NLC TEST ACCELERATOR

NLCTA Note #42

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Subject: Proposed RF Monitor Signal Processing

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This Note describes RF monitor signal processing. Details of the hardware components of the monitoring system, including the directional couplers and other microwave electronics, are not included here. The desired locations of the RF monitor couplers for each rf station are indicated schematically in Figure 1. (Note that the injector station is unique only in that it contains prebuncher cavities PB1 and PB2 and their associated rf couplers; otherwise, it is identical to the linac stations.) The monitored signals will be processed by two different classes of RF detectors—waveform and single sample. The rf signals to be monitored by each of these two types of detectors are summarized in Table 1. The use of history buffers for saving information about some of the signals is indicated in the last columm of Table 1. Itemization of the number of signals in the scheme is indicated in Table 2.

Waveform Sampling Monitor Signals

One class of RF detectors consists of waveform vector detectors that demodulate the time-varying cartesian components of a phasor, I and Q, with high-bandwidth (100–200 MHz). The demodulated (video) components will be digitized by an HP E1428A digitizing oscilloscope with sampling rate of 1 GSa/s. Each of these VXI scope modules has two channels (one for I and one for Q). Derived quantities, such as

$$|V(t)| \equiv \{[I(t)]^2 + [Q(t)]^2\}^{1/2}$$

and

$$\Phi(t) \equiv \tan^{-1}[Q(t)/I(t)],$$

which are proportional to voltage and phase, respectively, will be displayed and analyzed by the VXI processor. In order to maximally preserve rf phase information, the 11.4-GHz signals will not be multiplexed; a dedicated vector-demodulator channel will be assigned to each rf monitor channel for which I and Q information is desired. The cost of one pair of vector-demodulator channels (I and Q) is estimated to be approximately $9k in small quantities.

A large measure of cost savings will be achieved by multiplexing the demodulated video signals (I's and Q's) from each RF station into one or two HP E1428A two-channel digitizing oscilloscopes which, at $13k each, are relatively expensive. Multiplexing can be performed by the HP E1472A 50-Ω RF Multiplexer, which is a B-size, single-slot, register-based VXI module containing six computer-controlled 4:1 switches with 1.3-GHz bandwidth (more than adequate for the video pulses), at a cost of $2600 per module. One possible multiplexing scheme is shown in Figures 2 and 3, where a single HP 1472A multiplexer module and one or two HP 1428A scope modules are used in each RF station. The maximum number of channels that can be multiplexed may be limited by the set-up and digitization rate of the HP E1428A scope, and the multiplexer switching rate, since the multiplexed hardware configuration must be capable of supporting multiple-channel sampling at sufficient repetition rate to perform the necessary monitoring, control, and feedback functions. The injector-station configuration shown in Figure 2 has one more digitizing scope than the linac stations (Figure 3) in order to accomodate the larger number of channels likely to require monitoring in the injector. It may be desirable to dedicate one of the injector-station scopes to monitoring, and the other one to closed-loop controls.

Considerable data reduction will be necessary before archiving the waveform information from the high-bandwidth vector demodulators, since the data is acquired by VXI digitizing oscilloscopes with 1-GSa/s sampling rate. We plan to use the VXI processor to derive the voltage and phase waveforms from the measured I and Q waveforms, and to reduce the waveform data by using linear fits to functions of the I and Q data sets. The functions, $V(I(t), Q(t))$ and $\Phi(I(t), Q(t))$, will be fit to the hypothesis that they are composed of at most two continuous regions of different slope, and will be characterized by the set of parameters: (1) intersection point, (2) region-1 average, (3) region-1 slope, (4) rms residual of region-1 fit, (5) region-2 average, (6) region-2 slope, (7) rms residual of region-2 fit. The intersection point will be found from the data by using a non-linear multi-step fitting procedure. Typical voltage waveforms will consist of a linear rise followed by a flat region. Typical phase waveforms will be flat. Reduced data, consisting of the fit parameters described above, is indicated in Table 1 as $V(t)$ and $\Phi(t)$.

