Summary of Studies on PEP-II LLRF Driver Amplifiers

John D. Fox. Themis Mastorides, Claudio Rivetta, Dan Van Winkle, Jiajing Xu

Talk Outline

- Operational Experience, PEP-II LLRF
- Insights from the LLRF-Beam Dynamics simulations
- Imperfections in the MPE driver amplifiers
- Options for Improved driver amplifiers
- Recommended action

For details on these topics

Claudio Rivetta's talk October 2006 MAC Review

Dan Van Winkle's talk October 2006 MAC Review

Themis Mastorides' note on "Measurements of All the MPE Amplifiers"

Klystron_Pre-Amp_Proposal (November 2006)

Operational Experience, PEP-II LLRF

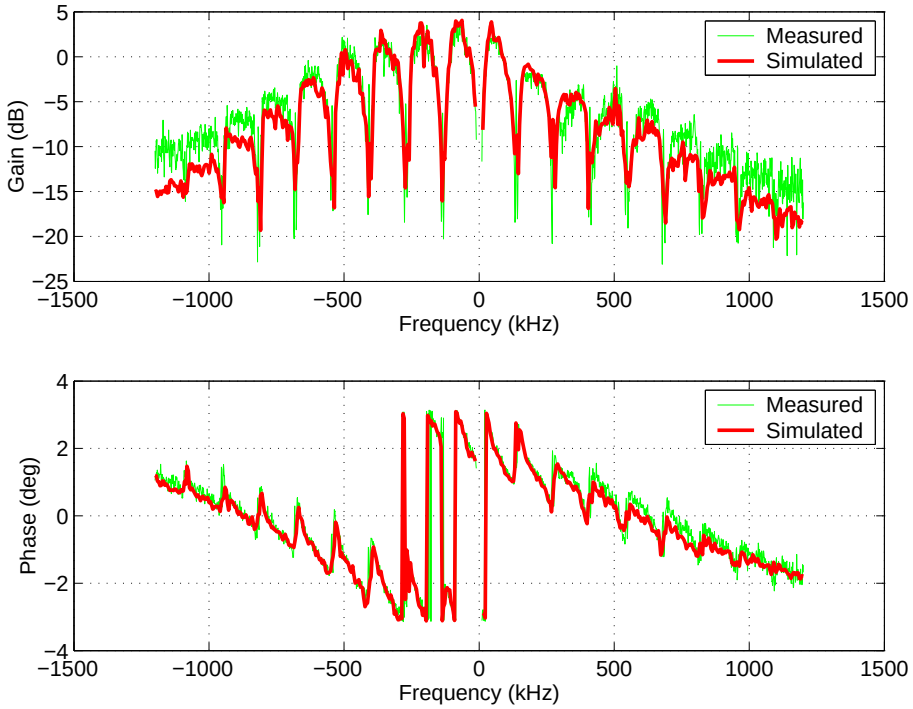
Configuration of the RF stations via models

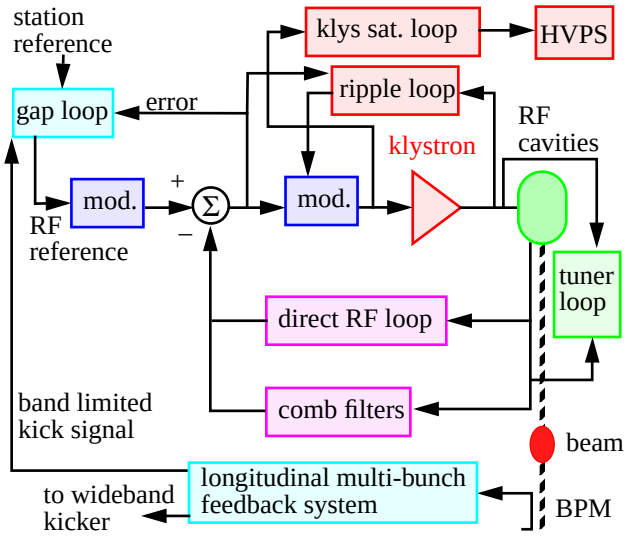
Stations require periodic calibration and operating point selection. Each station requires a unique set-point to achieve the best overall ring operation

The individual stations have varying dynamics, and have unique specific implementation imperfections

The fault file methodology has been very helpful in identifying stations which are more problematic than typical stations

Nonlinear elements in the RFP, driver amp, and klystron are inside the direct and comb loops.





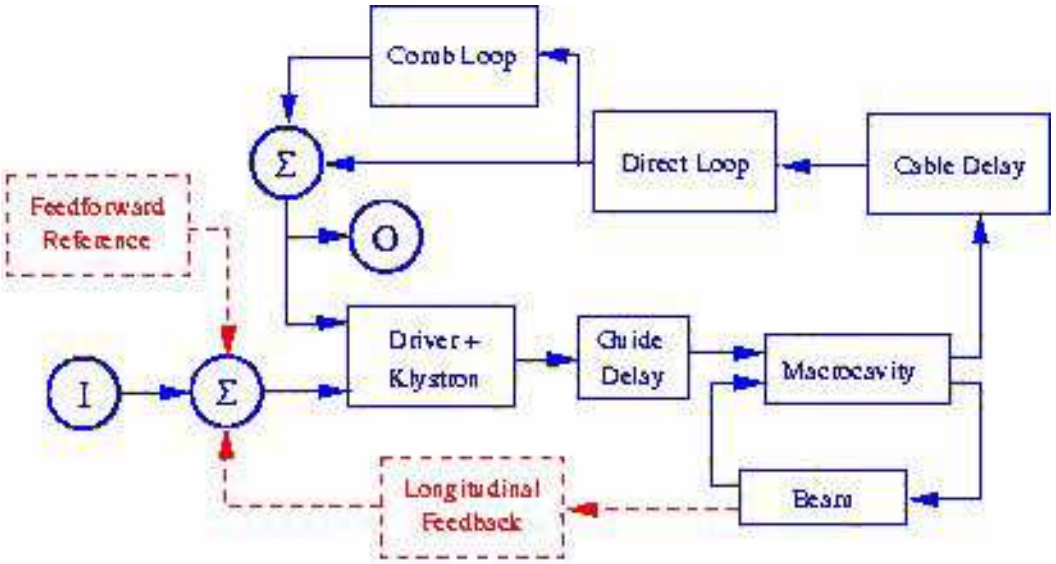
The LLRF in PEP-II includes fast analog, fast digital and slow digital control loops. Impedance control via the direct and comb loops.

