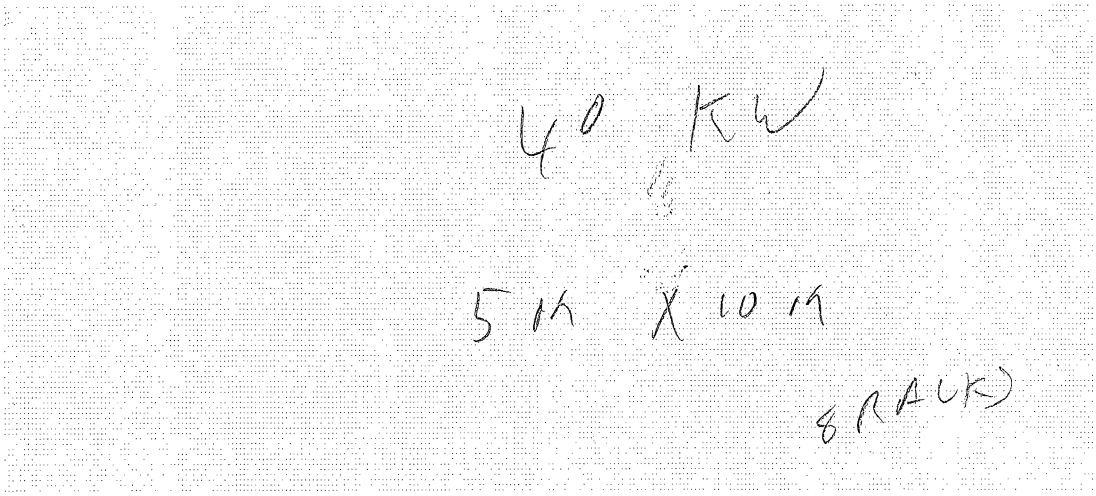

ACA Correlator Technical Specifications and Requirements

ALMA-J-62.00.00.00-001-A-SPE

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1 Summary

This document describes the technical specifications and requirements of ALMA ACA correlator. The ACA correlator is a FX-type correlator to realize an enhanced spectroscopic capability that enables a flexible allocation of frequency resolution and the widest bandwidth. The detailed specifications of the ACA correlator are summarized in Table 1.

Table 1. Specifications of the ACA Correlator.

Item	Specifications	Remarks
Number of antennas	16	
Number of max. cross-correlations	120	
Bandwidth per baseband	2 GHz	
Number of baseband input per antenna	8	Input format 3bit, 4Gsps
Correlation functions	cross + auto	
180-degree phase switching	yes	
Image band rejection (90-degree switching)	yes	
delay compensation	30 km	
Highest frequency resolution	3.8 kHz	Without a reduction of the total bandwidth
Correlation: Number of bits	4 bits	3bit + sign
Maximum number of frequency channels per baseband pair per baseline	8192 channels	
Minimum integration time	1 msec (auto) 16 msec (cross)	
Number of Sub-array	2	Supports single-dish mode and ACA interferometry simultaneously
Polarimetry	yes	HH,VV,HV,VH(for orthogonal H and V)*
VLBI phase-up mode	yes	

*Resulting in 8192, 4096, and 2048 spectral channels across the baseband spectrum, depending on polarization mode.

The ACA correlator supports a simultaneous operation both of the ACA interferometric observations with twelve 7-m antennas and the single-dish observations with four 12-m antennas. All 16-element interferometric observations of ACA system are also supported. One more important point is high sensitivity. The loss of sensitivity caused by quantization of the signal should be minimized. Thus the ACA correlator calculates 4-bit correlation, recovering 9 % in sensitivity relative to the 2-bit correlation case of ALMA baseline correlator (eBLC) (see RD 01). This is a great compensating advantage for the smaller collecting area of the ACA antennas to assure that the ACA system can provide the single-dish and short-baseline data for the ALMA science programs whenever necessary.

