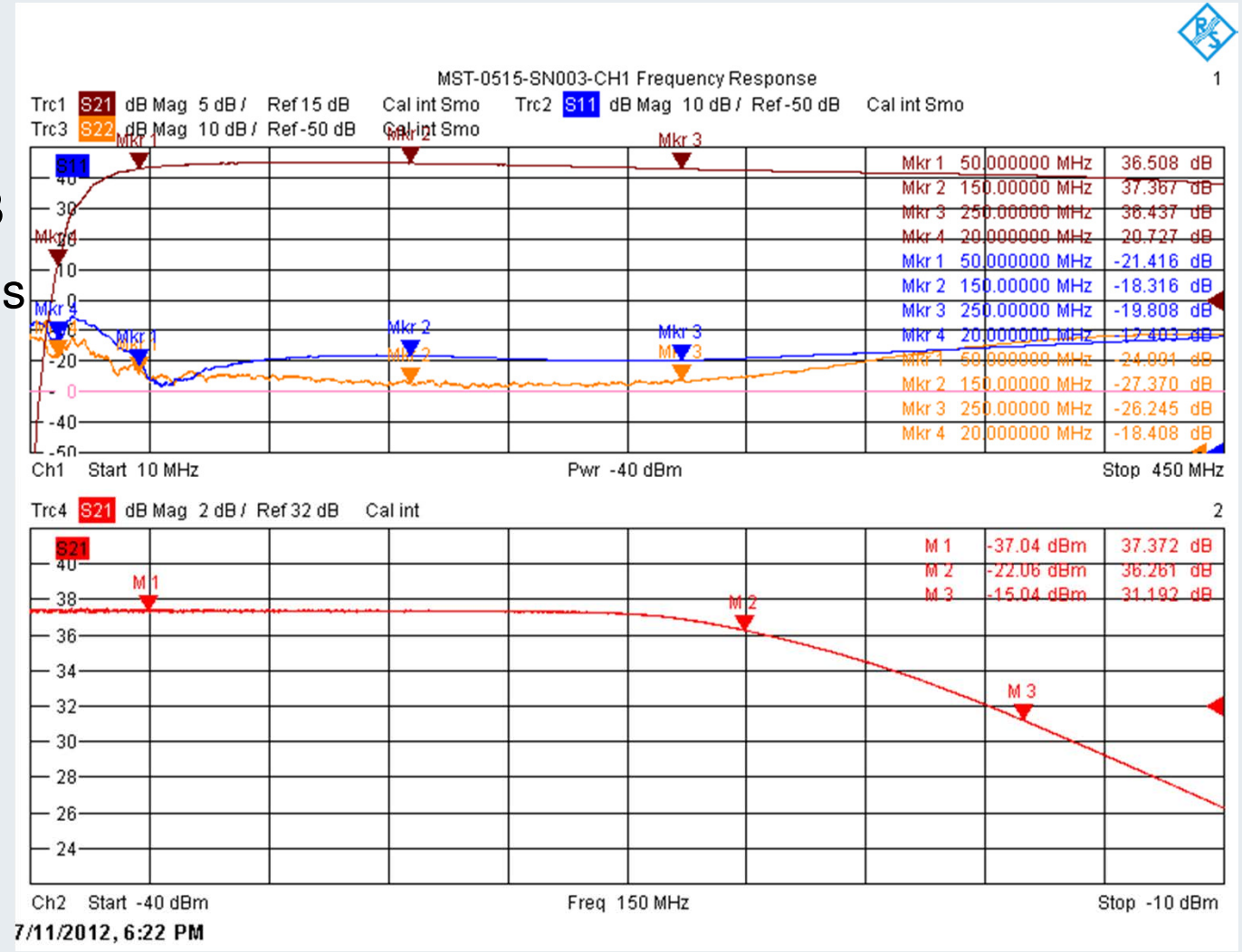
Front End Photo



Front End Gain/P1dB

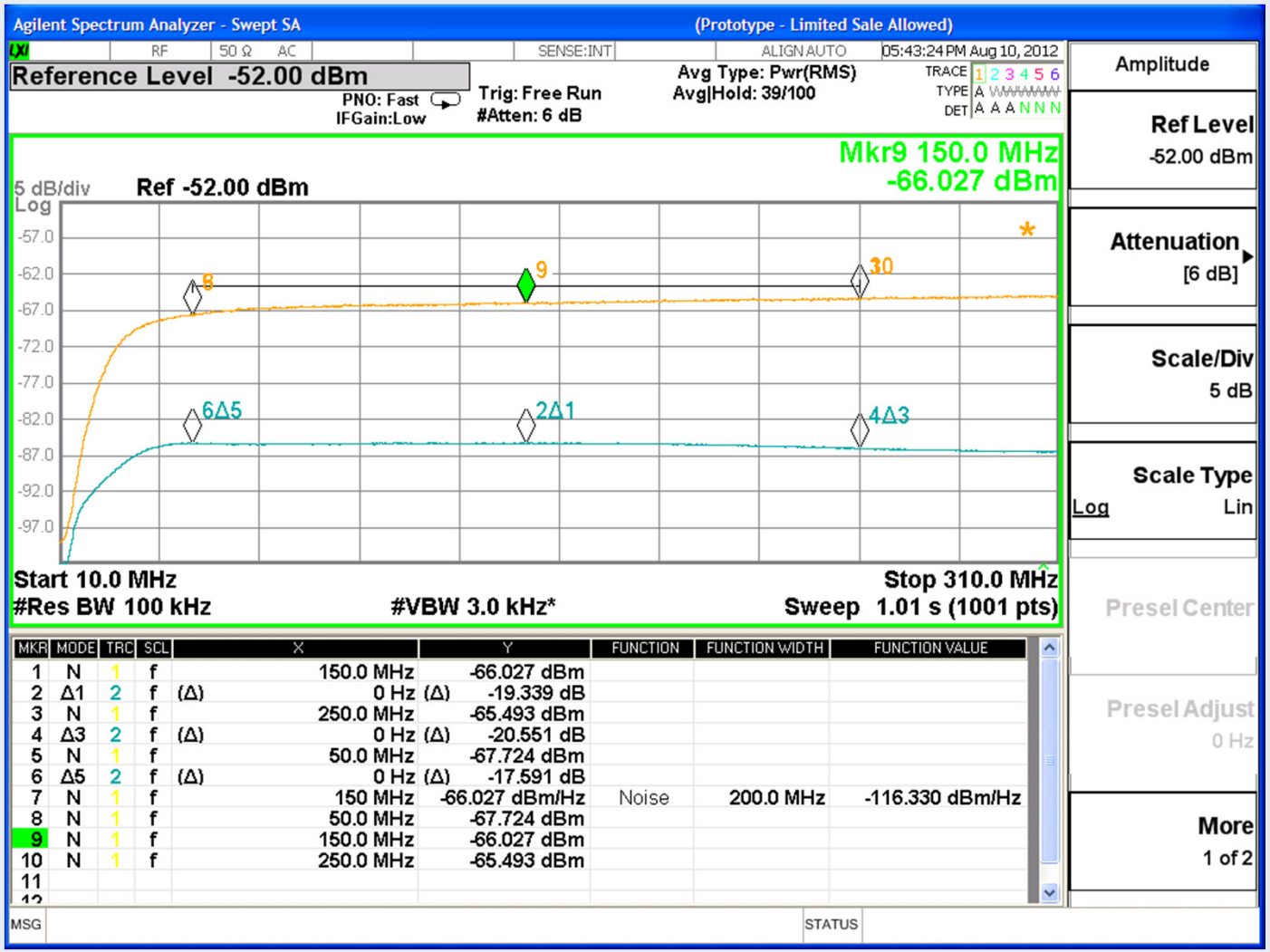
- 37dB Gain
- 1.2 VSWR
- 14dBm P1dB
- 0.5dB flatness



