David 10/7/91

New Spectrometer for the GBT

Technologies

1. XF Correlator (traditional lag correlator)
    a. Quantization
    b. Oversampling
    c. Used by Mark IV, NRAO 12m

2. FX Spectrometer (Fourier transform first)
    a. Quantization
    b. Data padding
    c. Used by Spectral Processor, VLBA

3. Hybrid (filter bank plus digital spectrometer)
    a. Versatile IF
    b. Matchup problems
    c. Used by NRAO 12m, VLBA

4. Acousto-Optic Spectrometer
    a. Cost effective
    b. Used by SEST, KOSMA

5. Other new techniques
    a. Adaptive interference filtering
    b. Digital filtering
    c. Xilinx spectrometer

NEW SPECTROMETER FOR THE GBT

1. VLSI CORRELATOR CHIPS

VLSI Chip	Tech.	Quant.	Lags Per Chip	Clock Rate (Mhz)	Integ. Depth (bits)	X per Sec. (billion)
VLA (2 chips)	ECL Custom	3 Level	2	100	14	0.2
NFRA Bos	CMOS Gate Array	Modified 2-Bit	16	50	16	0.8
CalTech - OVRO	ECL Macro Cell	Modified 2-Bit	8	256	6	2.05
JPL	ECL Gate Array	Modified 2-Bit	26	256	3 (prescale)	6.66
CalTech - CSO (Development)	CMOS Custom	Modified 2-Bit	320	250	16	80
Spaceboume (Proposed)	CMOS Custom	Modified 2-Bit	16 (256)	1000	32	16 (256)

2. SENSITIVITY

		Nyquist Rate	2x Nyquist Rate
a. Full 2 Bit	=	**0.88**	**0.94**
b. Modified 2 Bit	=	**0.87**	**0.93**
c. 3 Level	=	**0.82**	**0.89**

3. REFERENCE

1. Brian Von Herzen, "VLSI Partitioning of a 2-Ga/s Digital Spectrometer", IEEE Solid-State Circuits, Vol. 26, No. 5, pp 768-772, May 1991.

2. K. Chandra and W. Wilson, "Digital Autocorrelator Spectrometer", JPL Internal Report # JPL D-8056, Dec. 1990.

3. A. Bos, "The NFRA Correlator Chip", NFRA Internal Report #176, Rev. April 1989.

JPL CORRELATOR

- SPECIFICATIONS - Test correlator built in 1990

Clock Rate	-	256 MHz
Bandwidth	-	128 MHz
Power	-	250 mW/channel
Channels	-	52 (2 chips)

- CHIPS APPLICATION

  Microwave Limb Sounder (Eos/MLS)

  Submillimeter Infrared Line Survey (SMILS)

  Large Deployable Reflector (LDR)