2 Related Documents and Drawings

2.1 References

No	Document Title	Date	Reference
RD 01	64 Antenna Correlator Specifications and Requirements	2004-02-11	ALMA-J-60.00.00.00-001-B-SPE

2.2 Abbreviations and Acronyms

RD	Reference Document
ACA	Atacama Compact Array
ALMA	Atacama Large Millimeter Array
ALMA-B	ALMA Bilateral
ALMA-J	ALMA Japan
SE&I	System Engineering and Integration
eBLC	enhanced Baseline Correlator
IPT	Integration Product Team
BE	Back-End
WDM	Wavelength Division Multiplexing
DTS	Data Transmission System
FO	Fiber Optical
DTS-R	DTS Receiver
FFT	Fast Fourier Transformation
STI	Short Term Integration
CRG	Central Reference Generator
CRD	Central Reference Distributor
CCC	Correlator Control Computer
CDP	Correlator Data Processor

3 System Block Diagram

The ACA correlator is characterized by the following performances: wideband (2000 MHz) and **high frequency resolution**. **The highest spectral resolution is 3.8 kHz**. We plan **4-bit correlation** for 3-bit input data. Just after the calculation of correlation, the output frequency bins are reduced to be 8192 per two basebands. Total correlation number is 8 times 120 for cross-correlation and 8 times 16 for auto-correlation.

We show the system block diagrams of the ACA correlator in Figure 1. Each square represents the requested functions for the ACA correlator whose specifications are listed in Table 1. The optical data from two polarization-pair basebands of one antenna are sent to the DTS Receiver (DTS-R) part in the ACA correlator. After the Optical-to-Electronic signal conversion, 3-bit digital data are sent to the FFT (F) part with 125MHz clock. In the F part, delay compensation and FFT are performed and the spectral data are obtained. After the re-arrangement of data by corner-turner, the correlations of the spectral data from different antennas are calculated and the frequency-channel binning is performed in the Correlation (X) part. Then the number of frequency bins is reduced to 8192 per 2- baseband data and the spectral data are integrated up to 16 msec for the cross-correlation and 1 msec for the auto-correlation.

Figure 2 represents the relationship between the ACA correlator subsystem and the ACA Backend and computing system. Data interfaces between the ACA Backend system and the correlator (the input optical IF data and the FO receiver) are marked with a red circle named A. Clock signals of 125 MHz and 48 msec are also supplied from Central Reference Generator (CRG) and Central Reference Distributor (CRD) in AOS technical building to the correlator, respectively (a red circle named B in Figure 2). Control interface between the DTS-R part in the correlator and ALMA control subsystem through CANBUS is marked with a blue circle named C. They (A, B, and C) are the same as those used in the 64-array ALMA system. Interface between the ACA correlator software subsystem and ALMA control system marked with blue circles D and E are also almost the same as those of the 64-array ALMA system. ACA CCC and CDP are directly interfaced with the ALMA computing system. Black circles are the internal interface points between the ACA correlator and the ACA correlator software subsystem.

