EIS Data Throughput

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CCD

format: 512 x 2048 pixels (x,λ)
full well: 1.5×10^5 e^-
# of ports: 2 readout ports (only 1 assumed here)
clock speed: 50 - 500 kHz
electrons per photon at 284 : $12398/(284 \times 3.65) = 12e^- \pm 3.5$

Table			
CCD clock rate	Read Noise (e-)	Readout Time (s)	CTI
50 kHz (20 µs)	3 ?	21	0.86 ?
150 kHz (7µs)	4 ?	7	0.92 ?
500 kHz (2µs)	5 ?	2.1	0.99 ?

Typically, the DN/e^- will be set to noise level at low count rates
At low count rates, noise is dominated by CCD read noise and electron noise

Low count rate noise level = $(5^2 + 3.5^2)^{½} = 6$

At high count rates, noise will be dominated by poisson noise.

At 500 kHz

1 DN = 6 e^-
full well = 2.5×10^4 DN = 14.6 bits

Alternatively, we can set 1 DN to the number of electrons per photon

1 DN = 12 e^-
full well = 1.25×10^4 DN = 13.6 bits

Conclusion: it will be necessary to do at least a 14 bit A/D

Transfer rates in EIS data path

EIS CCD Camera to EIS ICU (IEEE 1334):	2 - 4 Mbps
EIS ICU to MDP (RS 422):	1 Mbps (0.5 Mbps ?)
MDP to DHU and downlink	64 kbps (average) 167 kbps (max)

Other data rates

CCD Camera: readout x A/D x windowing = 500 kHz x 14 bits x 0.122 = 0.85 Mbps

The CCD will be read out in 2.1 s

Slot rate: ?

Data Compression

Windowing:

Typically select 10 lines, each located in a 25 pixel interval which corresponds to velocities of ±280 km/s. This corresponds to a compression rate of: (10 x 25)/2048 = **0.122**. This assumes that all of the profiles along the slit are used. Currently, it appears that windowing can be performed in the camera. This is necessary in order to get the full CCD data rate to the EIS ICU.

For flares, an interval corresponding to [-300,+1000] km/s = 60 pixels might be more appropriate.

Slot: in terms of data throughput, it may be necessary to limit the size of the slot to no more than about 250 pixels, although windowing of the slot is always possible as well.

Image Compression

Lossless schemes: typically a **factor of 2** compression is achieved. When lossless compression schemes were studied for LASCO we came to the conclusion that the Rice scheme was preferable to the DPCM scheme.

Jpeg: our preliminary analysis suggests that this might not be acceptable for spectra. The case for either spectra or slot data needs to be evaluated

Hcompress (wavelet): our preliminary analysis suggests that compression factors on the order of a **factor of 0.2 (1/5)** produces satisfactory results. Higher compression rates may be achieved for slot data but this has not been studied.

Square root + **lossless**: A combination of square root compression followed by lossless compression should give a **factor of about 4-7**. This scheme has been compared to Hcompressed LASCO data. At the same level of compression, the Hcompress scheme was found to be more accurate. However, this should be re-evaluated.

A Rough Data Throughput Calculation

Assume the 2 CCDs are alternately read out at a rate of 500 kHz and that spectral windows are selected in the camera. This leads to a sustained data rate of 500 kHz x 14 bits x 0.122 = 0.85 Mbps. It will take 2 s to read out the CCD.

This will be transfered from the CCD camera to the ICU on the IEEE 1334 bus at 2-4 Mbps. This is OK. It will take 0.3 s to transfer the image at 3 Mbps.

In the ICU, the data will be compressed at a factor of 0.2 (1/5). The data rate out of the ICU is then 0.85 Mbps x 0.2 = 170 kbps.

This will be transferred to the MDP over a RS 422 link at 1 Mbps (500 kbps ?). This is also OK.

The average data rate to the ground is 64 kbps. This is the problem.

Conclusion: For the assumptions made in these calculations, EIS delivers data at a rate of 170 kbps which is about a factor of 2.7 over the average transfer rate of 64 kbps to the ground. These 2 rates could be matched by longer exposure times (9 s), slower CCD readout rates (190 kHz), fewer windows (4), narrower windows, a reduced number of profiles along the slit (190 vs 512), higher compression factors (14) or by a combination of these various factors. Higher compression factors may result in unacceptable losses in data accuracy.

Issues

CCD readout rate

What is the electron read noise as a function of readout rate? The figures in the first table are from EEV's spec sheet.

Charge transfer inefficiency (CTI) appears to be a serious problem. It would tend to drive us to as high a clock rate as possible.

What other factors will determine the CCD clock rate?

CCD Windowing

The narrowness of the windows will depend on the curvature of the slit image on the CCD and on its alignment with respect to the CCD columns.

We need to confirm that windowing can be performed in the CCD camera.

Image Compression

How quickly can an image be compressed? Many of the images will be on the order of 250 x 512 pixels.

Which compression algorithms are most appropriate for spectra?

Which compression algorithms are most appropriate for slot spectra?

What levels of compression are acceptable in terms of retaining all the necessary accuracy in the line profiles?

Cadence

For the quiet sun, longer exposure times of about 15s, leading to about a 17s cadence may be the most acceptable way to match the EIS data rate to the downlink rate.

For active regions, exposure times of 2s will be acceptable for a few of the brightest lines but longer exposure times will be useful for temperature studies, line ratios etc.