A figure

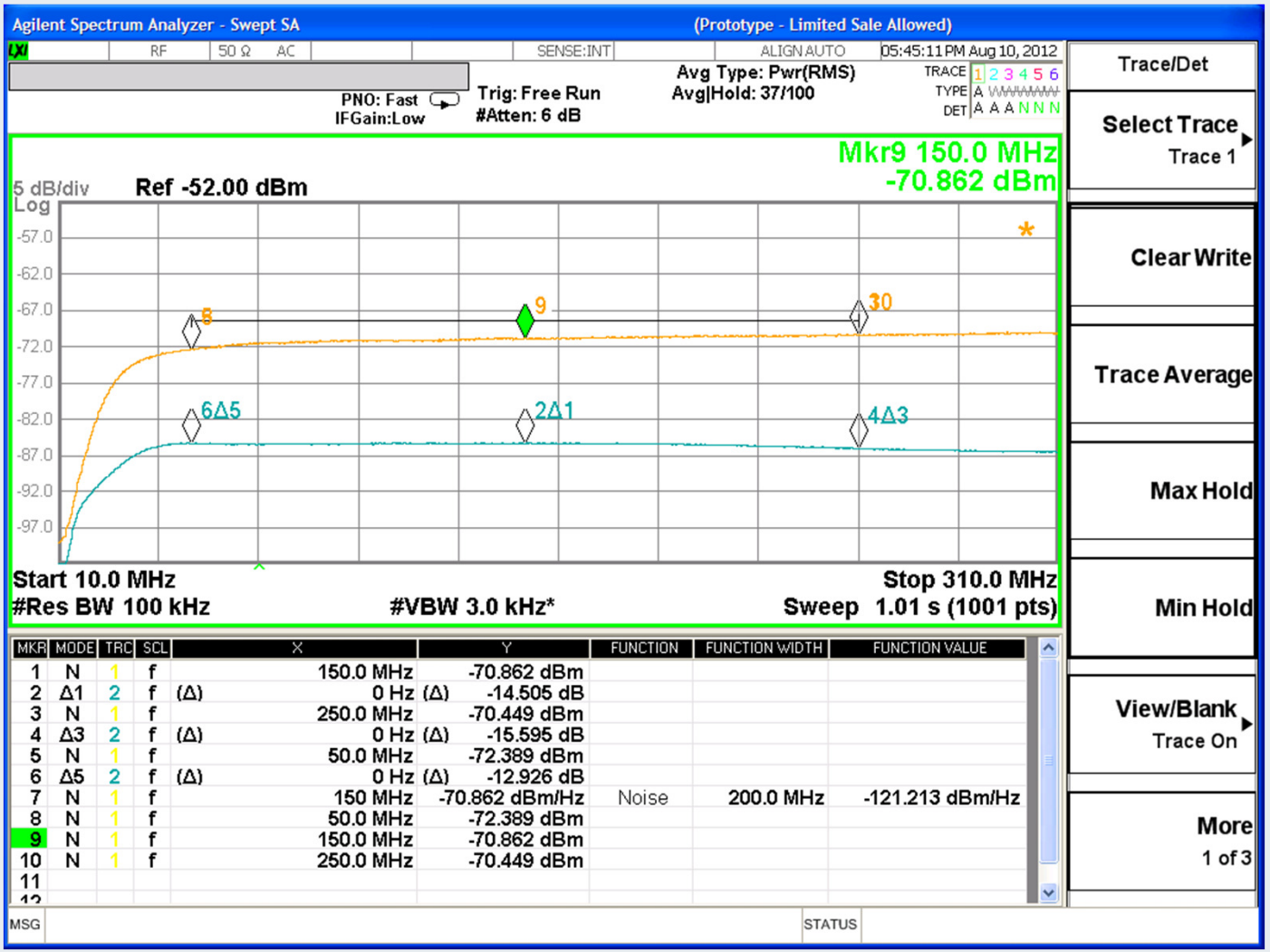
Internal NS 0dB

- Att 0dB



Internal NS -5dB

- Att 5dB



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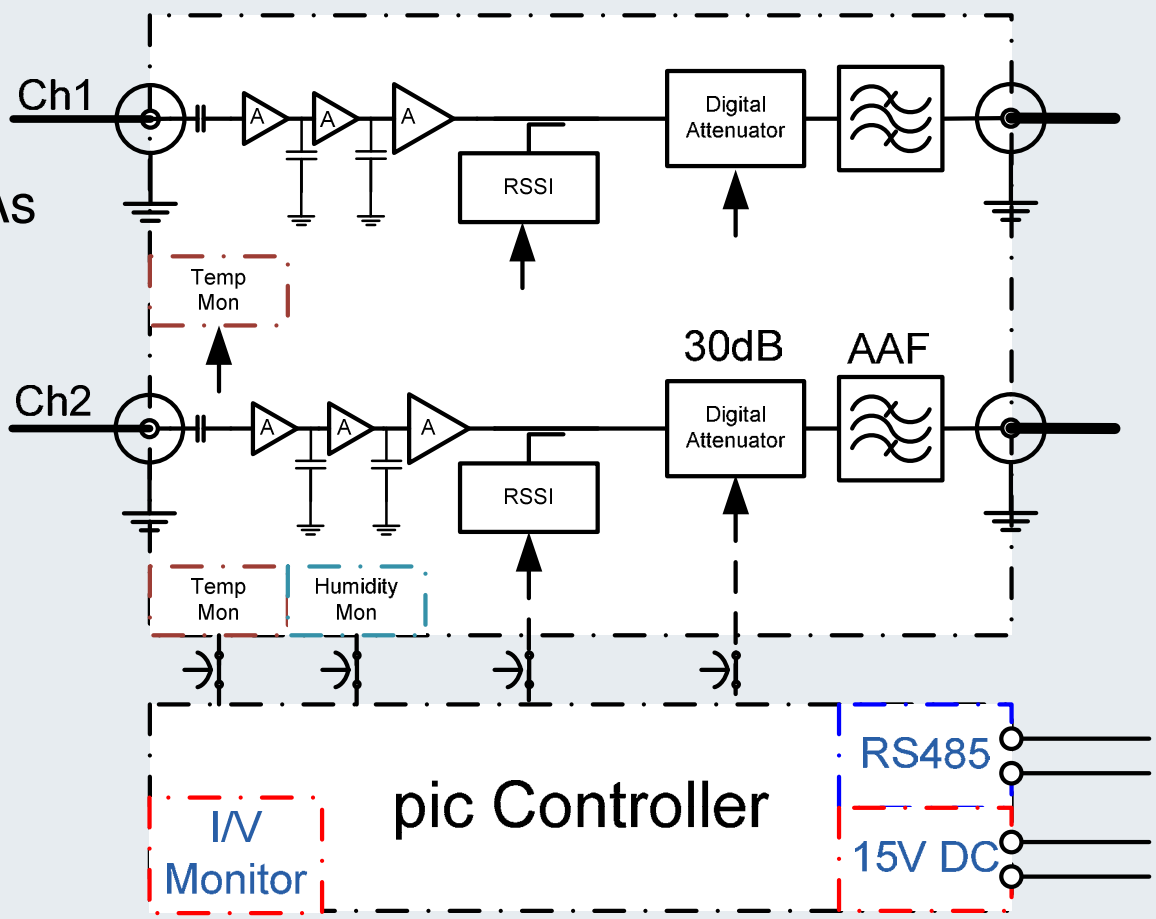
Front End Results

Parameter	Value
IN/OUT Return Loss (50-250MHz)	>20 dB (Γ <0.1, VSWR <1.22)
1dB Compression	> +14 dBm
Gain (50-250MHz) $\Delta G/G$	37 ± 0.5 dB ~0.02dB / ^{o}C
Minimum Switching Rate	250ms
Noise Source (NC4925)	-137.5dBm/Hz (1,288,000K)
Antenna Switch Isolation, Return Loss	>60dB, >20dB
NF (SW/CPL/LNA)	200 ± 20K
NF (LNA)	< 1.2dB (90K)

Gain Module

- Block Diagram
  - 2 Identical Chains
  - Filtered Multistage LNAs
  - Power monitor (RSSI)
  - 50dB dynamic range
  - Gain Control
  - Anti-Alias Output Filter
  - Temp Sensor
  - Humidity Sensor