Single Sample Monitor Signals

The second class of detectors consists of single-sample-per-pulse power- and/or phase-detection circuits with 10–20 MHz bandwidth. Data is acquired from these detectors by a CAMAC GADC, or by a peak-and-hold (or sample-and-hold) signal-processing circuit connected to a CAMAC SAM. We are planning to install an inexpensive diode peak-and-hold circuit on each channel of the RF monitor head. Power and phase channels will be used for SLED-II delay-line tuning, as described in NLCTA Note #16. The power peak-and-hold channels will be used for protection functions, including reflected-power monitoring.

The sample-and-hold and peak-and-hold data, acquired via the CAMAC interface, will be archived into history buffers in the usual (SLC) way.

TABLE 1. Processing of RF Monitor Signals from an RF Station

	Monitor Coupler Location	Power-Flow Direction	VXI Digitizing Scope [1]	CAMAC GADC	Peak & Hold, CAMAC SAM	SCP History Buffer [4]
Each RF Station						
1	RF Reference	F	—	—	P	P (SAM)
2	Vector Modulator Out.	F	I & Q	—	P	P (SAM)
3	TWT Output	F	I & Q	—	P	P (SAM), V(t)
4	Klystron Output	F	I & Q	P	P	P (SAM), V(t)
5		R	—	P [2]	P [3]	P (SAM)
6	SLED Output	F	I & Q	P, $\Delta\phi$ [2]	P	P (SAM), $\Delta\phi$, V(t), Φ(t)
7		R	—	P	P	P (SAM)
8	Accel. 1 Input	F	I & Q	P	P	P (SAM), V(t), Φ(t)
9		R	—	—	P	P (SAM)
10	Accel. 1 Output	F	—	—	P	P (SAM)
11		R	—	—	P	P (SAM)
12	Accel. 2 Input	F	I & Q	P	P	P (SAM), V(t), Φ(t)
13		R	—	—	P	P (SAM)
14	Accel. 2 Output	F	I & Q	—	P	P (SAM), V(t), Φ(t)
15		R	—	—	P	P (SAM)
Injector Station Only						
16	PB 1 Input	F	I & Q	P	P	P (SAM), V(t), Φ(t)
17		R	—	P	P	P (SAM)
18	PB 2 Input	F	I & Q	P	P	P (SAM), V(t), Φ(t)
19		R	—	P	P	P (SAM)

Notes:

[1] Other pulsed signals to be analyzed by HP1428A digitizing scopes will include, for each high-power RF station, modulator voltage, klystron #1 beam current, and klystron #2 beam current.

[2] These signals will be used for SLED delay-line tuning as described in NLCTA Note #16. The phase shift, $\Delta\phi$, is the phase of the SLED output with respect to the SLED input.

[3] A duplicate of this signal, processed by separate electronic circuits, will be used for klystron protection; if the reflected power exceeds a pre-set threshold, the station RF drive will be disabled.

[4] The RF pulse voltage and phase, as functions of time, will be derived from the digitized, demodulated I and Q pulses, and fit to the hypothesis that they are composed of at most two continuous regions of different slope. The fit will be characterized by the set of parameters: (1) intersection point, (2) region-1 average, (3) region-1 slope, (4) rms residual of region-1 fit, (5) region-2 average, (6) region-2 slope, (7) rms residual of region-2 fit. Reduced data, consisting of the fit parameters described above, is indicated in the table as "V(t)" and "ϕ(t)."

TABLE 2. Count of RF Monitor System Signals

	RF from monitor couplers to RF heads	RF to vector demodulators	Video to multiplexers	Video from multiplexers to VXI scopes	Video from diodes (or $\Delta\phi$ circuit) to CAMAC GADCs	Video from diodes to Peak & Holds, CAMAC SAMs
Injector RF Station	19	9	$(2\times9)+3$*	4	11	19
Each Linac RF Station	15	7	$(2\times7)+3$*	2	7	15

*The additional three signals in each high-power rf station are the modulator voltage, klystron #1 beam current, and klystron #2 beam current.