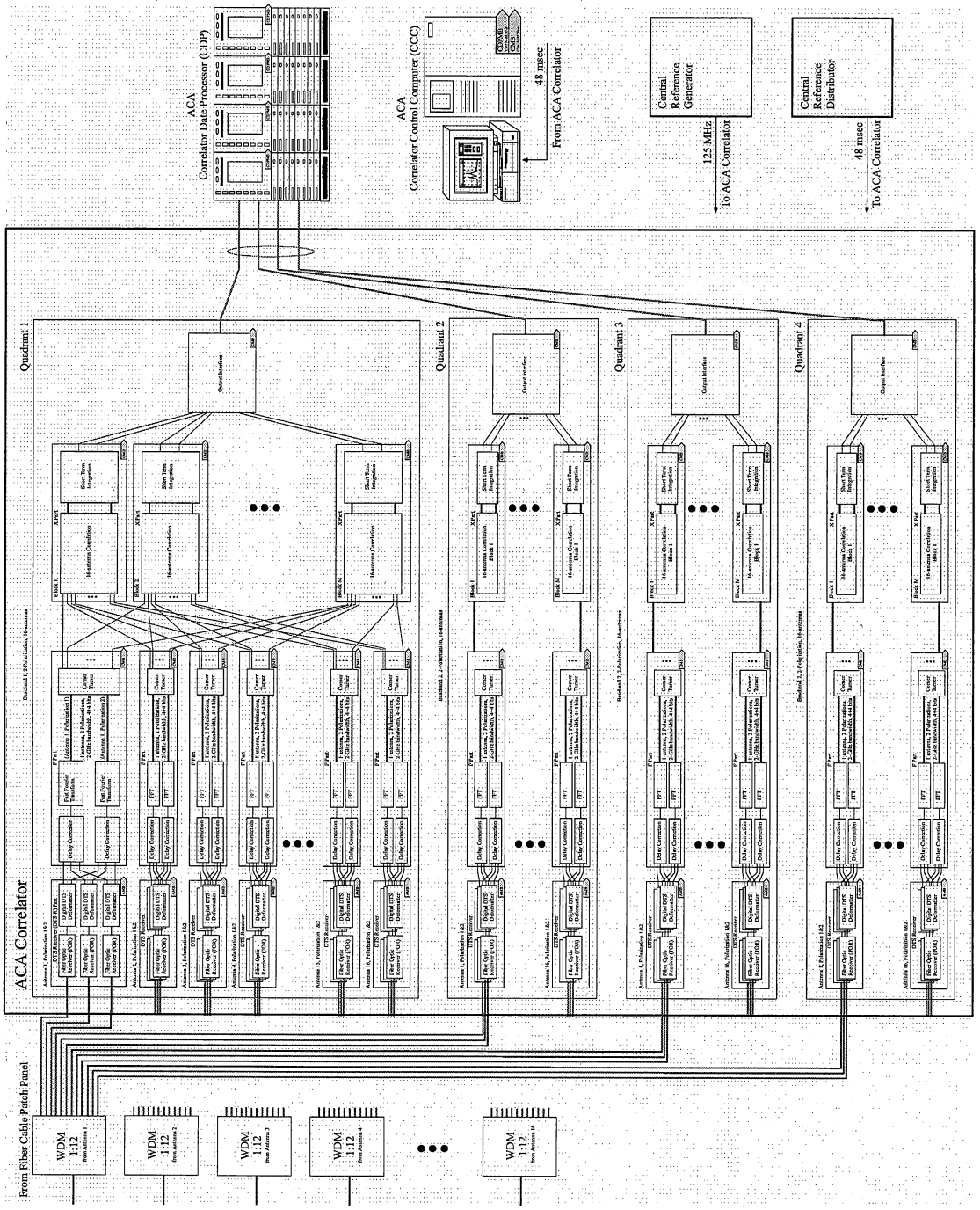

Figure 1. ACA Correlator system block diagram.