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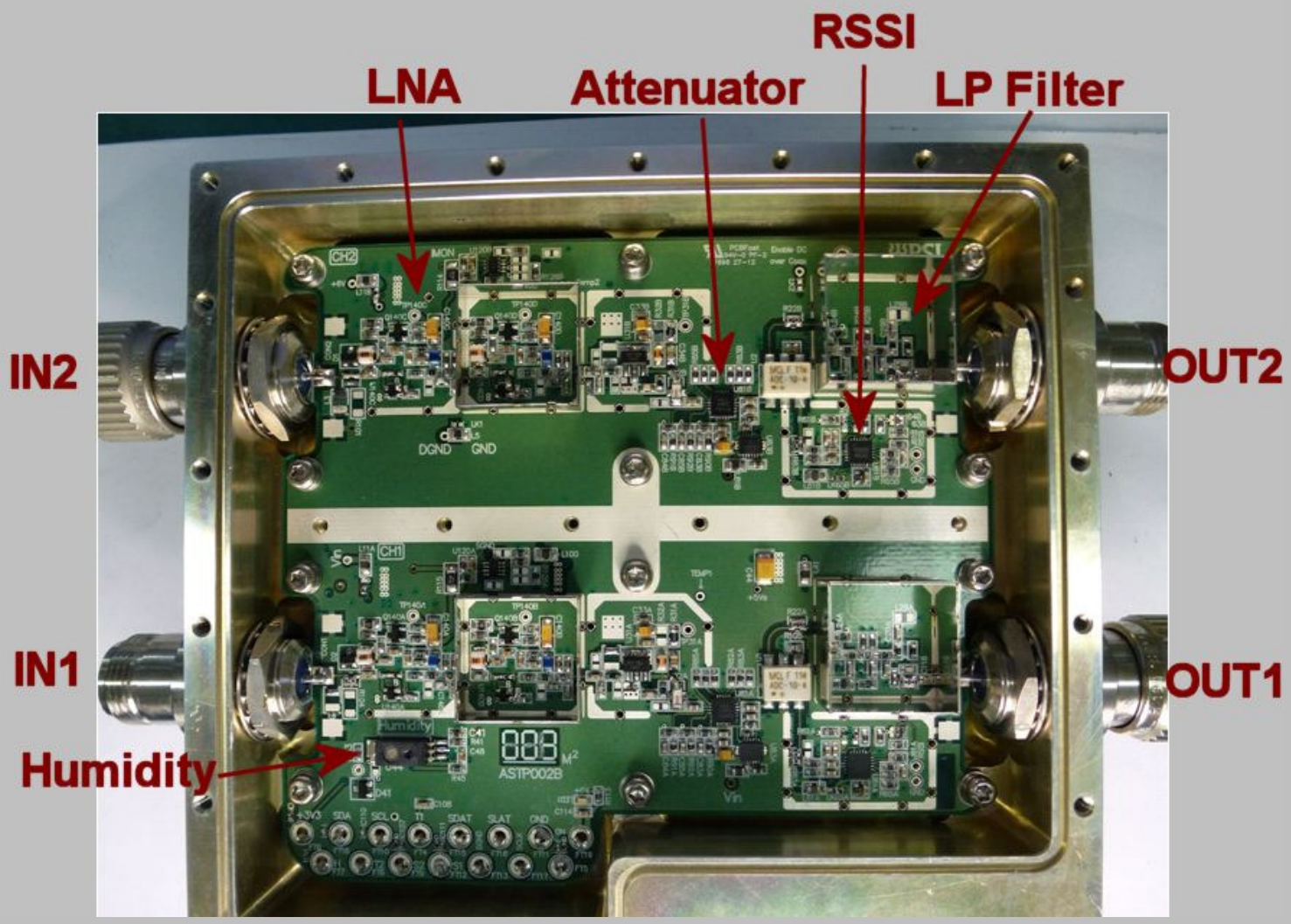
Gain Module Photo



