NATIONAL RADIO ASTRONOMY OBSERVATORY

SPECTRAL PROCESSOR PROJECT

SPECIFICATIONS

UPDATE 3

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SPECIFICATIONS
UPDATE 3

0. INTRODUCTION

These updated specifications are based on the December 1982 meeting of the NRAO staff and pulsar and spectral-line astronomers. See Spectral Processor Memo No. 18.

These specifications are goals. Practical cost, hardware and manpower limitations, and trade-offs encountered in the design and prototyping processes will require revisions. Further specification updates may be issued in this memo series.

1. POLARIZATIONS

User selects:

(a) One polarization (P_1).

(b) Sum of 2 orthogonal polarizations (P_σ).

(c) Two orthogonal polarizations (P_2).

(d) Four polarizations which yield 4 Stokes parameters (P_4 obtained by 2 IF inputs and 4 spectrometer/processors singly or in combination).

2. INSTANTANEOUS TOTAL BANDWIDTH f_B OF OUTPUT FREQUENCY SPECTRA

(a) 20 MHz total available bandwidth is necessary from each spectrometer quadrant.

(b) 40 MHz from each spectrometer half.

(c) Narrower total bandwidths are required to achieve higher frequency resolution and to avoid extremely strong RFI.

3. FREQUENCY RESOLUTION (Δf) AND MERGING IN FREQUENCY OF OUTPUT SPECTRA

(a) Δf is center-to-center frequency spacing between channels.

(b) Require spectral resolution Δf ranging from 76 Hz to 78 kHz in each spectrometer quadrant.

(c) User selects Δf in steps of 1, 2, 4, 8, 16 ..., i.e., divide by 2^0 to 2^{10}.

(d) Wider Δf's may be derived by summing adjacent filters (merging in frequency).

4. FREQUENCY RESPONSE OF INDIVIDUAL CHANNELS

(a) The frequency response of a single frequency output channel of the FFT shall be selectable according to the resolution and interference rejection requirements.

(b) The highest resolution frequency response shall be very close to $(\sin(\pi s)/\pi s)^2$ where s is the frequency offset in units of the channel spacing.

(c) The best narrow-band interference handling frequency response shall be below 55 dB when the signal is more than five channels away in frequency.

(d) A frequency response intermediate between (b) and (c) shall be available which provides better interference rejection than $(\sin(\pi s)/\pi s)^2$, but has better resolution and signal-to-noise ratio than option (c).

5. TIME RESOLUTION (Δt) AND MERGING IN TIME OF OUTPUT SPECTRA

(a) $\Delta t = 256/f_B$ per quadrant in pulsar mode or $\Delta t = 1024/f_B$ per half in line mode (e.g., $\Delta t = 12.8$ μs for $f_B = 20$ MHz per quadrant).

(b) User selects longer ΔT time resolution by averaging each channel over n Δt (merging in time) for $\Delta T = n\ \Delta t$ up to 20 s.

(c) Direct time-series sampling: it is highly desirable to be able to bypass the FFT and store (possibly with some time merging) complex time samples up to the limit of the buffer memory. This can be done in a "burst mode" fashion.

6. DEDISPERSING FREQUENCY SPECTRA, SHIFTING IN TIME VS. FREQUENCY

(a) User selects 0 μs to 10 ms channel-to-channel time delay Δt_D by inputting dispersion measure and sky center frequency.

(b) Δt_D increment = Δt and multiples.

(c) $\leq 0.5\ \Delta t$ uncertainty in delay of a single channel with respect to nominal delay.

(d) On-line computer selects 2nd order delay distribution across filter banks so that Δt_D of i^{th} channel = $k\ (f_{sky})^{-2}$.

(e) There should be the capacity to handle signals with sky frequency increasing or decreasing with channel number (IF spectrum non-inverted or inverted relative to sky spectrum).

(f) User/on-line computer sets Δt_D independently in quadrants A, B, C, D to permit offset sky frequencies f_{SA}, f_{SB}, f_{SC}, f_{SD} for dispersion measurements.

7. PERIODIC TIME AVERAGING OF FREQUENCY SPECTRA, PERIODIC MERGING IN TIME

   (a) User selects 300 μs to 10 s pulsar period (P_p).

   (b) 4 x 2048 point pulse profile storage capability is required.

   (c) 32 x 256 point spectrum storage capability is required.

   (d) User selects number of periods in average (N_p) up to 256.