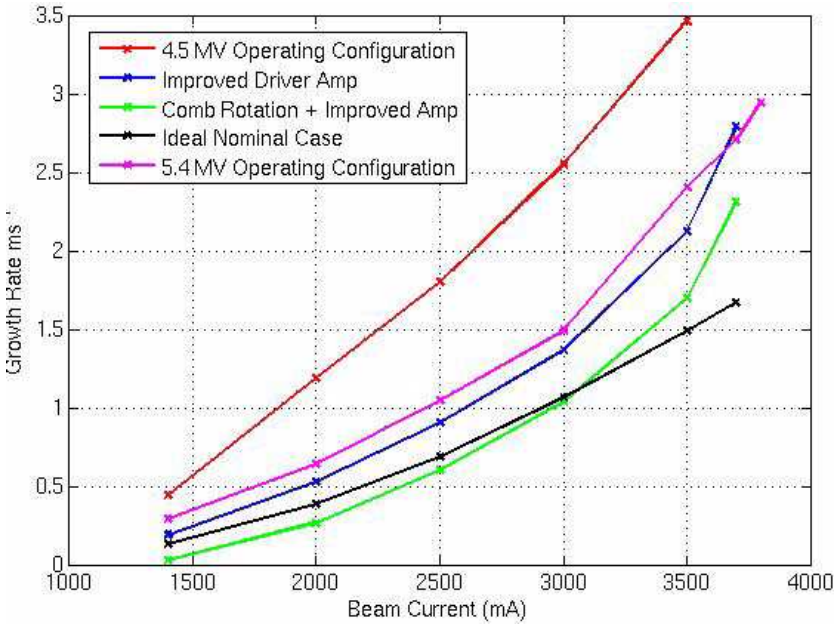
Insights from the LLRF-Beam Simulations

See the MAC talk by Claudio Rivetta and Themis Mastorides

Overview - the interactions of the low-mode beam dynamics, and the dynamics of the RF stations have been studied via a non-linear simulation. There are two significant dynamic systems, each which must be optimized. The LLRF station has dynamics from the direct and comb feedback paths - the station must be configured carefully for stability. The low-mode longitudinal instabilities of the beam are driven by the effective impedance of the RF systems. There are trade-offs in configuration between these two dynamic systems.

The significance of the driver amp imperfections is seen in the simulations. The simulation suggests that the LER cannot exceed roughly 3150 mA without improving the driver amplifiers