A figure

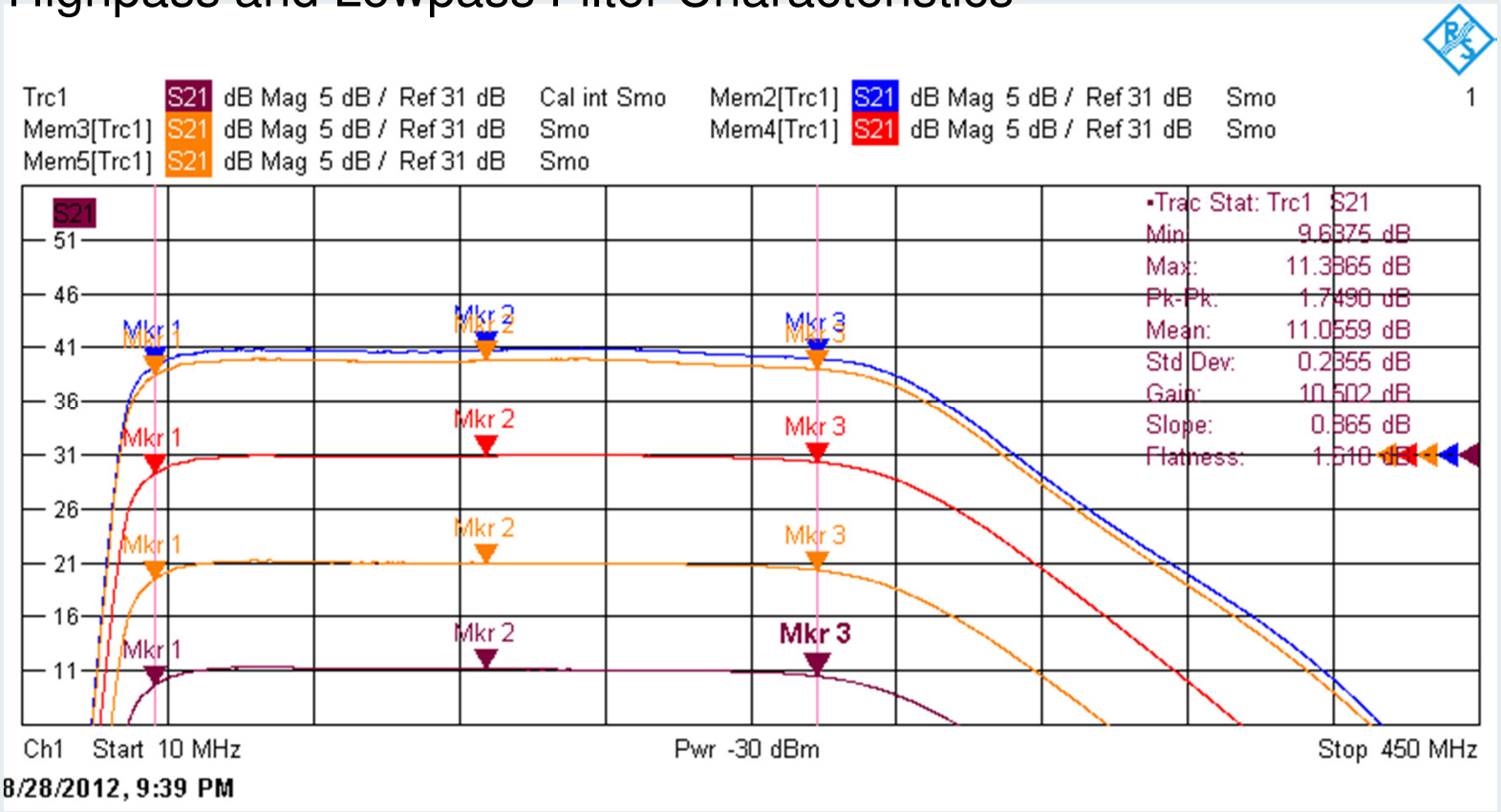
Gain Module Results

Parameter	Value
IN & OUT VSWR (50-250MHz)	<1.2 (Γ <0.1, RL >20)
Output 1dB Compression	+14 dBm
Gain (50-250MHz)	39±1 dB
Attenuation Control	0 to -31.5 dB in 0.5dB steps
Power Monitor (RSSI)	50dB (-90 to -40dBm) ±1dB accuracy
Anti Alias Filter Stop Frequency	LP - Down by 56dB @ 480MHz HP - Down by 20dB @ 20MHz
