JIVE/EVN CORRELATOR CONFIGURATIONS, THE ASTRONOMICAL PERSPECTIVE

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This is a rewrite of EVN memo #50. It has changed in several respects to older versions (e.g. 0.04 was distributed to several people). The current version attempts to be more precise in lining out the capabilities of the correlator, in particular I have studied more closely the relation between SU and correlator segments. Also, I have changed the aim slightly, to make it more closely connected to the physical implementation. Therefore, especially the tables are set up differently. Future versions should probably attempt to describe more functions than just the correlator configurations.

I have hurried to put out this draft version for comments, because I feel an urgency to discuss the need for fan-in/oversampled modes to enable small bandwidths to be correlated with sufficient spectral channels. Questions and remarks should be sent to `huib@jive.nfra.nl`.

1. Introduction

This document discusses the astronomical capabilities of the JIVE/EVN MkIV correlator in combination with different recording formats. Its aim is to have a single source of information of what the correlator can and cannot do. But it could also serve as a high level description of the processor, where global information can be found. Therefore, it is not aimed at the average astronomer who wants to have his data processed at the correlator, but it should become the source from which JIVE support personnel can derive such information.

A large fraction of the document describes which combinations of correlator parameters are allowed for a number of recording modes. In the process I have written a small suite of `C++` programs that verify and calculate these combinations. This allows an easy check of unlisted combinations. This I found necessary because the parameter space set up by the flexibility of the correlator is so large that it is impossible to cover all possible configurations.

At the moment I have not worked in any limitations set by the specific software (C^3 or low–level) implementation. I imagine there will be at some stage, because the configuration of the complete correlator seems a very complex process. The document is merely based on the design specifications of individual elements. Here is a list of the documents:

- EVN#68
- EVN#4 Revision C, 930224, "The EVN/Mark IV Station Unit: Straw-man design" by Anderson. Appendix to the SU design specification. Description of how the SU could work.
- EVN #6 (NFRA ITR # 202), Revision 1, October 1993, "The EVNFRA Correlator: Design considerations" by Bos.
- EVN# 19, version 931103, "EVN Correlator: Over Sampling" by Anderson. Signals the need for oversampling in the SU or SUIM. [[**So far it seems that this has NOT been followed up, Parsley private communication**]].

- "Functional Description of the EVN-Mark IV Data Processor", by Casse. Useful description of overall setup, unfinished.

1.2. Definitions

It is necessary to define a number of terms in order to avoid confusion.

- *sub-bands/basebands*, $N_{\rm sub}$. I use this term to denote different data streams from the telescope. A sub-band has a specific frequency, bandwidth, polarization, which usually make it unique.
- *interferometer products or simply interferometers*, $N_{\rm intf}$. The product of two sub-bands in either lag or frequency domain. An autocorrelation is also an interferometer.
- *frequency points*, $N_{\rm freq}$. I try to use this word for spectral points or channels. The word channel is confusing, because it can be taken to refer to sub-bands.
- *baselines*. There are $\frac{1}{2}N_{\rm tel}(N_{\rm tel}-1)$ cross- plus N autocorrelation baselines. On a baseline we can have a number of interferometer products, from combining different sub-bands.
- *polarizations*, $N_{\rm pol}$. When no cross polarization is produced the number of products is usually simply the number of sub-bands: $N_{\rm pol}=1,2$, even when both parallel hand are available. For cross polarization the number doubles to $N_{\rm pol}=4$.

2. Description & Constraints

In this section the different elements of the are described and discussed in terms of how they influence the user capabilities. Where possible I will point out complex, simple or even trivial constraints on the correlator functions and possible "observing" modes.