Signal Dynamics in the LLRF Signal Path

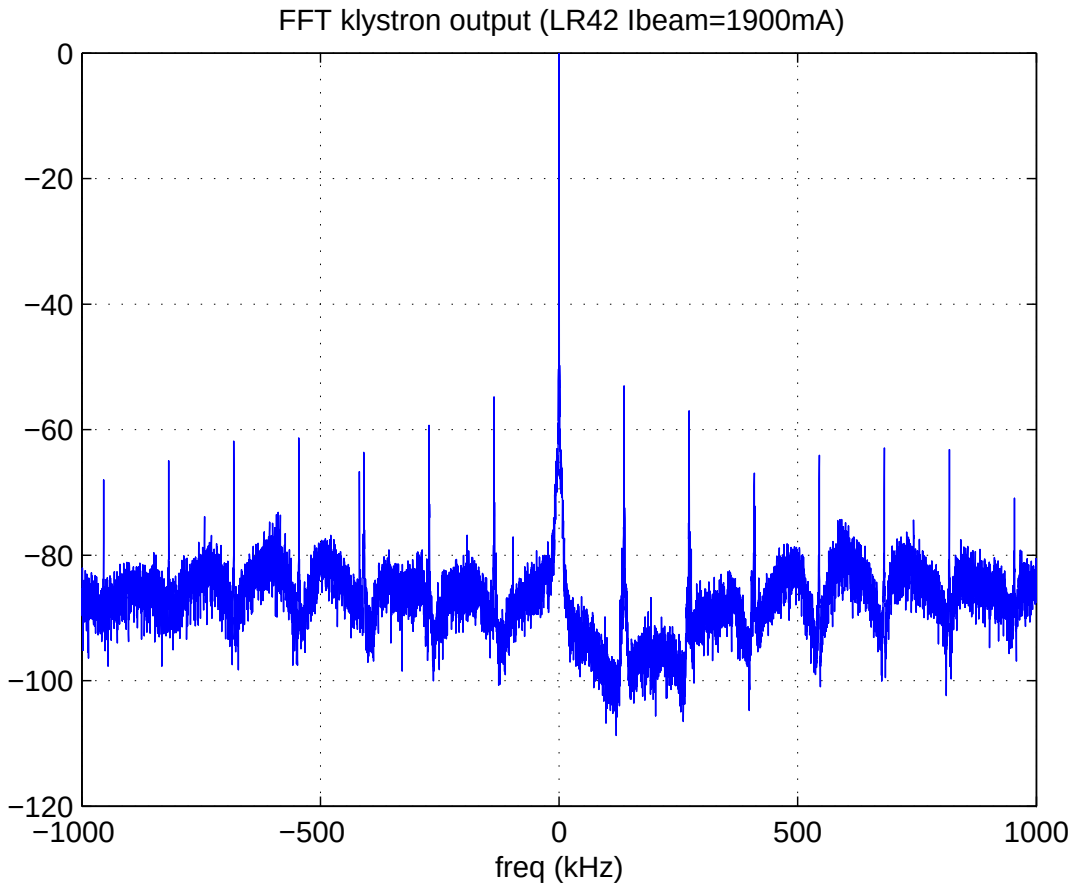
Typical operating Klystron with beam

Carrier (Fundamental) at 476 MHz

Sidebands at +/- 136 n*KHz

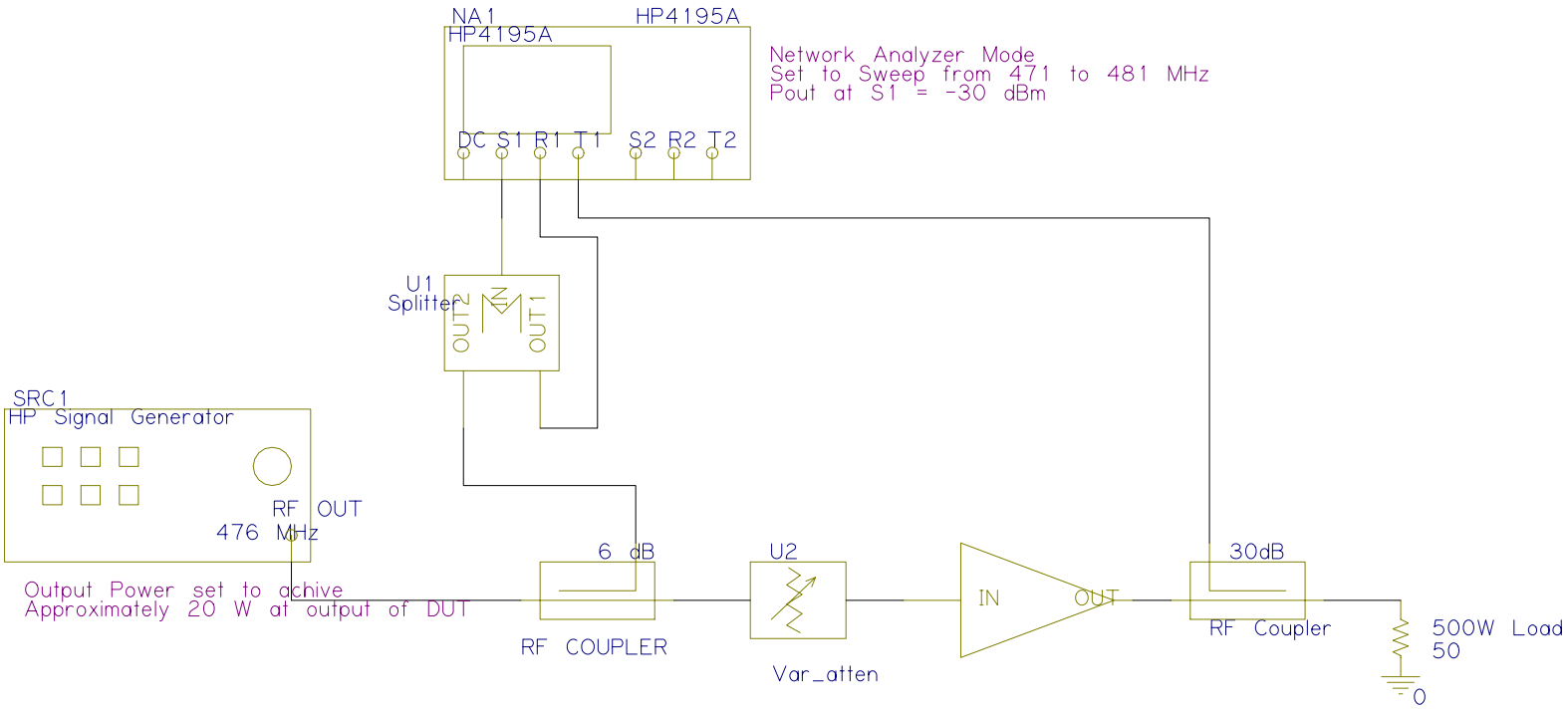
Impedance control signals are roughly -50 to -60 (-80) dB below the fundamental carrier