DC Power	6-15V, < 1A
NF (LNA)	1.2dB (90-100K)

A figure

Gain Module Results

- Gain adjustment using a digital attenuator from 0 to 30dB
- Highpass and Lowpass Filter Characteristics



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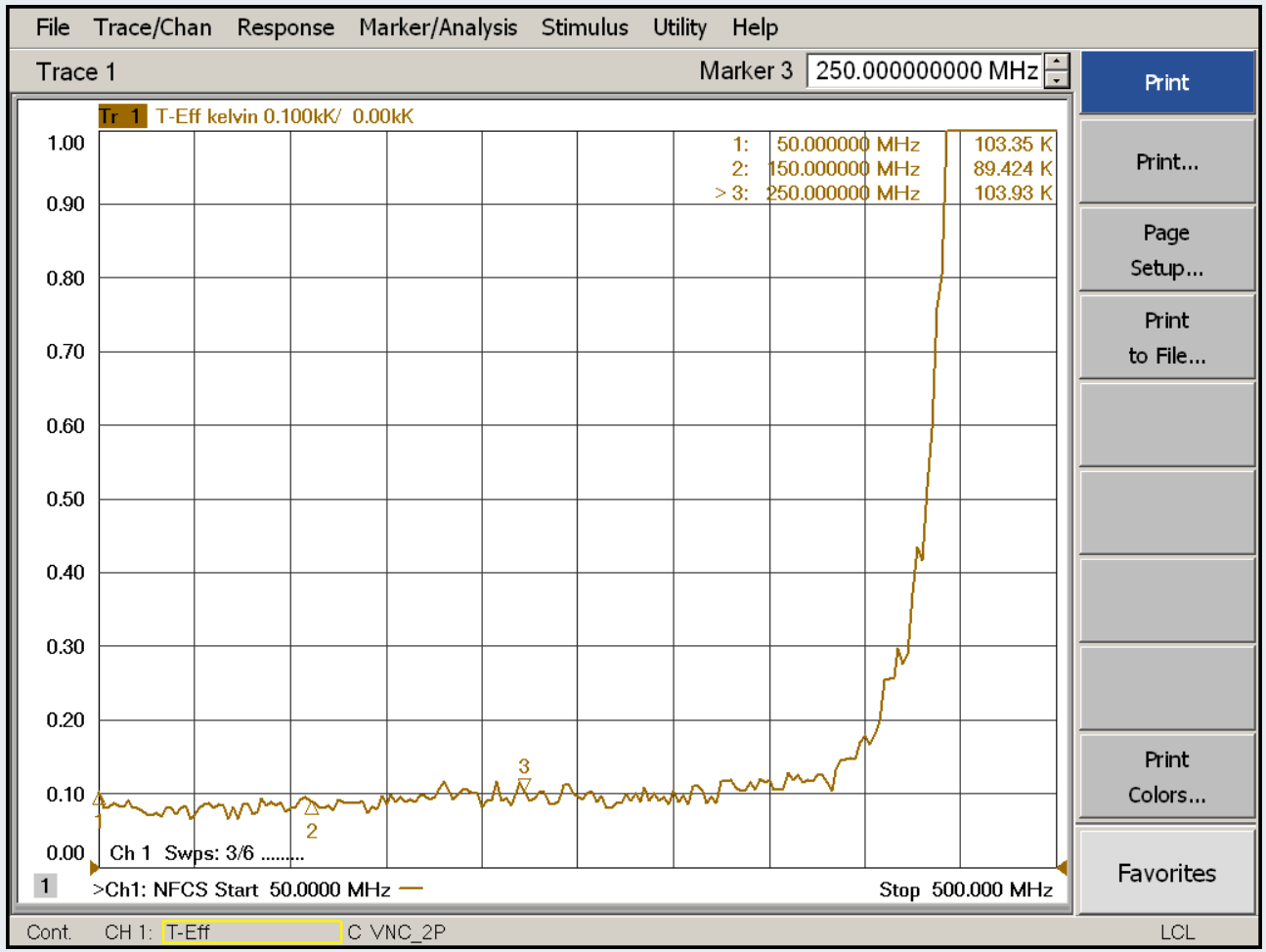
Gain Module Results