2.1. Overall layout

The correlator's basic building blocks are (16) Data Playback Units, which read the tapes. They have built in a Station Unit (SU), which task is basically to decode the signals. The correlator is designed to be a 16 station processor, possibly extendible to 32 stations. There might be an early stage when there are fewer DPU/SUs. And there will be times when not all playback stations are operational. In principle the correlator can deal with up top 32 stations, but has a fixed amount of correlator space. However, in that case more DPUs, SUs and communication links would be required. Anyway, a trivial constraint to the list of possible configurations is that the number of stations cannot exceed a fixed number (16).

The Test/Synchronization/Pulsar Gate Unit (TSPU) is responsible for the overall clock signal, produces artificial test data and steers the pulsar gating. The actual correlation is done in the correlator unit, which includes the so–called Data Distributor, responsible for routing the signals and setting up the recirculation. On output the data are flushed out to a UNIX platform, the Data to Disk Distributor (D^3), which is responsible for further processing. The correlator is driven from a Central Control Computer (C^3) by sending specific messages to all elements.

I will follow this data path and describe the components in more detail below.

2.2. Data Playback Unit

The Playback Units are built by Penny+Giles. Important constraints set by the DPUs are the number of tracks that can be read simultaneously. The standard heads that are used in wide-band VLBI can read/write 36 tracks. It is envisioned that the JIVE correlator will have 2 heads in every drive. So, a constraint is that no more than $N_{\mathrm{heads\_dpu}} \times 36$ bit-streams could be read simultaneously. In fact we will see below, that a single SU will process only 32 streams from each headstack, which conforms to common practice of recording VLBI data on MkIII/MkIV/VLBA recorders. At the moment dual head recording is not operational or tested. A transition period with single head DPUs could be anticipated (because of ware it is not advisable to mount 2 heads if only 1 is to be used).

The maximum speed for which the drives are designed is 320 ips. At high density (MkIV: 56250 or VLBA: 56700) this corresponds to 18 Mbit/s/tr bit rate. Because 1 in every 9 bits is a parity bit this is equivalent to a data rate of 16 Mbit/s/tr. Currently it is not quite clear whether the highest speed will be practical with the current generation of heads. It is likely that 160 and 80 ips will be used mostly. Mechanically the drives are also able to work at 40 and 20 ips, but equalizers for these speed are not in the system. It must be assumed these options are initially not available. Note that the VLBA and MkIV telescopes have been tested successfully at 40 ips and 2 Mbit/s/tr. Thus we find here limits to the playback speed both on the high and low end.

The possibility of having S2 playback is not discussed (yet) in this document.

2.3. Station Unit

The SU is responsible for decoding, synchronizing and tracking the data from the tape. In addition it houses the phase cal detection system. It is a very complex piece of electronics. Here we focus on the aspects that set constraints on the astronomy that the correlator can produce.

The SU can deal with VLBA and MkIII/IV encoded signals, including modulation and barrel–rolling. A complete SU can process 64 input bit streams. This allows it to process MkIV data using 2 headstacks, but also up to 36 tracks, possibly used in VLBA recordings. For a single, fully populated SU this constrains the data input. It is in principle possible to have 2 SUs per DPU in order to process 4 headstack data.

The SU design supports data which was "fanned-out" (1:2 or 1:4) or "fanned-in" (2:1 or 4:1) at recording time. This means respectively that the bits for a specific data stream are recorded on many tracks or many data streams on a single track. Fan-out is a very commonly used feature as it allows us record the highest bandwidth with fewer channels. Unfortunately fan-in is currently not used at the VLBA and not complete in the MkIV formatter. It is not unthinkable that this feature will not be available from the start or ever for Global observing. This would certainly compromise the spectral line capabilities of the MkIV correlator. A discussion of these issues is given in section 3.2.

On output the SU can transmit up to 16 data-streams of 32 MSamp/s. These can be 2-bit sampled (in fact the data streams are 3 bit wide, including validity information). This bandwidth cannot be configured into 32 1-bit signals. So the equivalent bandwidth of sub-bands is constraint to 32 Msamples/s. The SU can output data at the rate desired for the SUIM, currently between 16 to 2 MHz. It has been claimed that the SU can run at slower rates too, at least at 1 MHz [[**and lower?**]], but that is not supported by other elements in the chain. [[**Could the tapes played back slower than recorded?**]].