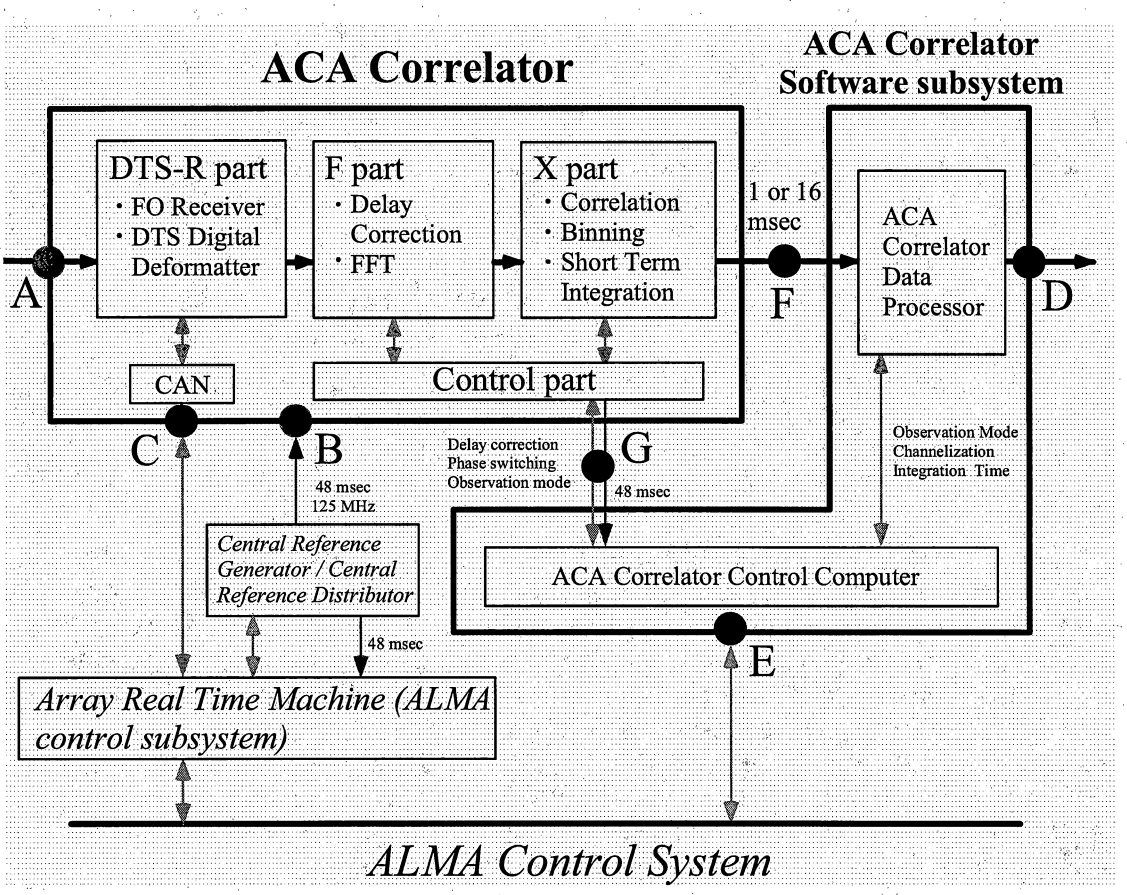

Figure 2. Relationship between the ACA correlator subsystem and ACA BE and computing system.

4 Sub-system Description

4.1 DTS-R Part

The ACA correlator includes the ACA DTS Receiver consisting of FO receiver and DTS digital deformatter. This configuration is specified in the ACA Correlator, similar to eBLC (see RD 01). Eight sets of 4Gsps 3-bit digital signals are sent to the Data Transmission System, which will carry the digital signals with the form of optical signals from the antennas to the ACA correlator located in the technical building in AOS. The system block diagram of all the ACA Backend system is the same as that of the ALMA 64-array BE system (see RD 01).

FO receiver and DTS digital deformatter communicate with Array Real Time Machine through CAN interface. The same monitor and control functions will be installed on the CAN interface in the correlator hardware.

4.2 F Part

The digital data from two polarization-pair basebands of one antenna are sent to the F part of the FX correlator with 125MHz clock. We can use **the imaginary-part circuit of FFT for the calculation of another time-series (segment) of data.** The input signal to FFT is originally real-signal and the nominal imaginary part is the complex conjugate of the real part. We can separate two sets of time-series (segments) of data after calculating FFT. This will increase the effective processing speed and reduce the total amount of the FFT circuit. Functions of phase switching and delta W correction (residual fringe rotation) are also supported in the FFT-part. After the FFT and phase switching and correction, the spectral data are normalized and **re-quantized** using auto-correlation data. Then the spectral data are sent to the X part with the re-arrangement according to the order of frequency. **Re-quantization** is to decrease the number of bits of the complex data sent to X part from more than 9 bits to 4 bits. This function resolves the pin-limitation and cabling problem between F part and X part.

4.3 X Part

The spectral data is divided to M frequency blocks, and is correlated by the baseline number of 120 for cross correlation. **The flexible frequency-channel smoothing** is performed in the calculation of correlation. **No fan-out of the station-based spectral data is proceeded except for the correlation LSI.** It also minimizes the pin-limitation problem in the X part. **Flexible frequency-channel smoothing** is also newly applied for the spectral data just after the calculation of correlation in the X part. Observers can determine the appropriate frequency-resolution for the corresponding frequency ranges almost freely at the unit of highest frequency-resolution over the full 2-GHz baseband. The example of the frequency-channel smoothing is shown in Figure 3. We can also support all the same performance modes of eBLC listed in Table 2-4. Then the number of frequency channels is reduced to 8192 per 2-baseband data. The correlated spectral data are integrated up to 16 msec in the circuit of Short Term Integration for cross- and auto- correlations. Minimum dump time of 1 msec is supported in case for the auto-correlation of four 12-m antennas.