Periodic structure in signal from revolution harmonics



Measuring Small-Signal Transfer Functions

Central Idea - measure small signal in presence of much larger CW carrier

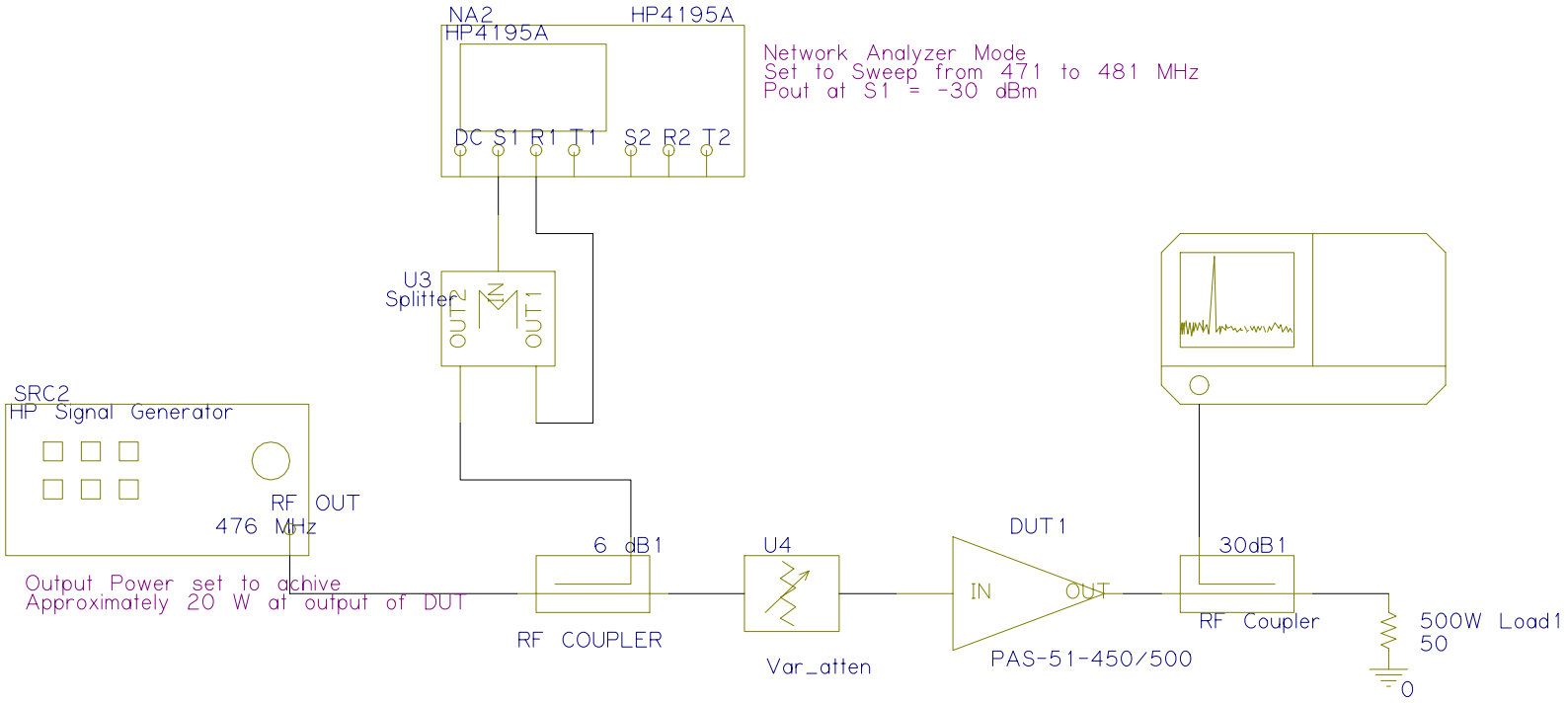


The existing MPE amplifiers were specified and tested based on CW operation.

However, in our system they must operate with significant dynamic range, and excellent small signal gain linearity.

Measuring Single-Sideband Intermodulation Distortion

Central Idea - measure small signal in presence of much larger CW carrier



A variant of a traditional two-tone intermodulation test. A sideband (typically -30 dB relative to a carrier) is swept over the band while the spectrum analyzer records the response at the image frequency. Using the Max-Hold display gives a graph of image level vs. frequency

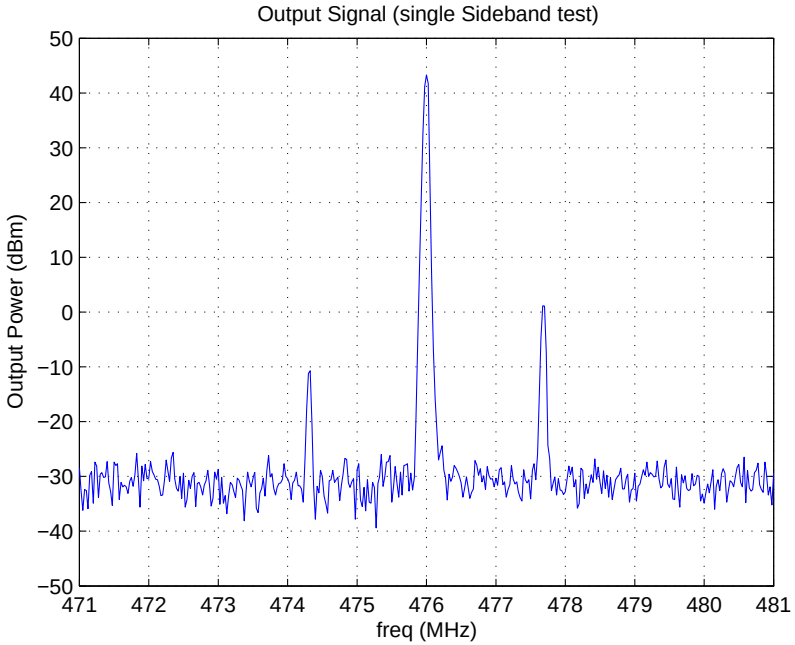
Imperfections in the MPE driver amplifiers