2.4. SUIM and serial links

Important here is the way the data is communicated to the correlator unit. For data at lower rates than the standard 32MHz clock of the correlator the data is "over-clocked". In this case a number of $N_{\mathrm{overclock}}$ bits are set to an identical value to represent a bit of a $N_{\mathrm{overclock}}$ lower rate. The maximum "over-clocking" currently anticipated is 16, corresponding to a 2 MHz sample rate. It seems possible to implement also over-clocking of 32, 64 and 128 as used in the WSRT application. [[**(Progrebenko private communication), everybody agrees?**]]

At this stage even lower bandwidth recordings can in fact be dealt with by performing the processing faster than the data was recorded. With an additional speed-up of up to a factor of 16 (depending on the record and playback tape speeds) the minimum bandwidth can in principle be 62.5 kHz, the smallest filter available in the field. But in fact it will turn out that without oversampling or fan-in there is no way to get such datarates from the tape.

I mention the possibility that the SUIM/serial links deal with oversampled data, by dropping the redundant bits. This however, requires a method to deal properly with the header information. It would yield a way in which small bandwidths could be supported without asking for a large range in tape-speeds.

2.5. Test Signal and Pulsar gate Unit

Remains to be written...

2.6. Data Distributor

Remains to be written...

2.7. The Correlator

The modes of operation of the correlator are described in detail in EVN #6 (NFRA ITR #202). The correlator is designed to handle two bit sampled data from 16 stations in 8 sub-bands (4×2 polarizations) of 16 MHz each and produce 16 complex frequency points on each of the 4 polarization products (local validity mode). To accomplish this the JIVE/EVN correlator consists of 4 crates. Each crate holds 8 correlator boards. Groups of 4 boards are referred to as a segment, there are therefore 8 such segments. A segment is sufficient to process a single sub-band of 16 stations.

Because cross-correlations require $2N_{\mathrm{freq}}$ lags and autocorrelations require N_{freq} lags, a segment requires 496×64 complex lags for cross-correlation and 32×32 complex lags to obtain the autocorrelations. This total of 1024×32 $(p\,s^2\,f)$ lags can be delivered by 32 chips on of the 4 boards: 256 complex lags on a chip (to be used with up to 8 products per chip). A total of 1024 chips deliver 262144 lags. A chip is logically divided in up to 8 correlator cells with 32 complex lags.

The correlator capacity can be distributed flexibly to handle for example 16×16 MHz 2 bit data (1024 Mbits/s) in a single polarization for 16 stations with 64 frequency points, or even 32×16MHz from 8 stations with 128 frequency points. This would however require 4 heads and 2 SUs on 8 playback units and recordings to be made with 4 heads as well. Thus, whether such a mode of operation is going to be used, depends on the recording system and play–back formats. Equivalently there is capacity to correlate 8 basebands from 32 stations, but that is not a likely mode, as only 16 station units are currently planned.

A constraint is that it is not possible to use more than an entire board on a single interferometer, i.e. 4096 frequency points on a complex cross correlation. [[**Are these the only constraints on flexibility?**]]

For spectral line observing the correlator has the possibility to utilize recirculation when it is presented a small bandwidth signal. This is "time–sharing" of correlator space in order to have a large number of lags available, thus obtaining a high resolution spectrum. This requires the data-distributor to be completed, which is not planned for the initial stage.