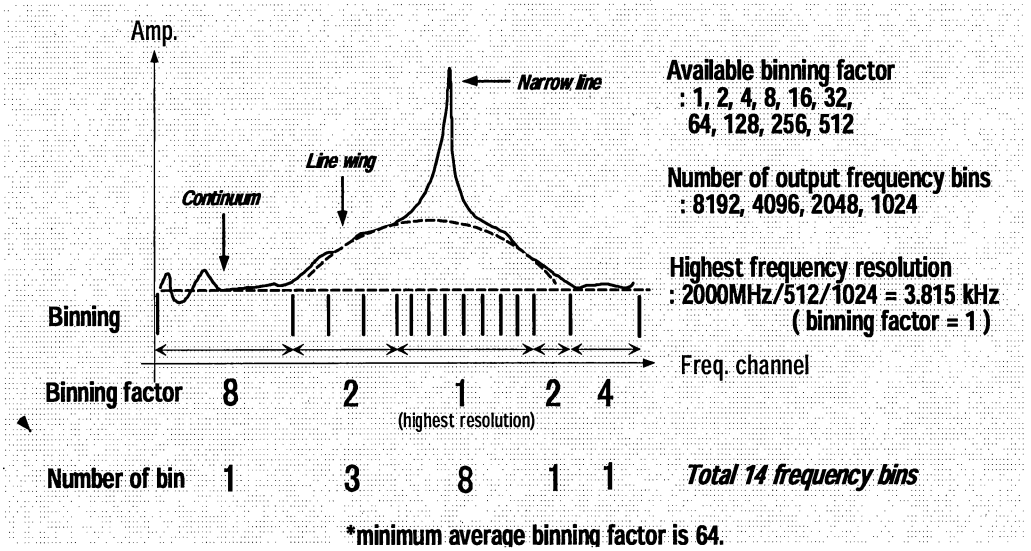

Figure 3. Schematic view of the flexible frequency-channel smoothing for the example of visibility ampliture spectrum.

4.4 Control Part

ACA correlator communicates with ACA-CCC through its control part as shown in Figure 2. Internal ICD between ACA-CCC and the control part of ACA correlator are being prepared. All the commands to be controlled from ALMA control system are sent from ACA-CCC. The control part also communicates with F and X parts to change their parameters.

5 Performance

After the ALMA Second-Generation Correlator (2GC) informal meeting during the URSI 2002, we started the design study for both FX and H-XF including their hardware estimations according to the spirit of the 2GC NOBEYAMA meeting 2001. ALMA 2GC should satisfy all the ASAC recommendation and guidelines (see Chapter VII in "Scientific Justifications for the ALMA enhancement", http://www.alma.nrao.edu/committees/ASAC/enhancements.pdf and "Report of the ASAC: September 2001 meeting",

http://www.alma.nrao.edu/committees/ASAC/asacreport_2001Sep.pdf). There are two designs discussed for ALMA 2GC: Hybrid XF-type and FX-type correlators. In the XF-type correlator the cross-correlation is calculated before a Fourier transformation, and "Hybrid" means that FIR digital filter banks are installed before the correlation unit of the XF-type correlator. Canadian E-VLA correlator[Carlson et al. 2003] is a similar architecture to the Hybrid XF correlator. In the FX-type correlator, a Fourier transformation is performed before cross multiplication. European correlator group discussed the Hybrid XF-type correlator and Japanese group proposed the FX-type correlator as ALMA 2GC.

In 2003, US correlator group proposed the enhancement of the baseline correlator (ALMA memo No.441). After the intensive discussion with US and European correlator groups, tunable digital filter banks based on the 2GC design (ALMA memo No.476) are jointly proposed to ALMA correlator CDR. On the other hand, FX-type correlator was proposed by Japanese correlator group as ACA correlator at Japan ALMA week on February 2004.

Finally ehnahnced BLC and ACA FX correlator has almost the same performance, in terms of bandwidth and frequency resolution, as shown in Table 2 – 4. The efficiency of 4-bit correlation is 0.99 and the total quantization efficiency is 0.95 (=0.96 x 0.99) in ACA system.

Table 2. Mode chart with one baseband channel per two baseband pair input.

Num. of subband filters	Total BW	Number of Spectral Points	Spectral Resolution	Velocity resolution at 230 GHz
32	2 GHz	8192	244 kHz	0.32 km/s
32	2 GHz	4096	488 kHz	0.64 km/s
32	2 GHz	2048	976 kHz	1.28 km/s
16	1 GHz	8192	122 kHz	0.16 km/s
16	1 GHz	4096	244 kHz	0.32 km/s
16	1 GHz	2048	488 kHz	0.64 km/s
16	1 GHz	1024	976 kHz	1.28 km/s
8	500 MHz	8192	61 kHz	0.08 km/s
8	500 MHz	4096	122 kHz	0.16 km/s
8	500 MHz	2048	244 kHz	0.32 km/s
8	500 MHz	1024	488 kHz	0.64 km/s
4	250 MHz	8192	30 kHz	0.04 km/s
4	250 MHz	4096	61 kHz	0.08 km/s
4	250 MHz	2048	122 kHz	0.16 km/s
4	250 MHz	1024	244 kHz	0.32 k m/s
2	125 MHz	8192	15 kHz	0.02 km/s
2	125 MHz	4096	30 kHz	0.04 km/s
2	125 MHz	2048	61 kHz	0.08 km/s
2	125 MHz	1024	122 kHz	0.16 km/s
1	62.5 MHz	8192	7.6 kHz	0.01 km/s
1	62.5 MHz	4096	15 kHz	0.02 km/s
1	62.5 MHz	2048	30 kHz	0.04 km/s
1	62.5 MHz	1024	61 kHz	0.08 km/s
1	31.25 MHz	8192	3.8 kHz	0.005 km/s
1	31.25 MHz	2048	15 kHz	0.02 km/s
Time Division Mode	2 GHz	256	7.8 MHz	10.2 km/s