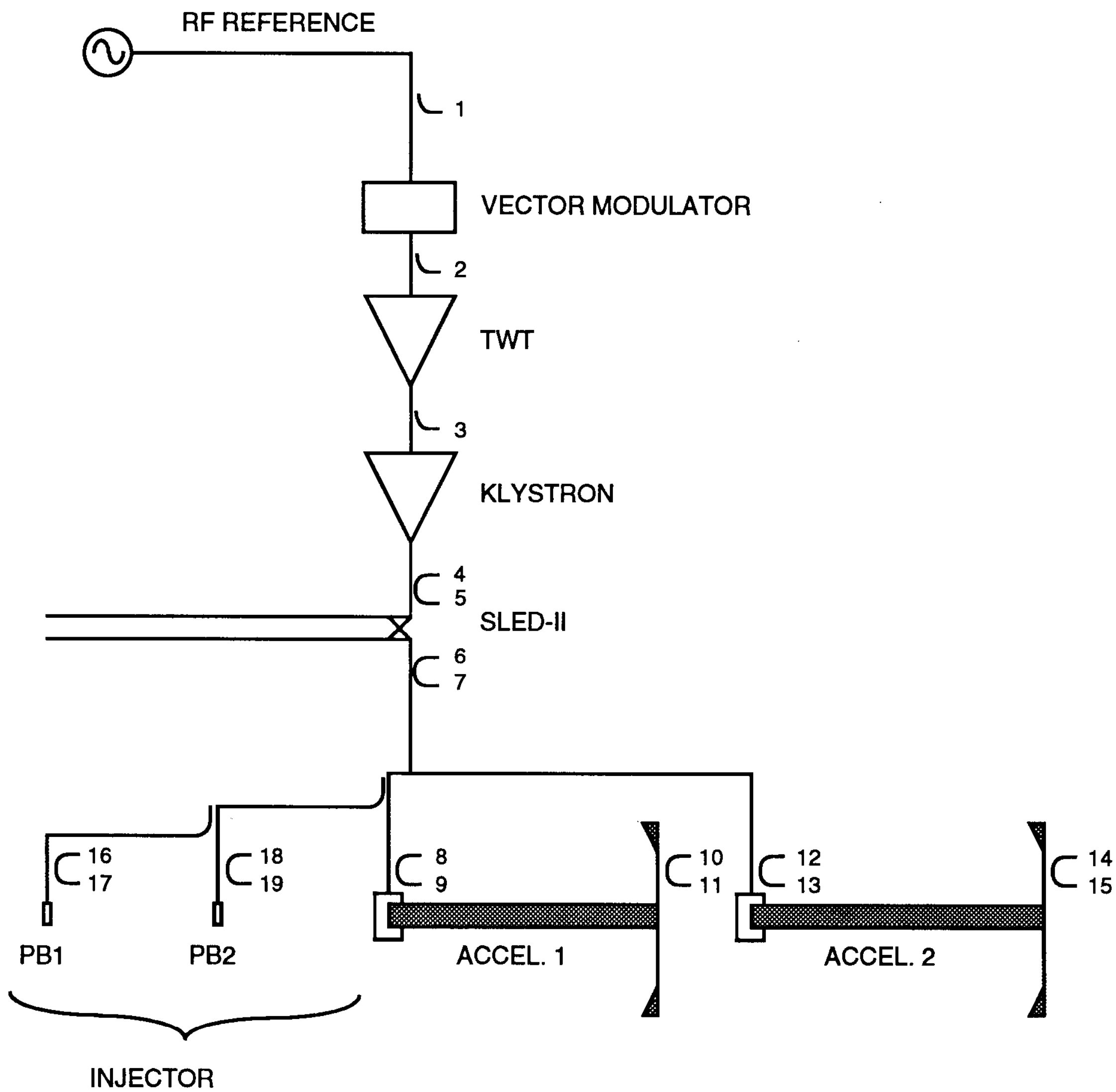

FIGURE 1. Locations of RF monitor couplers in each rf station.