- CHIP ADVANTAGES

  1. Most powerful chip available today
  2. Gate-Array design would allow some modification.
  3. Moderate power usage

- CHIP DISADVANTAGES

  1. Non-ideal integrator design
  2. Expensive packaging

JPL 5-Channel Correlator

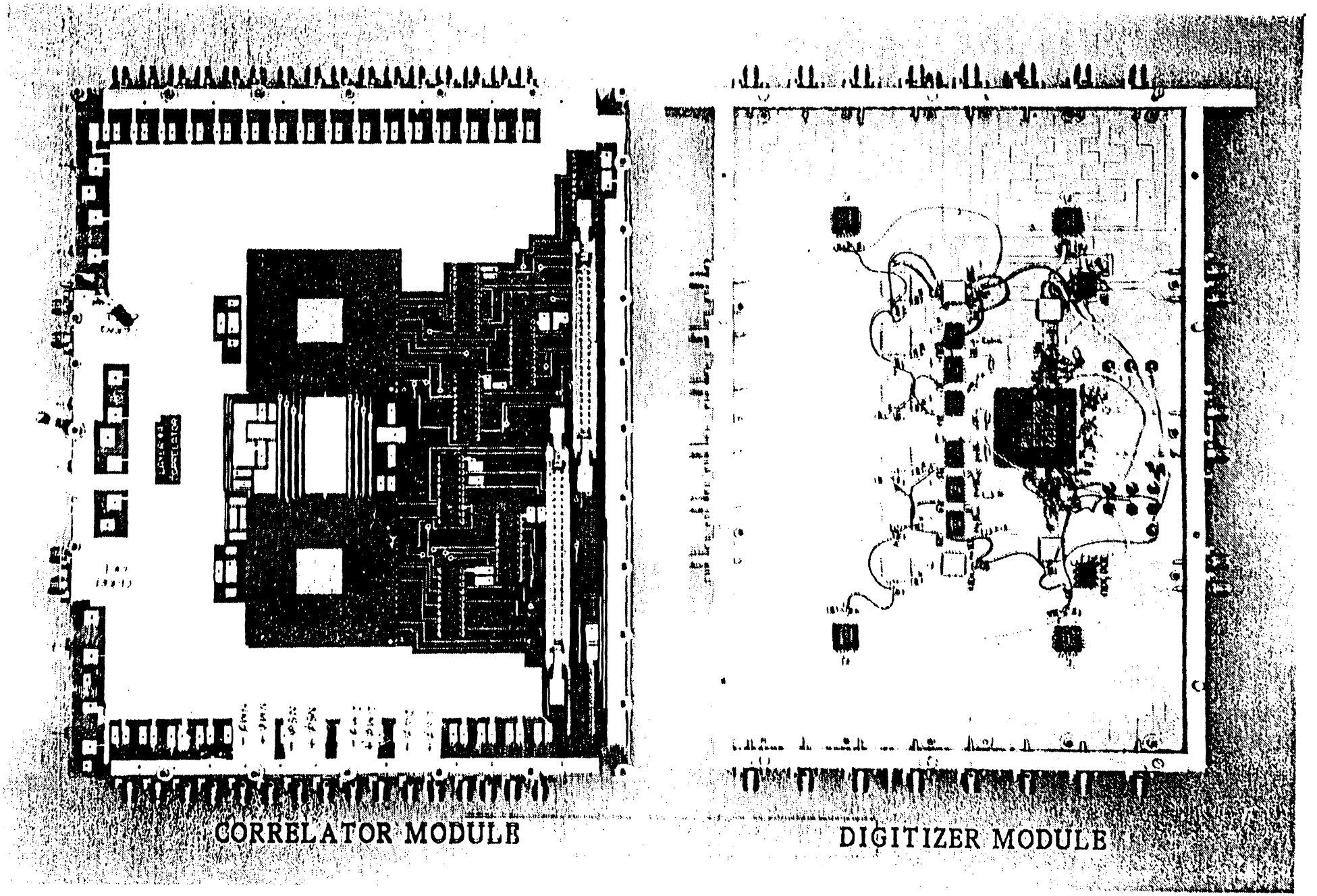


FIG. 8

CALTECH CSO CORRELATOR

- SPECIFICATIONS - Development board due Jan. 1992

Clock rate	-	250 MHz
Bandwidth	-	1 GHz
Power	-	18 mW/channel
Channels	-	320 (8 chips)

- CHIP APPLICATION

  CalTech Submillimeter Observatory (CSO)

- CHIP ADVANTAGES

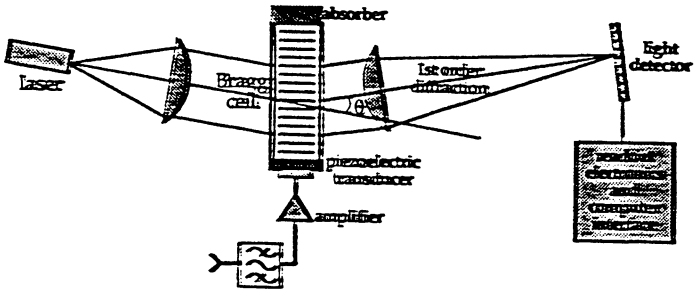
  1. Major advance in performance
  2. CMOS, LO power
  3. Full accumulator

- CHIP DISADVANTAGES

  1. No cascading outputs
     (i.e., requires external delays)
  2. Still in development

New Spectrometer for the GBT

1. Acousto-Optic Spectrometer



2. Cheap

3. Off-the-shelf AOS spectrometers available.
   a. Elson
   b. Automates et Automatisivies
   c. University of Cologne

4. Polarization Switching Bragg Cells improve stability

5. Wide-bandwidths AND high-resolution (>1000 frequency samples)
   a. Multi IF channel device cost is not proportional to number of IF channels

6. No quantization loss

7. Input power dynamic range very good (60 db)
   a. Therefore, does not cause degradation in the presence of strong interference.