For flares, exposure times near 0.1 s will be needed to avoid blooming. A high cadence approaching perhaps 0.5 s could be attained by limiting the number of profiles downlinked and the number of spectral lines. However, could the image compressor etc keep up?

It would be useful to develop a number of observing programs to understand the constraints of data throughput with respect to cadence, profile accuracy, number of lines, field of view, etc., for quiet sun, active regions and flares. The 4s cadence shown in Figure 1 is probably most relevant to active regions and not even all active region observations.

EIS ICU to MDP link

It has been proposed that this be a 12 bit link, as opposed to an 8 or 16 bit link..

If data is compressed in the EIS ICU, the compressed data will be 16 bits. Can this be transferred over a 12 bit link?

What are the other issues with respect to the bit size of the link? The system side would like to settle this matter by July 15.

EIS Downlink Rate

My understanding is that the average downlink rate for EIS data is 64 kbps. However, I have recently heard figures of 10 kbps. What is the correct value?

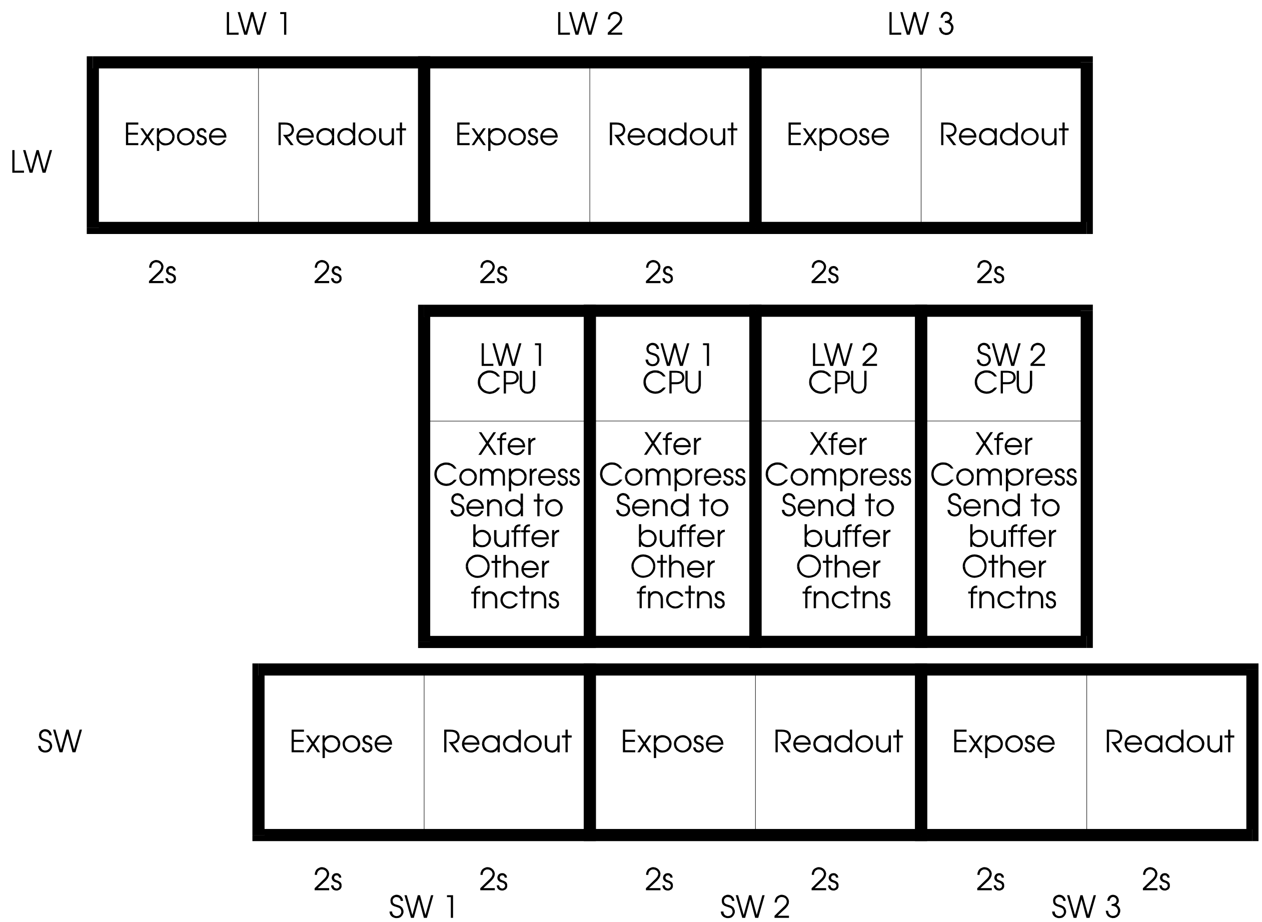

Figure 1: An observing mode with a 4 s cadence using both SW and LW detectors. Cadence is determined by the CCD readout time and is most appropriate for active regions.

CPU tasks

To maintain the cadence depicted in the above schematic, it will be necessary for the EIS ICU perform the following tasks in 2s:

- Transfer CCD windowed image from CCD to ICU (~0.3 s ?)
- Compress the image
- Transfer the image to the output buffer
- Initiate the transfer to the MDP
- Other CPU functions
  - Exposure control
  - Temperature control
  - Receive commands
  - Transmit housekeeping
  - Etc