Table 3. Mode chart with two baseband channels per two baseband pair input.

Num. of subband filters	Total BW	Number of Spectral Points	Spectral Resolution	Velocity resolution at 230 GHz
32	2 GHz	4096	488 kHz	0.64 km/s
16	1 GHz	4096	244 kHz	0.32 km/s
16	1 GHz	2048	488 kHz	0.64 km/s
16	1 GHz	1024	976 kHz	1.28 km/s
8	500 MHz	4096	122 kHz	0.16 km/s
8	500 MHz	2048	244 kHz	0.32 km/s
8	500 MHz	1024	488 kHz	0.64 km/s
8	500 MHz	512	976 kHz	1.28 km/s
4	250 MHz	4096	61 kHz	0.08 km/s
4	250 MHz	2048	122 kHz	0.16 km/s
4	250 MHz	1024	244 kHz	0.32 km/s
4	250 MHz	512	488 kHz	0.64 km/s
2	125 MHz	4096	30 kHz	0.04 km/s
2	125 MHz	2048	61 kHz	0.08 km/s
2	125 MHz	1024	122 kHz	0.16 km/s
2	125 MHz	512	244 kHz	0.32 km/s
1	62.5 MHz	4096	15 kHz	0.02 km/s
1	62.5 MHz	2048	30 kHz	0.04 km/s
1	62.5 MHz	1024	61 kHz	0.08 km/s
1	62.5 MHz	512	122 kHz	0.16 km/s
1	31.25 MHz	4096	7.6 kHz	0.01km/s
1	31.25 MHz	1024	30 kHz	0.04 km/s
Time Division Mode	2 GHz	128	15.6 MHz	20.4 km/s

Table 4. Mode chart with two baseband channel per two baseband pair input with polarization cross products.

Num. of subband filters	Total BW	Number of Spectral Points	Spectral Resolution	Velocity resolution at 230 GHz
32	2 GHz	2048	976 kHz	1.28 km/s
16	1 GHz	2048	488 kHz	0.64 km/s
16	1 GHz	1024	976 kHz	1.28 km/s
8	500 MHz	2048	244 kHz	0.32 km/s
8	500 MHz	1024	488 kHz	0.64 km/s
8	500 MHz	512	976 kHz	1.28 km/s
4	250 MHz	2048	122 kHz	0.16 km/s
4	250 MHz	1024	244 kHz	0.32 km/s
4	250 MHz	512	488 kHz	0.64 km/s
4	250 MHz	256	976 kHz	1.28 km/s
2	125 MHz	2048	61 kHz	0.08 km/s
2	125 MHz	1024	122 kHz	0.16 km/s
2	125 MHz	512	244 kHz	0.32 km/s
2	125 MHz	256	488 kHz	0.64 km/s
1	62.5 MHz	2048	30 kHz	0.04 km/s
1	62.5 MHz	1024	61 kHz	0.08 km/s
1	62.5 MHz	512	122 kHz	0.16 km/s
1	62.5 MHz	256	244 kHz	0.32 km/s
1	31.25 MHz	2048	15 kHz	0.02 km/s
1	31.25 MHz	512	61 kHz	0.08 km/s
Time Division Mode	2 GHz	64	31,25 MHz	40.8 km/s

6 Size and Power Requirements

We estimate the hardware size and power consumption for the ACA correlator along with the previously-mentioned architecture including the new functions. The total power consumption will be estimated about 10 kW for two basebands including DTS-R part, F part, X part, and control part. Thus the estimated total power consumption of the whole ACA correlator hardware is 40 kW as a typical value except for fan motors.