- Noise Temperature of 90K -100K (50-250MHz)

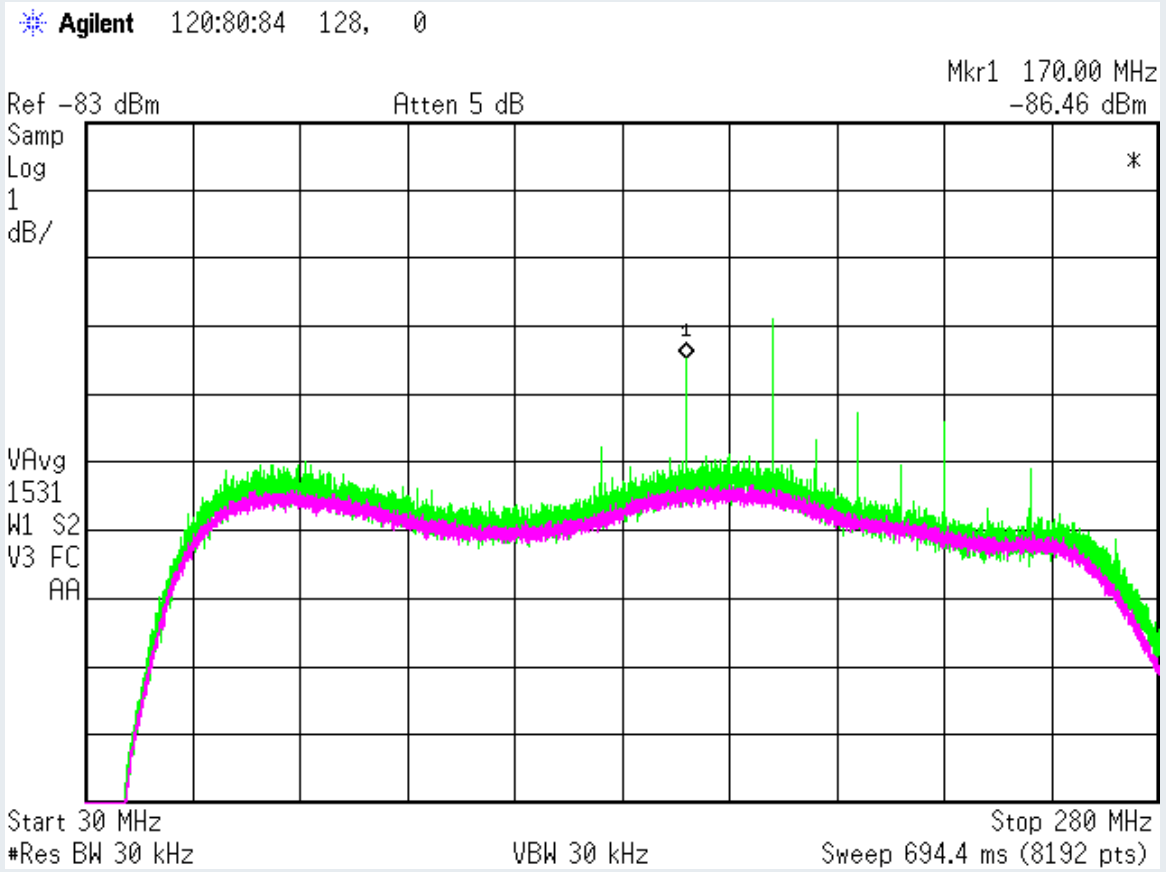


A figure

Gain Module Results

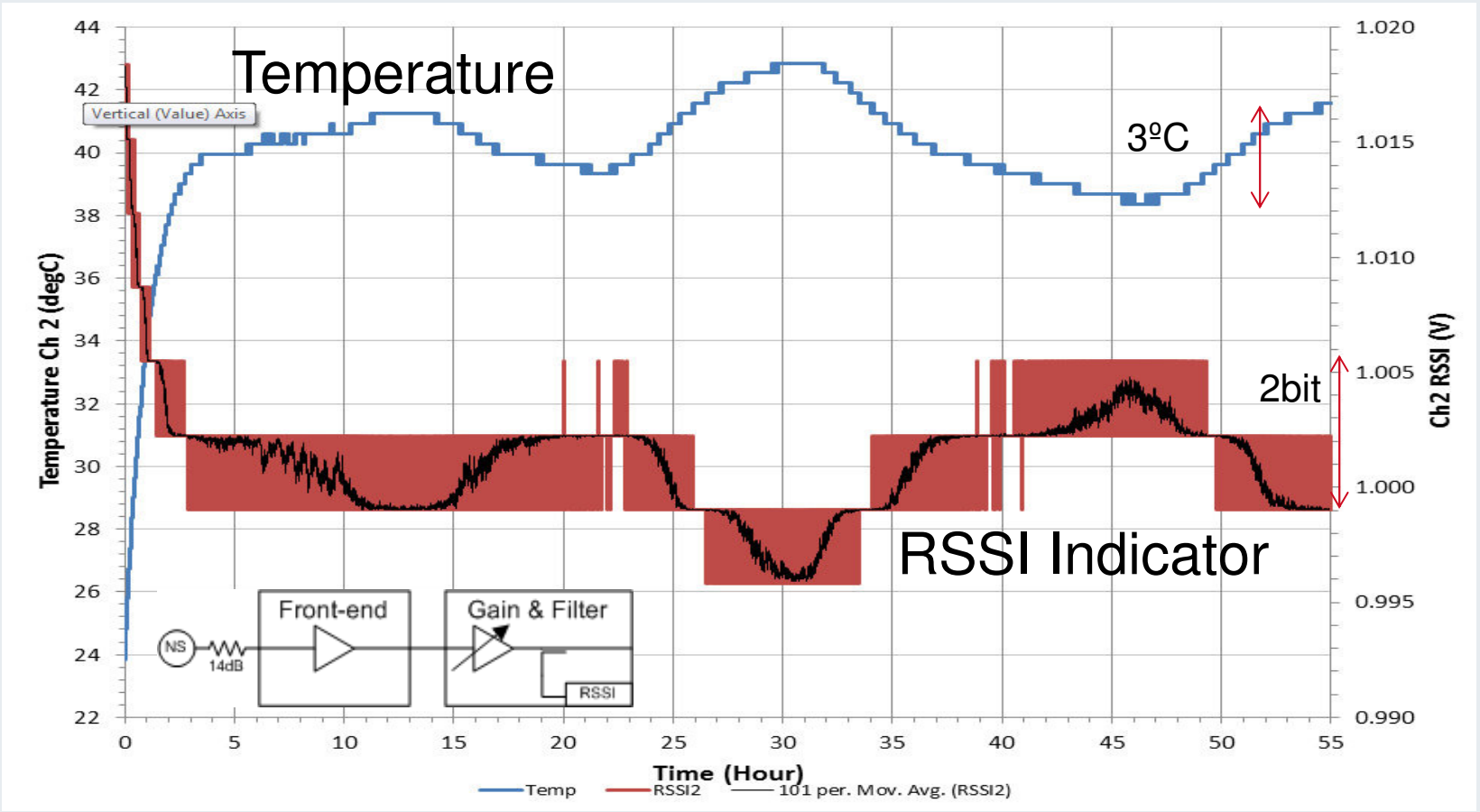
- Output Power Spectrum of the Gain Module (1dB/)
- Ch2 Clean spectrum (Magenta)
- ±1dB Flatness

- Ch1 - Controller on (G)
- 10MHz harm. on Ch1
- RS485 Spurious
- DGND/AGND issues