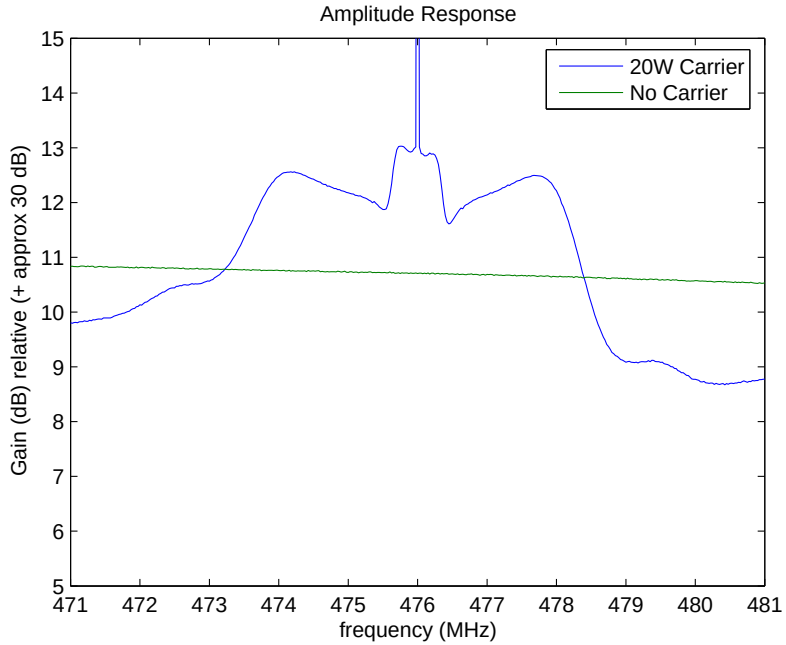
The existing MPE amplifiers were specified and tested based on CW operation.

However, in our system they must operate with significant dynamic range, and excellent small signal gain linearity.

We have measured all the MPE amplifiers, they vary tremendously in performance.

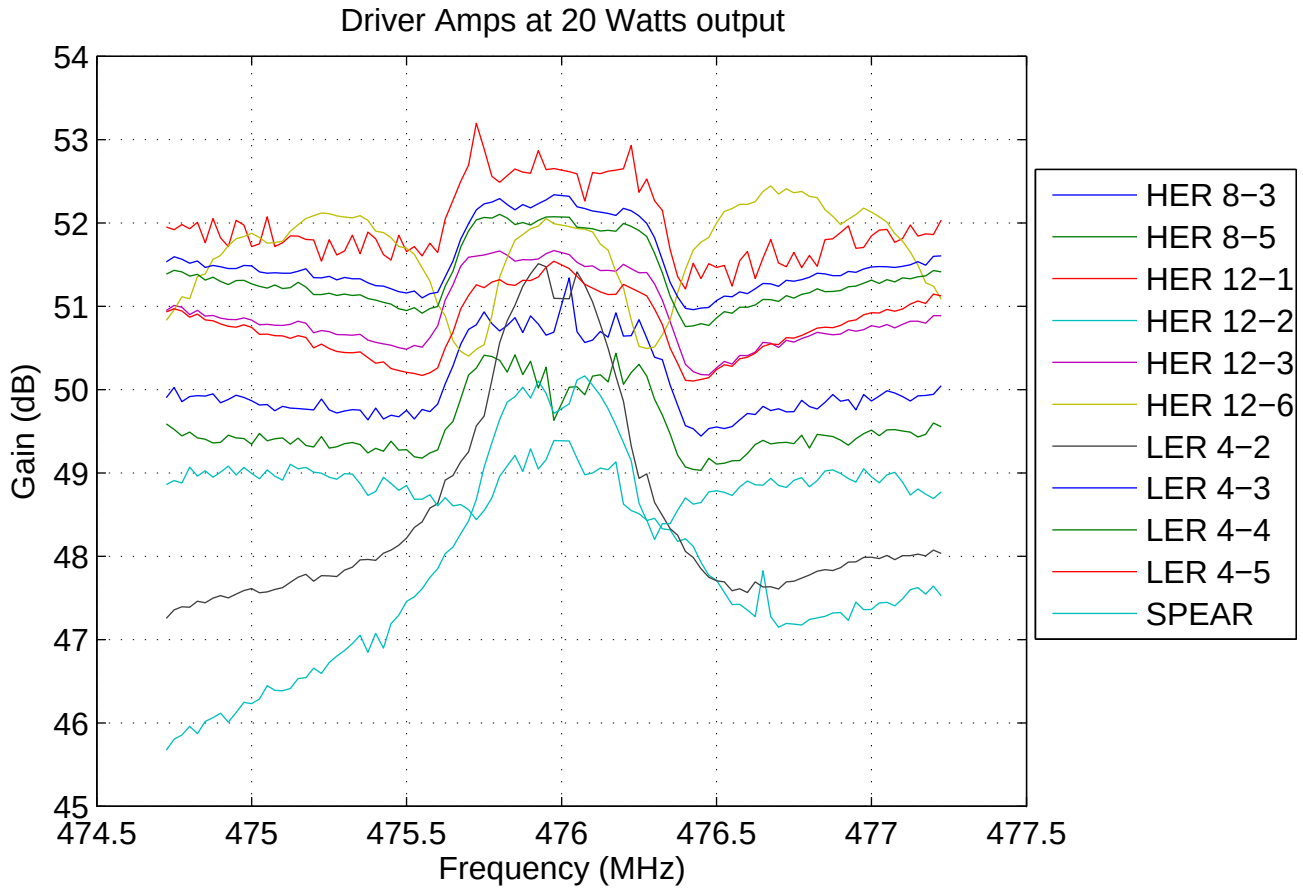
We use measures of small-signal frequency response, two-tone intermodulation response, and pulse response to characterize the amplifiers (see the report Klystron_Pre-Amp_Proposal)





