General Notes:

The 4 and 8 pack development is R+D. The LLRF system must be designed to allow flexibility in operational parameters, number of channels, etc.

It must be straightforward to add channels to the system

X-band cables have been a continuous source of problems. If X-band signals are to be transmitted over long distances, an engineering solution to the connector problem is required.

It should be possible to measure timing difference between the rising and falling edges of “related” RF signals (e.g.: structure in / structure out) to <1ns. This may have implications for IF frequencies, and for whether the IFs need to be locked to the master oscillator.

RF Control: Each Klystron must have independent phase and amplitude (or I/Q, or digital IF) control. The control requirements are:

8 and 4 Pack overall requirements:

LLRF output power >10dBm.

Adjustable X-band frequency control +/- 30MHz is required for some tests.

There must be either an analog input(s) or sufficient digital programming flexibility to allow arbitrary modulation of the RF with a 100MHz bandwidth. Providing analog inputs to an IQ modulator (or allowing the addition of an external IQ modulator) is sufficient.

4-Pack: 3 Klystrons to be controlled.

1. The signals to the 2 TWTs require independent slow (1 second time constant) phase and amplitude control. Stability ~5 degrees X-band. Accuracy: no tight requirements - will be controlled by measuring the output. This functionality may be included in the arbitrary I/Q control.

2. The phase of the LLRF signal to the 2 TWTs must be switched by 180 degrees with a switching time of less than 10ns (settle to 10 degree phase).

3. The output from the LLRF system must be switched in pulses with 10ns rise and fall times (to 10% power) and 50ns to 4 microsecond length. Eight pulses are required, with the last pulse starting at the time of the phase switch. This is to allow operation with shorter RF pulse lengths.
4. Note: the 4-pack functionality is a subset of the 8-pack functionality.

8-Pack: 8 Klystrons to be controlled.

1. The signals to the 8 TWTs require phase and amplitude control in 8 steps of ~400nsec each. I/Q steps should settle to ~1% in ~10ns. Stability should be 8 bit.

2. An additional ~8 phase and amplitude ramps, each 50ns, may need to be applied to all of the drive signals to compensate for the turn-on of the modulator. This signal would be the same for all klystrons.

Note that 1 and 2 could be achieved with a 20MHz, 8 bit (true) DAC driving each of the Is and Qs for modulating the RF.

3. The output from the LLRF system must be switched in pulses with 10ns rise and fall times (to 1% power) and 50ns to 4 microsecond length. 8 pulses (of identical length) are required, spaced by ~400ns. This is to allow operation with shorter RF pulse lengths. This switching is the same for the two (SLEDII) tubes, but may be different for the third tube.

**RF Diagnostics:**

**Diagnostic Types:**

1. Calibration / Special Purpose Diagnostics: These are used to look at a small number of signals, but must be switchable to look at any RF signals. Real time readout is not required. Digital IF processing at 200 MHz bandwidth (100MHz minimum) to 8 bits is required. Digitization should occur on all pulses, with ability to store on a “breakdown” pulse. This can be performed with a >1Gs/s scope. Any pair of signals should be available for measurement.

   Calibration: The system must allow for calibration of selected channels to 0.2dB absolute, 0.1dB stability. Note that additional equipment may be used to provide calibration of these selected channels.

2. Waveform Diagnostics: 100MS/s, 8 bit digitization of I / Q signals for a selected number of channels. Bandwidth > 50MHz. These signals should be recorded on every pulse, and read out on “breakdown” pulses. Note: This could also be achieved with a digital IF system using fast digitizers. All Waveform signals should also have Single Pulse Diagnostics.

   “Raw” RF signals (for digitized channels) must be available for measurement with oscilloscopes, spectrum analyzers, etc. Providing X-band, IF or IQ signals with >100MHz bandwidth is sufficient.
3. Single Pulse Diagnostics: Data values are measured and stored on every pulse. Note: #2 diagnostics could be used if price and data rate are reasonable. The following should be measured on selected pulses. This signals can be Peak ADCs, or Integrating ADCs. Peak ADCs should respond to 20ns width pulses. GADCs should have performance similar to LeCroy 2249W GADCs.

3a. Note that a decision on Peak or Integrating ADCs has not yet been made. Most likely Peak ADCs can be used for all channels.

4. Note: TDC, Peak Detect, and Integrated power functions will be performed in software on the data from the 100Ms/s digitizers.

**4-Pack Signal Counts:**

Total RF Signals: 37 (All go to pulse ADCs)
Signals to 100Ms/s I and Q Digitizers: 19 (38 Digitizer channels = 5 digitizers).

**8-Pack Signal Counts:** Including 6 structures (rough estimate)
Total RF Signals:100 (All go to pulse ADCs)
Signals to I and Q digitizers: 50 (100 digitizer channels = 12 digitizers)
4-Pack Layout / channel count - Klystrons

- LLRF
- TWT
- Klystron

Circular guide

- Pulse Monitor (diode - GADC)
- I/Q monitor (100Ms/s I, 100Ms/s Q, + diode - GADC)
  Also mux to Fast (>1Gs/s digitizer)
4-Pack channel count - Super Hybrid and DLDS

Circular Guide

Load | Load

Super Hybrid

Mode converter / test device

Load

Load

SLEDII

Note: no power expected to these loads

Pulse Monitor (diode - GADC)

I/Q monitor (100Ms/s I, 100Ms/s Q, + diode - GADC)
Also mux to Fast (>1Gs/s digitizer)