Back-to-back Test

- Gain Module Detected Output Stability
- Modules on lab bench over 55 hours



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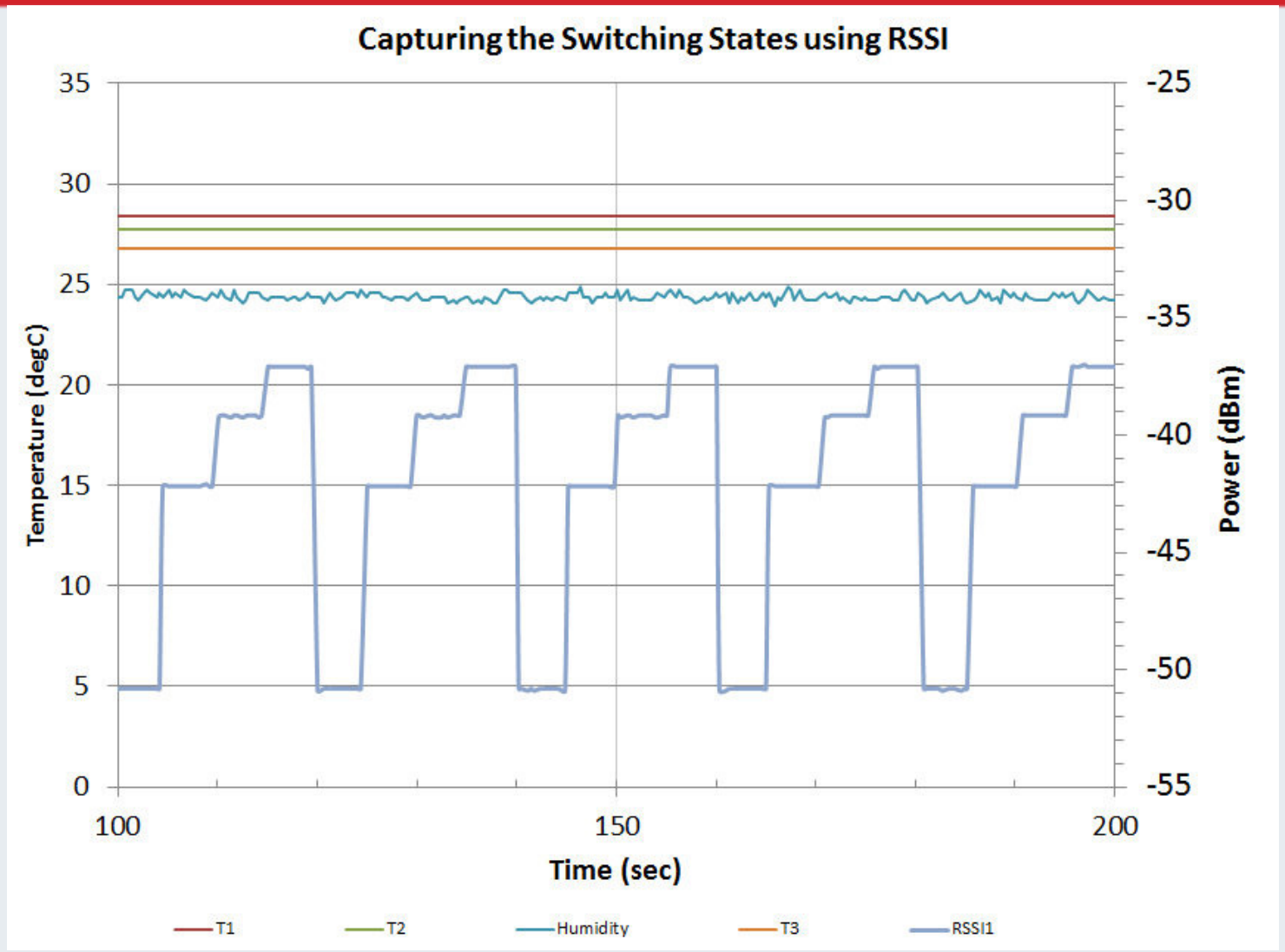
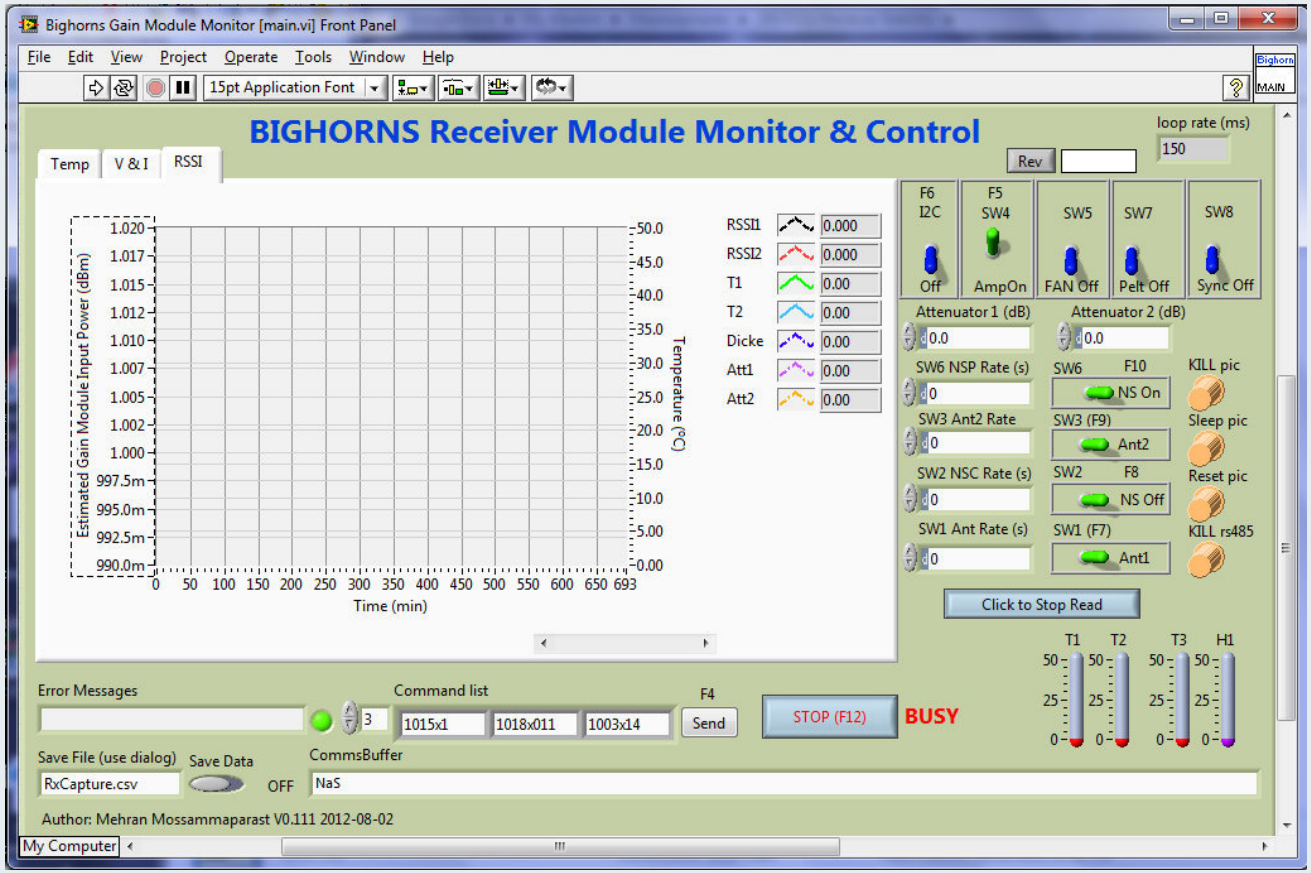
Front-end Switching



RS485 Monitoring

- Lab Testing using LabVIEW
- For Control and Monitoring the Module parameters



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Summary

The Current Receiver:

- Front-end reconfigurable as

1. A Single Channel Noise Adding Radiometer or
2. A Dual Channel Correlation Radiometer

- Front-end Module has a total low noise temperature 200K
- Sky Noise Limited to below 175MHz
- Gain Module has a total low noise temperature 100K
- Amplifiers designed with a highpass characteristics (<20dB at 20MHz)
- Further reduction of controller clock feed-through required
- Further Stability Testing required in Temperature Chamber