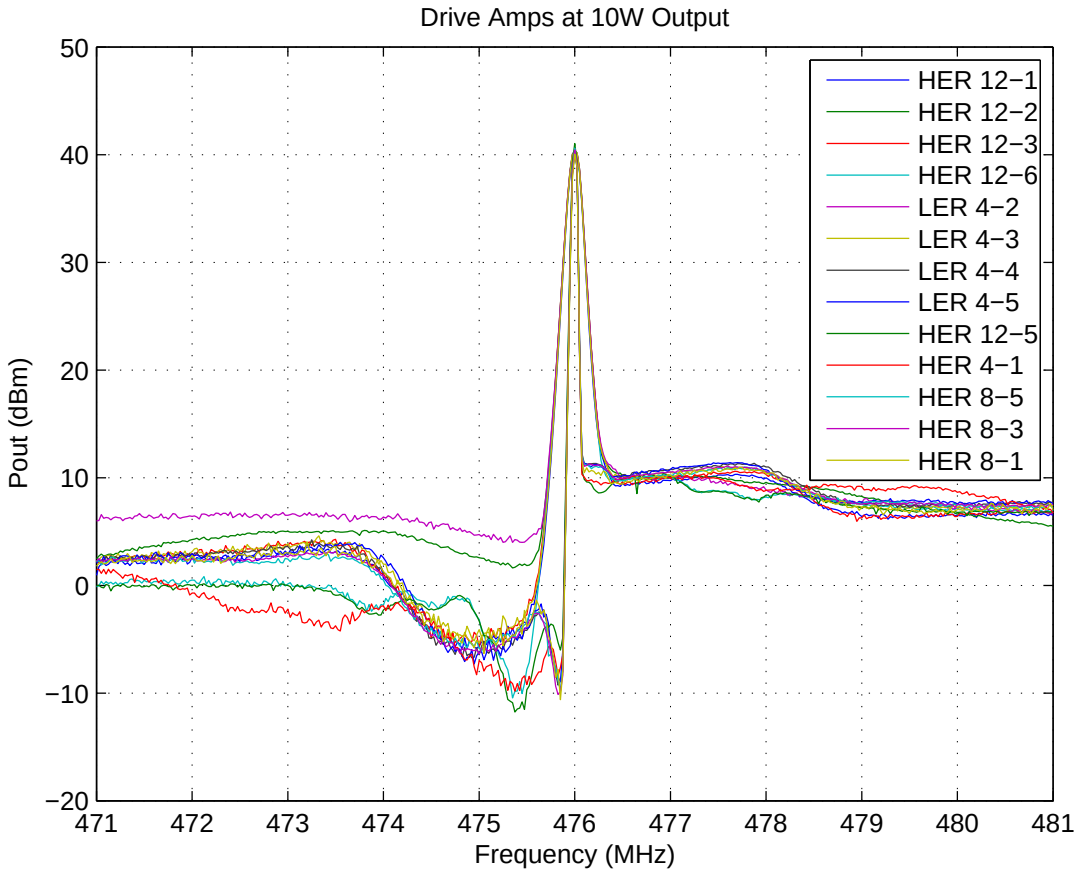
Variations in the MPE amplifier Small-Signal Transfer Functions

We discovered tremendous variation in response in the various existing Drive amplifiers.