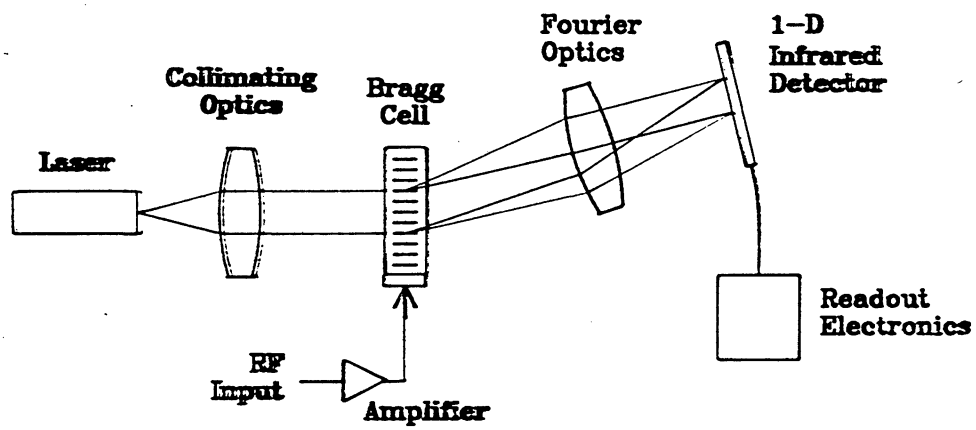
8. Requires frequency calibration

9. Fixed bandwidth and frequency resolution
   a. Requires multiple instruments to give useful range of bandwidth vs frequency resolution tradeoffs

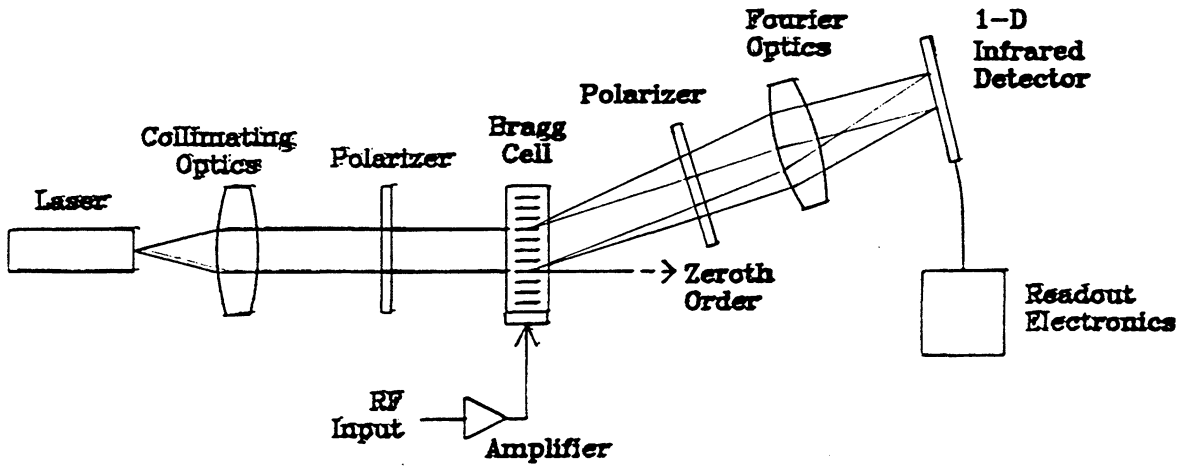
10. Analog device
    a. Stability questions
    b. Cross-correlations not possible

AOS – Polarizing Bragg Cell

Conventional AOS



Polarization Switching AOS



AOS SOURCES

FULL SPECTROMETERS

1. Automates et Automatisivies, Sa
   6/8 rue de Versailles
   78470 St. Remy Les Chevreuse
   France

   Tel: (33) 1.30.52.23.65

   Specified Products:

	SAO 60	SAO 180	SAO 500
BW (MHz)	60	180	500
Res (MHz)	0.15	0.4	1.2

2. Harris Corp.
   Electronic Systems Sector
   Melbourne, FL 32902

   Specified Product: (In development for JPL)