The fundamental formula for the correlator is given as

$$B \times P \times F \times S^2 \times V \leq R \times 262\,144.$$

In this formula B is the number of frequency basebands. There is no constraint on B other than that the total bandwidth coming from the station unit is limited to 16×16 MHz = 256 MHz, as discussed before. Note that this cannot be increased by using 1 bit sampling, because the correlator has a fixed rate and handles 1 bit modes by not using the second bit line. F is the number of (complex) frequency points after correlation. Apart from the constraints on the total number above, there are no constraints on the number of frequency channels, except that $F = 2^n$. Next, S^2 is the number of stations to correlate. The S^2 includes correlation of all auto–correlations. This is the appropriate thing to do, even for continuum observations. The autocorrelation spectra contain useful information on bandpasses and interference and can be used to increase sensitivity and limit closure errors. The value of V can be either 1 or 2, denoting global or local validity checking. Local is recommended when possible and it will probably be used for all broad-band applications. When many channels are needed, and the data is of sufficient quality, the global validity checking mode may be used.

The factor R describes recirculation. This can be employed when a slow (i.e. small bandwidth) signal is fed into the correlator. In that case, by buffering the signal, the correlator units can be time–shared to correlate a factor of R more lags, and thus increase the resulting number of frequency points to $R \times F$. Whether the correlator is actually getting "slow" input or not, is not set by the bandwidth on the sky only, because the recording of small bandwidth may involve fan–in or "speed–up". This causes the output data rate to be higher in the correlator, and there would be no time left to recirculate. A constraint is $R < 16$.

2.8. the Data to Disk Distribution

An important constraint in the system is the output rate of the correlator. The anticipated output configuration has an RT system on every correlator board that can send out the integrated products on 10 Mb/s Ethernet links. A minimal set of operations on the data is planned, so that the correlator rate will be determined by this Ethernet bottleneck. It is estimated that 350 kByte/s will be the initial maximum output rate of the correlator. By using the 4 outputs in a parallel way, connecting to D^3 by 100 Mb/s Ethernet a higher output rate can possibly be obtained. The produced data rate for a certain configuration is calculated by assuming that it will be dominated by 4 byte real and imaginary values for every spectral point in each ineterferometer. It scales with $t_{\rm int}$ and the speed-up factor. [[**The current formula is very crude and may well be off!**]]

One should realize that when the correlation is performed with speed-up, i.e. faster than recorded that the output data-rate constraint is relatively more severe. This turns out to be a serious problem especially for low bandwidth recordings, which aim at spectral line sources.

2.9. Recording Constraints

In principle there are many constraints set by the recorders that produce this data. VLBA recorders have only a single headstack and in MkIV dual head operations have not been tested. The 320 ips recording has not been used in the filed either. Although the tape drives used have made succesful recording in MkIII mode at very low speeds (5 ips?), there is no software for operating MkIV at speeds below 40 ips, which is also the lowest VLBA operational recording speed. MkIII format does not allow fanning of any kind or 2 bit sampling, the fastest sample rate is 8 Msamp/s rather than the 32 Msamp/s available on the MkIV and VLBA.

Apart from the constraints set by recording formats there are additional constraints by the actual acquisition systems. For instance the MkIV format can in principle store 2048 Mbits/s, but a

1GHz bandwidth will not be feasible, as the currently planned acquisition systems will have only 16 formatters (and just 14 BBCs) and a maximum bandwidth of 32(28) $\times$ 16 MHz = 512 (448) MHz will be possible. Details are given in Appendix A.

2.9. Finally: Operational Constraints

No "speed-down" is allowed. *Remains to be written...*

3. User Modes

The first aim here is to list the capabilities of the correlator when it is completed. For all the tables in Appendix B a fully functional correlator was assumed, equipped with 16 SUs and DPUs, each with two headstacks. It has all 32 correlator boards functional and 1024 chips. The correlator output rate was allowed to be 350 kByte/s. In all cases the DPUs were assumed to have 2 headstacks and the assumption that over-clocking up to 16 is possible.

Standard tape speeds are 80, 160 and 320 ips, but the spectral discussion explores the advantage of having slower tape speeds. We will assume 4 crates of correlator are available and recirculation is implemented.