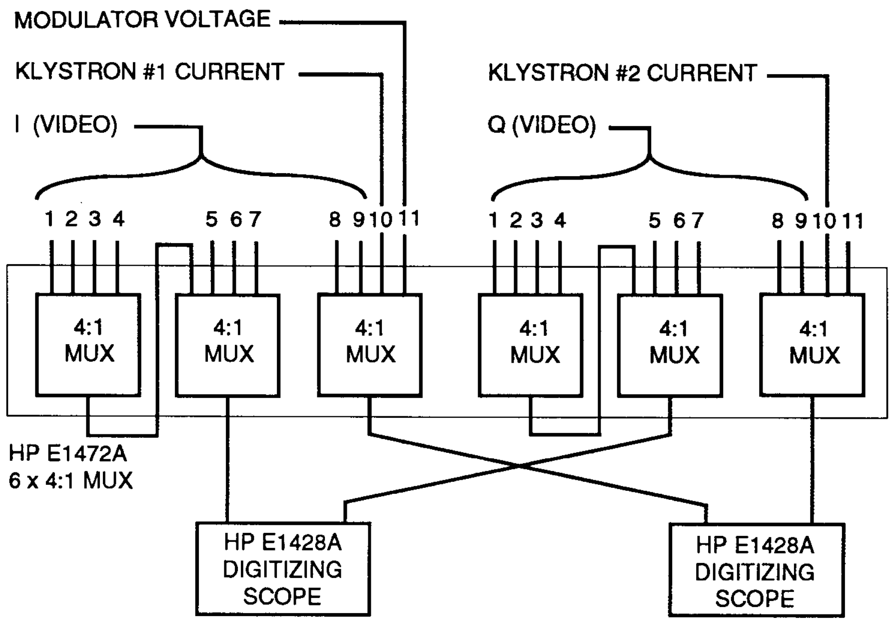

FIGURE 2. Possible video pulse multiplexing scheme for the injector RF station.

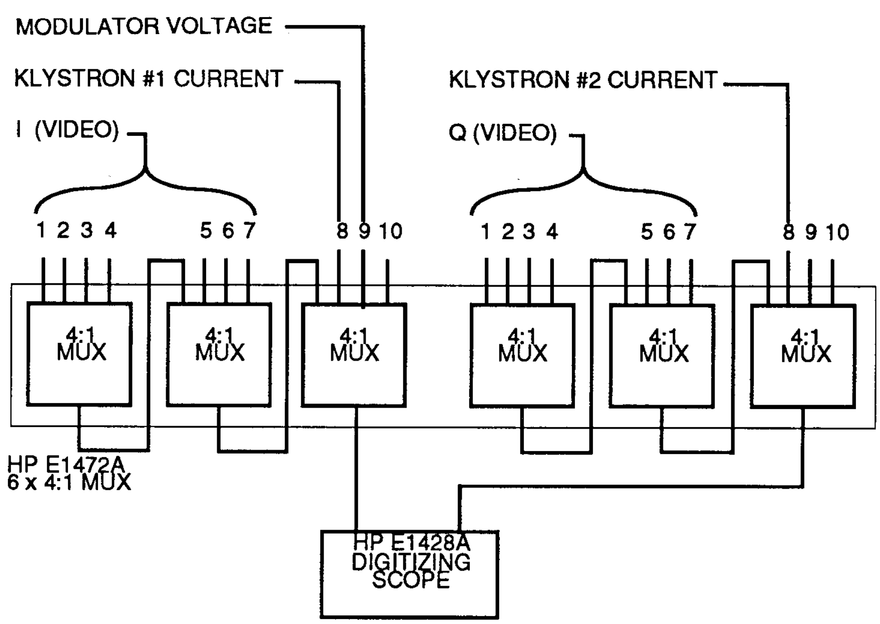

FIGURE 3. Possible video pulse multiplexing scheme for the linac RF stations.