   AOS_2 BW = 1 GHz

3. Elson
   L. J. Malkamäki
   Kuhatie 15
   SF-01490 Vantao
   Finland

   BW 500 MHz - 1.2 GHz

AOS SOURCES

BRAGG CELLS

1. GEC - Marconi
   West Hanningfield Rd.
   Great Baddow
   Chelmsford, Essex CM2 8HN
   England

   Tel. 0245 73331

2. Brimrose Corp.
   5020 Campbell Blvd.
   Baltimore, MD 21236

   Tel. (301) 931-7200

3. Newport Electro-Optics
   4451B Enterprise Court
   Melbourne, FL 32934

   Tel. (407) 254-0300

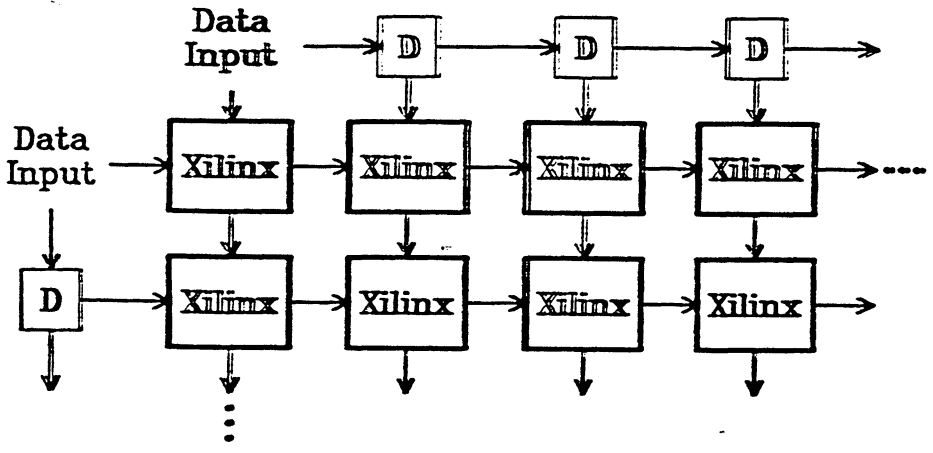
RESEARCH EFFORTS

1. JPL

2. University of Cologne

New Spectrometer for the GBT

1. Xilinx Spectrometer
   A. Electrically programmable gate array



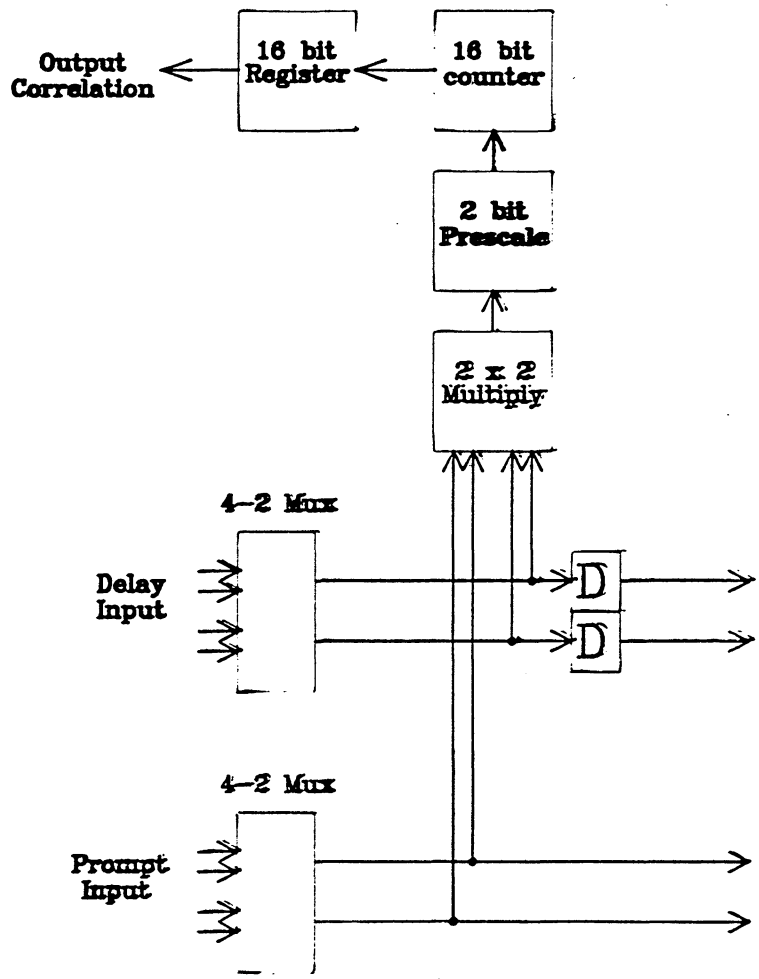
2. Downloadable Personality
   A. Tradeoff quantization for number of channels
      For examples:
      1 bit => x channels
      2 bit => x/2 channels
   B. Random sampling to increase resolution (tradeoff sensitivity)
   C. Oversampling
   D. Digital prefiltering
   E. FX-type spectrometer
   F. Cross-Correlation
   G. Simplifies mode design, i.e., data multiplexing