8. TIMING

   (a) 5 MHz maser standard is reference input.

   (b) 1 second UTC pulse is reference input.

   (c) UTC clock is referenced to VLBI clock.

   (d) Clock, delay and period generation must be phase-coherent.

   (e) LO's for frequency translators must be phase-coherent.

9. TOTAL SYSTEM DELAY

   (a) Must be measurable and put into on-line computer.

10. AMPLITUDE CALIBRATION

   (a) Front-end must have two independently controlled pulsed noise cals, one in each feed polarization.

   (b) User selects 0 to 10 s pulsed cal period, P_c.

   (c) User selects 0 to 5 s pulsed cal width, t_c.

   (d) User selects pulsed cal phase with respect to period, i.e., Δt_c.

   (e) Pulsed cal period, width and phase increments = Δt.

   (f) Front-end delay in turn-on and turn-off $\leq 0.1\ \Delta t$.

11. AMPLITUDE DYNAMIC RANGE

(a) None of the electronics shall measurably gain-compress (saturate) in the presence of a signal with an instantaneous power equal to 10 times the system noise power.

(b) The IF signal at the initial stages of the processor shall have sufficient amplitude resolution that changes in input noise power shall not have a measurable effect on the total system bandpass shape. The amplitude quantization shall not reduce the sensitivity of the spectrometer by more than 5%.

12. EXCISING RFI

(a) Automatic, high speed, temporal data excision will be available for wideband interference suppression. This feature may be disabled by the observer.

(b) Narrowband interference will be excised by manually or automatically dropping specified frequency channels before dedispersion.

13. DISPLAY

(a) All user input parameters will be continuously displayed or manually selected for display.

(b) Status of 5 MHz, 1 s UTC, UTC clock inputs and noise cal outputs will be displayable.

(c) Activity indicators for RFI excising, de-dispersion, averaging and digital output spectra in each spectrometer will be displayable.

(d) Real-time output spectra will be displayed for line observing and displayable in some limited form for pulsar observing.

(e) Real-time accumulated pulse profiles during signal averaging will be displayable.

14. USER INPUTS

User will input via manual means and via on-line computer the following:

(a) Pulsar or spectral line mode.

(b) Polarizations P_i.

(c) Total bandwidth f_B.

(d) Frequency resolution Δf if $> f_B/N$ where N = 256 for pulsar, N = 1024 for line mode.

14. USER INPUTS (Continued):

(e) Dispersion delays Δt_D, t_D and k; also sign.

(f) Pulsar period P_P and number of periods in average, N_p.

(g) Noise cal period P_C and duration t_c, delay Δt_c relative to start of period.

(h) IF and sky frequencies.

(i) RFI excising on/off status.

(j) Start/end scan; scan in progress.

15. DIGITAL OUTPUTS TO ON-LINE COMPUTER

(a) Must be compatible with DMA bus of on-line computer.

(b) Archive data will be output to 1/2" magnetic tape, 9 track, 1600 BPI (possibly 6250 BPI instead).

(c) Setup parameters.

(d) UTC time at start of current observation, resolution of 1 μs.

(e) Frequency spectra or pulse profiles from 4 spectrometer quadrants or 2 spectrometer halves, put out at time intervals of ΔT.

(f) Status of pulsed noise cals.

(g) Summary of RFI excising activity in some limited form.

16. PROCESSOR SET-UP PARAMETERS FOR OBSERVATIONAL OBJECTIVES

(a) See Table 1.

17. PROCESSOR FUNCTION DIAGRAM

(a) See Figures 1 and 2 which are the current working diagrams. Detailed design work can be expected to change them consistent with the specifications. Particularly, multiplying polarimetry (at the post-FFT "squarer" stage) and the combination of dedispersion and merging into a random access adder stage (cf. Hankins, memo No. 18) will be considered.