Now we combine the constraints above and list some of the possibilities of the correlator. At the moment I have done this only for standard MkIV recorders, with 2 headstacks, possibly 2 bit recording and standard fan-out. However, I have assumed the lowest feasible recording speed to be 40ips, in accordance with the VLBA. Slower recorders can only be processed at high speed-up factors, presumably leading to poor playback and undesired high data rates. The recorders are assumed to be connected to acquisition systems that can produce up to 32 basebands (i.e. 16 BBCs) and have filters in the range 62.5 kHz to 16 MHz.

The tables have been computed automatically by looping through a range of parameter values (usually in steps of factor 2) and validating the configuration. Only valid configurations are printed. Still, we have to constrain ourselves to a small part of the parameter space, otherwise many 10 000 configurations would have been checked and many thousands print. Therefore all the configurations printed are for instance limited to 10 telescopes. Similarly, no polarization configurations are printed, because these can simply be found by dividing the $N_{\rm freq}$ by a factor 2. Also for continuum modes the (user) integration time is fixed at 1 second, and for line modes at $10s$. The capabilities are usually set by the allowed output rate (for 10 antennas) and therefore scale linearly with integration time.

For simplicity I have only printed the correlator configuration with the highest possible spectral resolution, and the configuration with the highest possible speed-up, which is the highest operational efficiency. This strategy lists configurations close to the maximum output rate. It is important that will not become the common user practice; it would be an operational headache if all projects would run at such large production rates.

The entries in the table have been defined above. Note that there is redundant information in the tables just to make them more comprehensible.

3.1. Continuum configurations

For studying continuum configurations (Table B.1) all options were studied with local validity. Only configurations with total bit rate starting at 64 Mb/s were considered (MkIII mode B has 56 Mb/s). Modes with 2 or more sub-bands were considered.

Note that the 512 Mb/s modes require either 2 heads or 320 ips recording. For the 1024 Mb/s mode both these options are required. There is only one 1024 MB/s mode as there are only 16 SU outputs so the only sensible recording uses 2 bit mode. It must be recorded with 1:2 fan-out to write all 64 tracks at 16Mb/s/tr.

A minimum of 8 frequency points across every channel is deemed necessary for processing. Only a few configurations were rejected (with 10 telescopes and 1s integration) because of output rate considerations, mostly with speed-up more than 1. I conclude that 350kB/s is an acceptable initial data rate.

3.2. Line configurations

The "standard" line configurations (Table B.2) were calculated without the fan-out (or fan-in) options. The fan-in is initially assumed to be unavailable, the fan-out has no advantage for line configurations, as it reduces the data rate on the tape even further, while we will see that the low data rates are actually causing some problems.

The line configurations consider all modes with data rates between 0.25 Mb/s and 32 Mb/s with 1 to 4 sub-bands. For all line mode discussions global validity is used, but for the tables it would actually not make any difference as we are mostly limited by output bandwidth. The integration time per visibility is set to 10 seconds, otherwise hardly any useful spectral line configurations are obtained. Initially the configurations considered were calculated without fan-in, oversampling or slow playback speeds. These options will be discussed below.

Minimally, spectral line astronomers like to use 250 kHz with 128 spectral points for OH masers and 8 or even 16 MHz bands with 256 channels for H_2O and SiO masers. Higher resolution can be advantageous for example in polarimetry. In table B.2 we can see that even with 10s integration the line capabilities are limited, especially for the small bandwidths that are mostly missing from the table. The reason for this is mostly that the table is compiled taking into account that the recorders do not support recordings slower than 40 ips. The MkIV recorders can probably do this, I am aware that MkIII recordings have been done at least down to 5 ips (or the low density equivalent). Such slow recordings would result in high speed-up factors as the PBUs are not equipped to go slower than 80 ips. High speed-up puts serious pressure on the output data rate. In addition we have to worry if these high speedup factors will produce sensible data read-back quality. Even if the slow recording speeds would be allowed, the capabilities would be limited without oversampling or fan-in, because the output rate limits the usefulness of high speed-up.