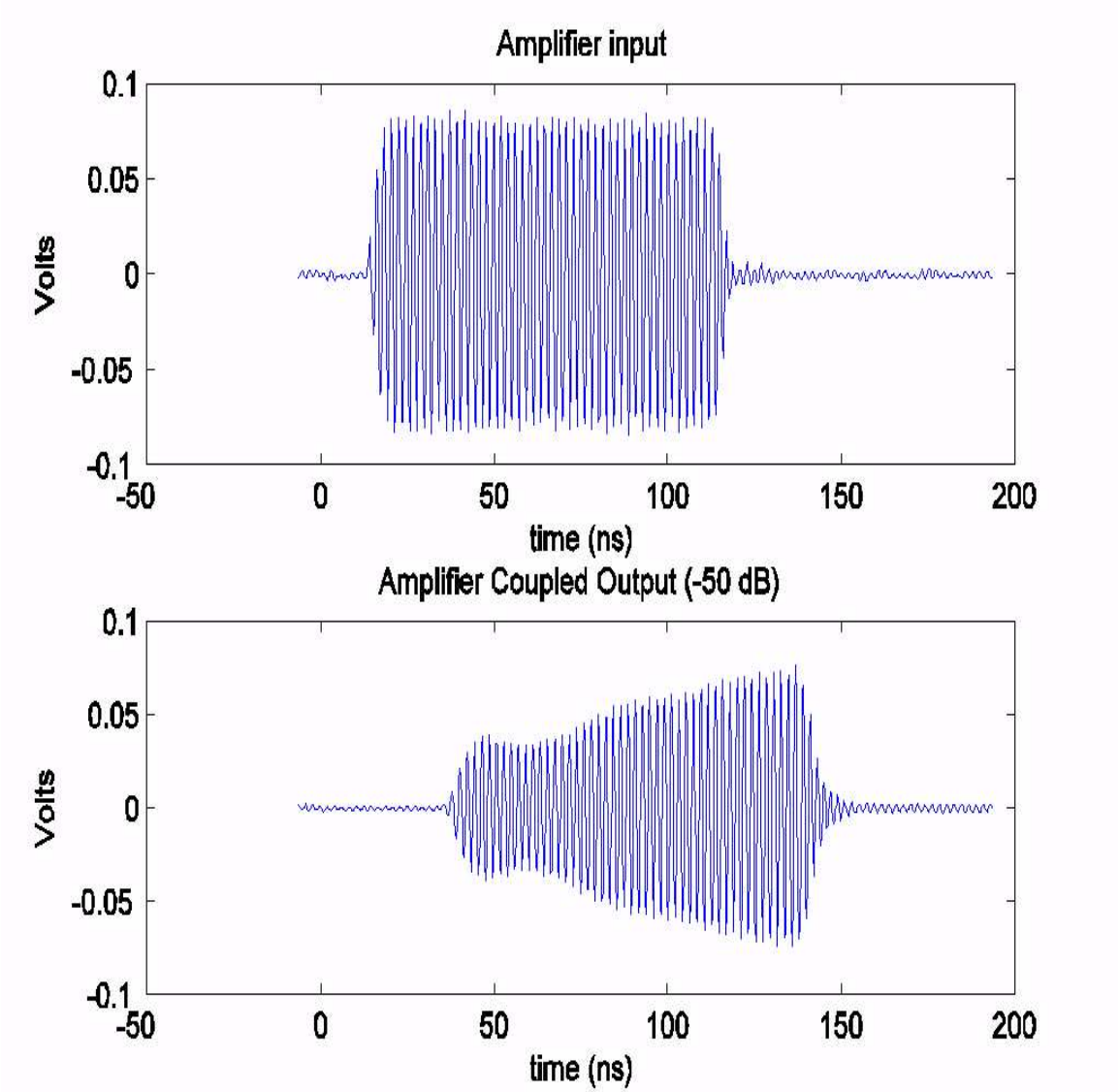


The worst amplifiers are in the stations with “most difficult to configure” operational history.

Variations in the MPE driver amplifier Single-Sideband Image Response



MPE driver amplifier Pulse Response



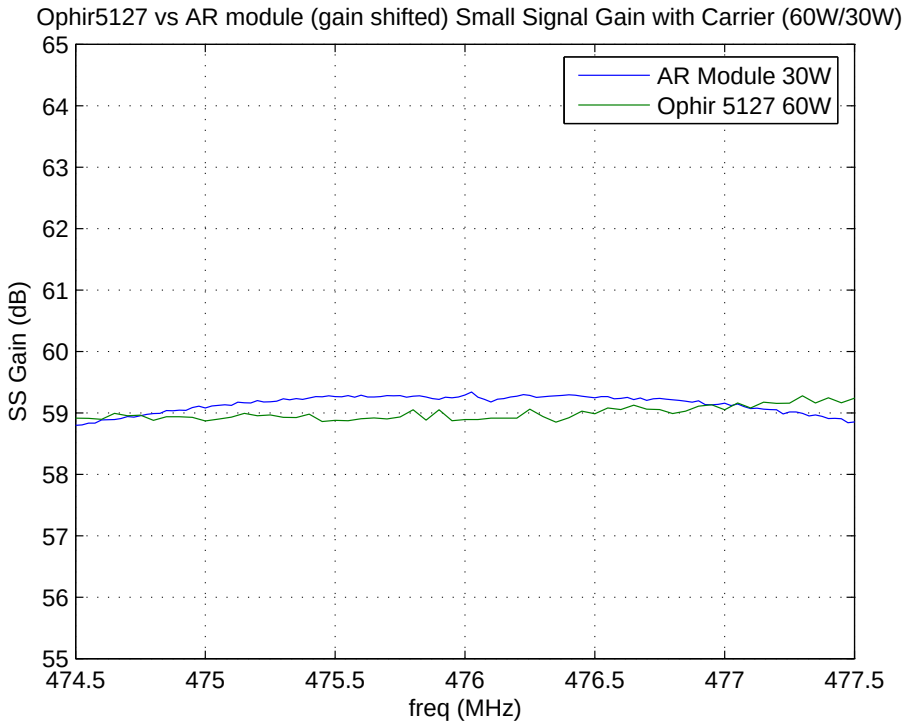
Options for Improved driver amplifiers

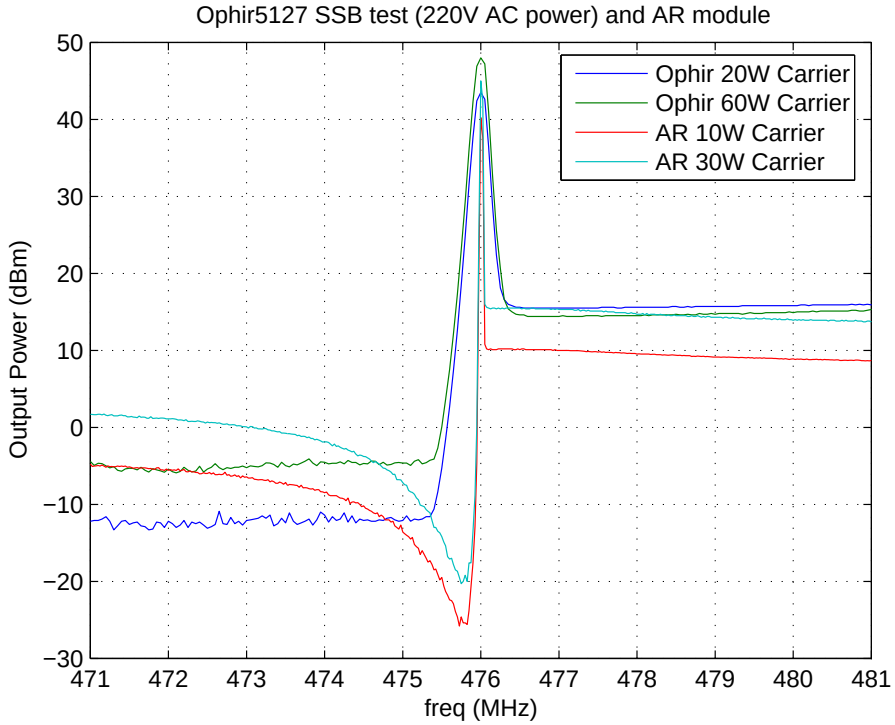
We have evaluated several paths - see the report Klystron_Pre-Amp_Proposal