PROCESSOR PARAMETER	OBSERVATIONAL OBJECTIVE				
	Pulsar Search	Pulsar Timing and Dispersion	Pulsar Polarization and Scintillation	Pulsar Single Pulse Profiles	Spectral Line
Instantaneous Bandwidth, f_B	$\leq$ 20 MHz 40 MHz useful	$\leq$ 20 MHz 40 MHz useful	$\leq$ 20 MHz	$\leq$ 20 MHz	$\leq$ 40 MHz
Number of Channels .... N	256/quad	256/quad	256/quad	256/quad	1024/half
Frequency Resolution ... Δf	0.05 kHz to 2 MHz	0.05 kHz to 2 MHz	0.05 kHz to 2 MHz	30 kHz to 2 MHz	0.1 kHz to 39 kHz
Time Resolution ..... ΔT	0.1 to 1 ms	0.01 to 1 ms	0.1 to 1 ms	$\geq$0.01 ms	1 to 20 s
Polarizations ..... P_i	Sum of 2 orthogonal	Two orthogonal	Four	Two orthogonal or 4	Sum or 2 orthogonal
Dedispersion	None.	Yes or none.	Yes.	Yes.	None.
Periodic Time Averaging	None.	Yes.	Yes or none.	None.	None.

TABLE 1

Processor Set-Up Parameters for Observational Objectives.