3. Capabilities can be expanded with improvements in Xilinx chips

4. Disadvantages:
   A. More expensive

Xilinx Correlator

XF Correlator Components



XILINX SPECTROMETER

Xilinx CLB's

Series 4000 64 - 900 CLB's per chip

Series 3000 64 - 320 CLB's per chip

Speed: 40 - 80 MHz

Correlator chip using XC4020

900 CLB's → 42 Lags

Assuming full utilization

Correlations per second (60 MHz) = 2.5 billion/sec

Correlation chip using XC3090

320 CLB's → 15 Lags

Assuming full utilization

Correlations per second (60 MHz) = 0.9 billion/sec

XILINX SPECTROMETER

MODIFIED 2-BIT CORRELATOR REQUIREMENTS

X = Number of Lags

	Device	Quantity Required	CLB's[1]
1.	4-to-2 Mux	2	2
2.	Delays	2X	X
3.	2 x 2 Multiplier (Modified)	1X	$2X^2$
4.	2-bit Prescaler	1X	2X
5.	16-bit Counter	1X	8X
6.	16-bit Shift Register	1X	8X

Total CLB's = 2 + 21X

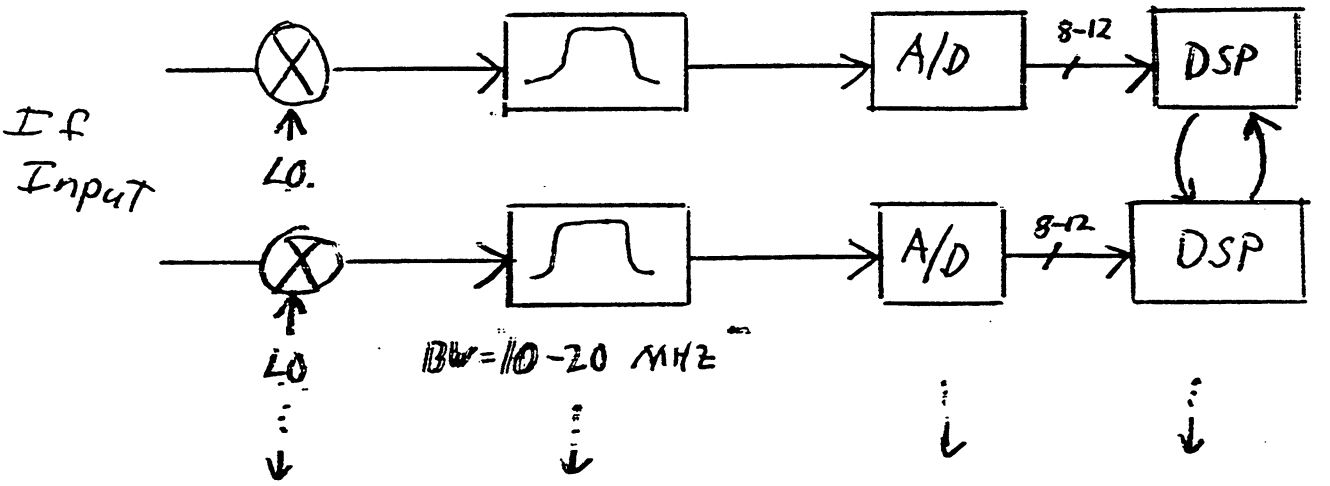
[1] Xilinx Data Book

[2] NFRA Technical Note #176

DSP SPECTROMETER

1. Use off-the-shelf DSP chips

   - Hybrid/FX architecture



2. Advantages

   - More control of transform
   - Adjustable parameters
   - Easier to avoid interference
   - Very high sensitivity

3. Disadvantages

   - More expensive
   - Very hybridized

New Spectrometer for the GBT

1. FX vs XF
   a. Similar cost using available VLSI chips

2. XF spectrometer (traditional lag correlator)
   a. Simple fixed precision arithmetic
   b. Plethora of VLSI chips available
   c. Simple quantization correction
   d. Less operations-per-sec for hybrid type
   e. Easier to blank (invalid data)

3. FX spectrometer (Fourier transform first)
   a. More complicated
   b. Tighter effective filter shape
   c. Could use VLBA butterfly chip
   d. Less operations-per-sec at high resolution and for cross-correlation modes.

4. Comparison of effective filter shape