We see two practical options (RF Module approach, Packaged Amplifier approach)

Practical issues with installation into operating machines, time frame for upgrades

If Heinz S. and Alan H. are willing to retrofit AR modules into the MPE chassis, this is a very cost effective path. It only is time-effective if we start off with a useful number of built-up amplifiers.





Options, Pulse Responses

OPHIR 5126 option, 120V input, 120 watts

(we could not directly evaluate the 5126 - we evaluated a 5127 at scaled power levels)

AR-Kalmus Module (200W)

AR-Kalmus Built-up amplifier in rack chassis 120V input, 200W

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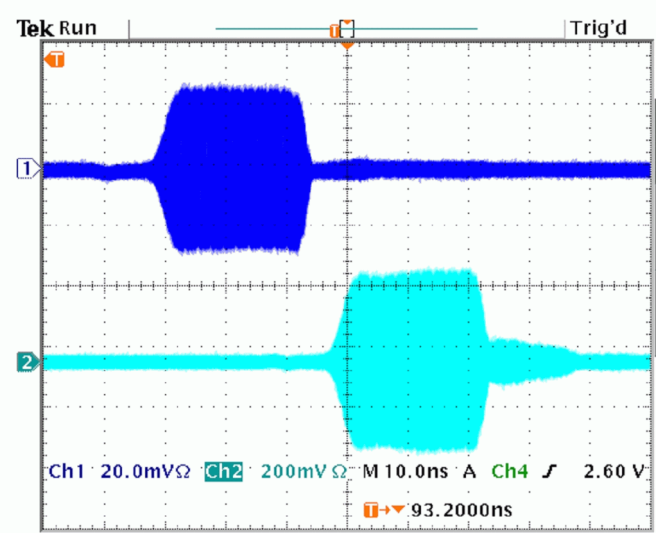

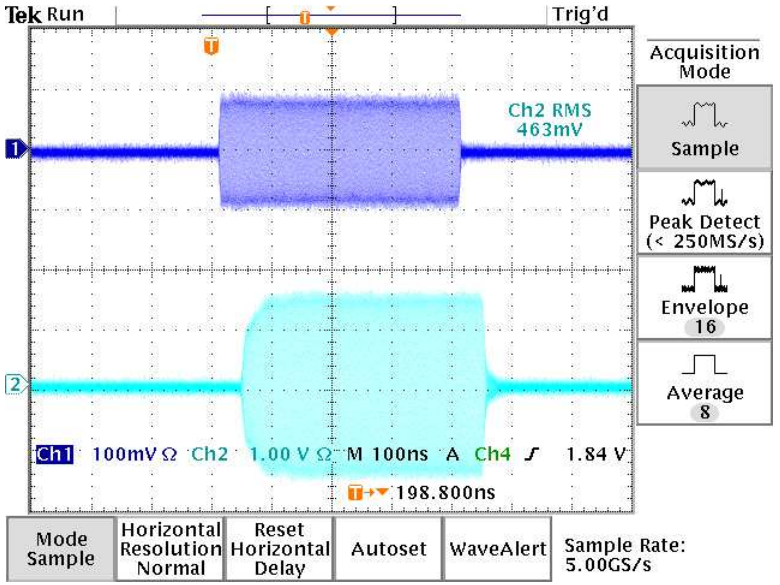

Recommended action

We should order 7 - 8 built-up amplifiers ASAP to fully populate the LER and worst performing amplifiers in the HER.

If the module approach is feasible, also order 7 - 9 modules to upgrade the amps pulled from the first pass (8 built-up plus 9 modules upgrades all the amps plus a spare).

-OR-

Increase initial order of built-up amplifiers - We suggest at least 10 be available total to address the number of “really bad” and “bad” MPE amplifiers. Themis’ HER modelling offers insight into the impact of imperfections in the HER LLRF stability and dynamics.

OPHIR vs. AR-Kalmus

The ONLY amplifier we have been able to evaluate in the final form, and which meets our technical test, is the AR-Kalmus. The OPHIR 5127 does test very well, but this 200W $18,000 amplifier requires a 220Vac primary power. This isn’t in our racks.

We have estimated the performance of the 5126 (a 120W amplifier with 120Vac primary power input) from the 5127 at a higher power output.

Options, Details

OPHIR 5126 option, 120V input, 120 watts $13,792 (quantity 1-4)

Delivery 45 - 60 days ARO (I think likely 60 -75 days)

(we could not directly evaluate the 5126 - we evaluated a 5127 at scaled power levels)

AR-Kalmus

AR-Kalmus Module (200W) $3,990 quantity 1-20

Delivery " by end of January 2007 for order placed 11/23 per specification. Alterations add 3- 4 weeks"

AR-Kalmus Built-up amplifier in rack chassis 120V input, 200W $11,500 quantity 1-20

Delivery "by first of march 2007 for order placed by 11/23"