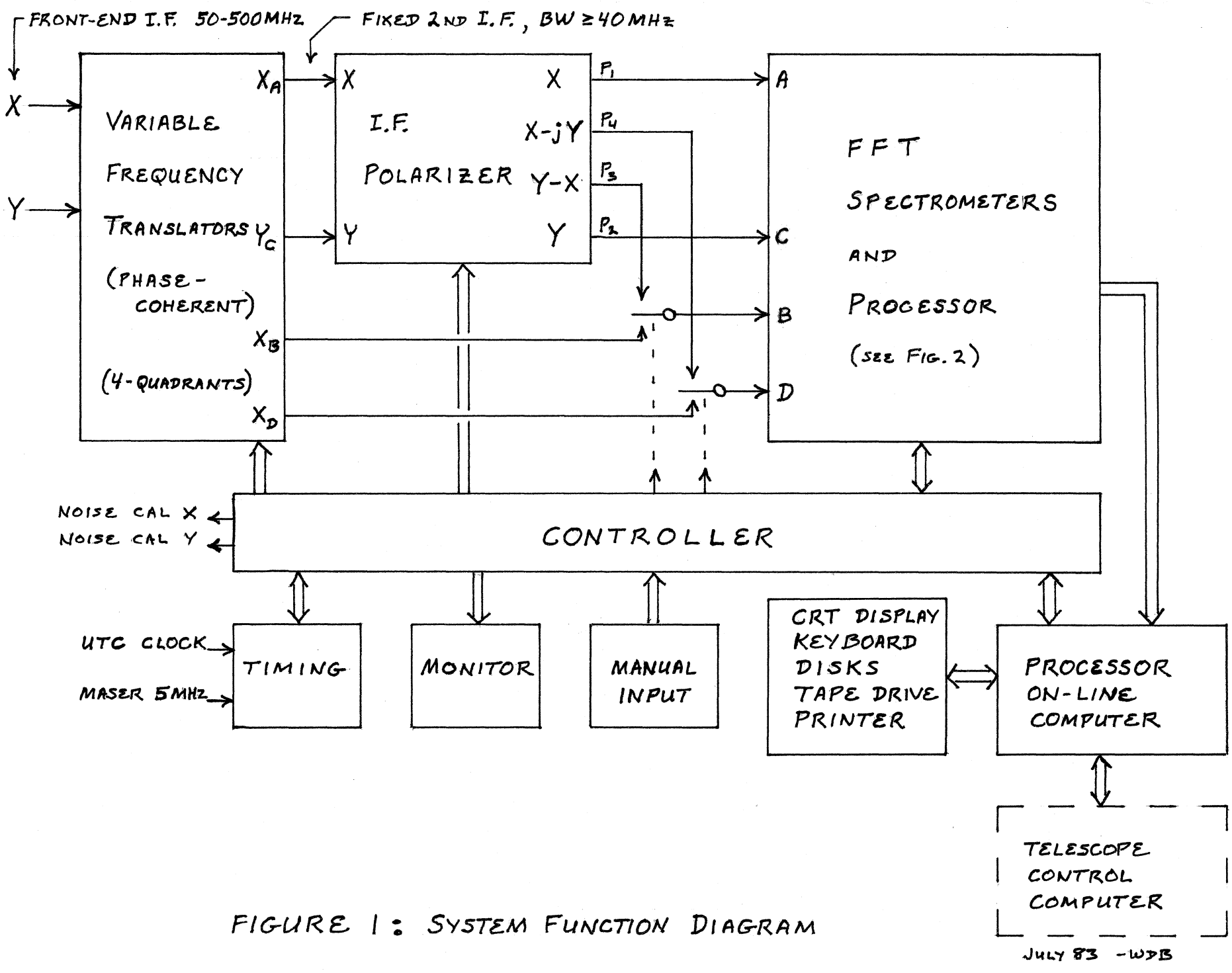

FIGURE 1: SYSTEM FUNCTION DIAGRAM

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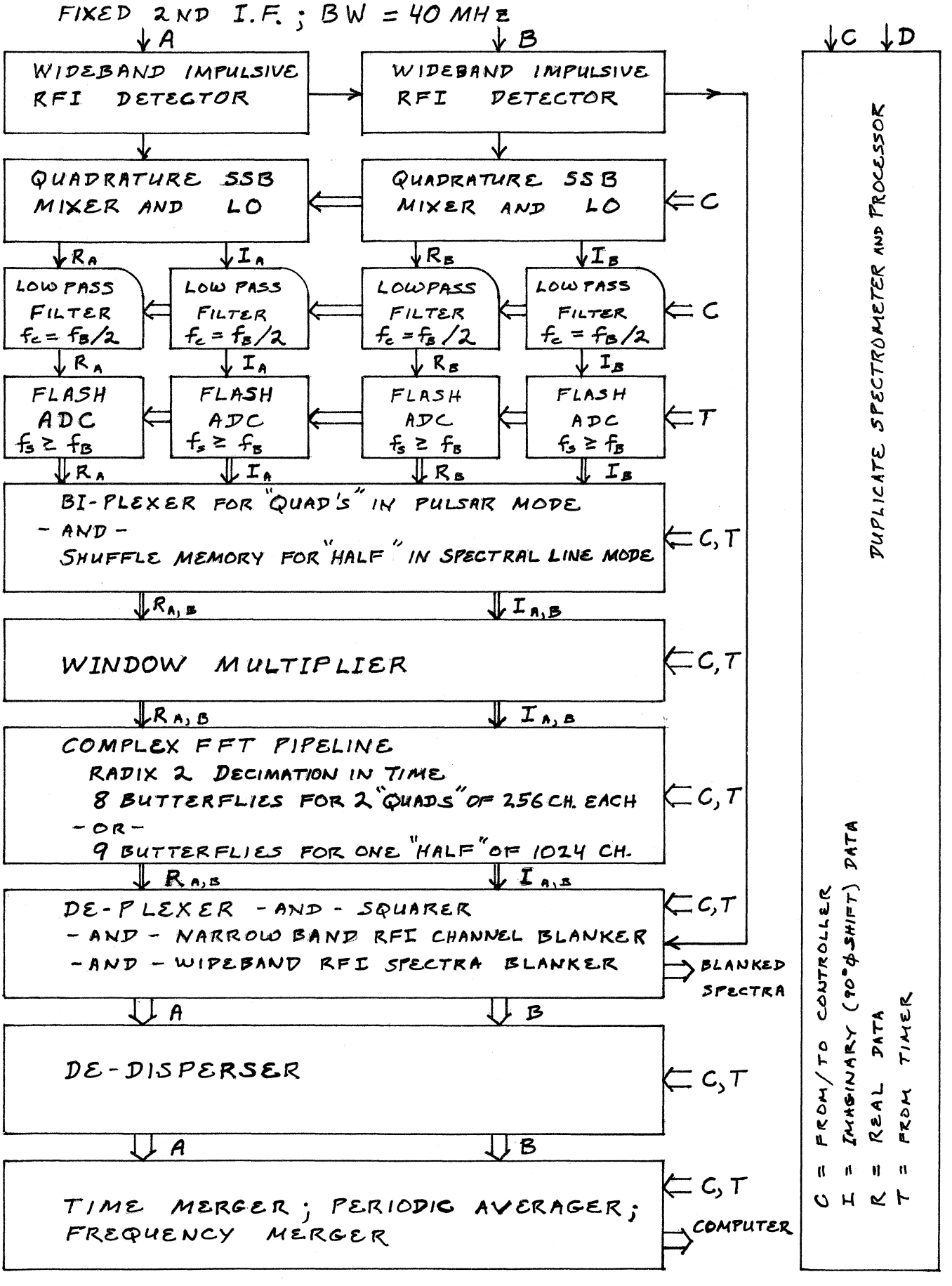

FIGURE 2: SPECTROMETER AND PROCESSOR FUNCTION DIAGRAM