Therefore, we see that the 4-4-2 mode that results in 4×250 kHz with 128 spectral channels is not possible without further special measures (I will refer to this as the "OH-mode").

3.2.1. Oversampling

The once proposed solution for this is to oversample the data during recording. This allows a factor of 2, 4 or 8 more bits to be recorded than is required at Nyquist rate. It is assumed that the SUIM/Input Board combination will drop these bits (see also EVNdoc 19). A complication is that the header information needs to be handled properly. This feature would increase the allowed spectral line configurations considerably. By introducing this feature we get access to bandwidths in the 250 – 500 kHz range. The "OH-mode" can now be observed as 16-4-2 and oversampling by a factor of 4, even 256 spectral channels will be possible. All the additional configurations that can be obtained this way are described in Table B.3.

Still, this way the lowest recorder bandwidths of 125 and 62.5 kHz are not accessible. Another drawback is that the tape consumption is 4 times higher than formally required (but quite low anyway).

3.2.2. Fan–in

Fan–in is more elegant way to reach a similar result. The results in Table B.4 show the additional configurations possible with respect to Table B.2, which can be obtained by fan-in 2:1 and 4:1. Fan-in by itself doesn't allow 125 or 62.5 kHz modes either, but the "OH-mode" can be observed.

3.2.3. *Slow tape speeds*

Table B.5 shows the additional configurations (with respect to B.2) which would become available if 40 ips playback would be supported. The list is short as the VLBA recorder slowest recording speed of 40 ips is also a constraint. Therefore all configurations are speed-up 1.

3.2.4. *Recirculation*

Recirculation is impractical without 2 MB/s output rates; even for 10 Telescopes and 10s integration we are producing too much data already anyway. The problem is that all the low-bandwidth modes need considerable speed-up which asks for correspondingly high output rates. The tables created with recirculation would look identical to the ones already produced, at least for this part of parameter space.

3.2.5. *Combinations*

Just to show what I think we desire I compiled the table B.6. It shows the entire list of low bandwidth recordings when oversampling, fan–in and 40 ips playback would be available. Note that still the lowest bandwidth cannot be obtained, higher overclocking must be implemented for that.

3.3. Other Outputs

Remains to be written...

3.4. Special Products

Remains to be written...

3.4.1. *Pulsar Gating*

Remains to be written...

3.4.2. *Multiple Phase Centers*

Remains to be written...

3.4.3. *Space VLBI*

Remains to be written...

4. Conclusions

- At an output rate of 350 kB/s all configurations are constrained by output rate rather than anything else. However, I find it is an acceptable production rate for initial operations.
- With 350 kB/s output rate any spectral line capability requires longer than $1s$ integration times (e.g. $10s$).
- Reasonable spectral capabilities are only obtainable if oversampling is implemented in the SU, or by using fan-in, or by using large speed-up factors (16) and slow recordings, which seems impractical.
- Complete spectral line capabilities require a combination of oversampling and fan-in (or slow read-back speeds) to be implemented.
- Recirculation is only useful for few antennas/long integration time or when very high output rates can be used.

Apendix A. Recording modes

A.1. MkIV

The MkIV recording mode has space for 64 tracks with 16 Mbits/s. It is anticipated that this will be used mostly with 2 bit sampling. The total maximum data rate is thus 1024 Mbit/s, with the 2 headstacks that are currently available. The total maximum bandwidth is thus 256 MHz for 2 bit mode. Both at recording and playback there can be no more than 16 different bit streams.

For the MkIV acquisition I will limit myself to upgraded MkIII systems, but with the MkIV formatter no more than 16 data streams can be formatted. As far as the data acquisition systems are concerned the MkIV upgrade currently foresees the implementation of 14 BBCs (plus a spare) which each will have filters of 16, 8, 4, 2, 0.5, 0.125 MHz available for each of the lower and upper side–band. In addition there will be 1, 0.25 and 0.0625 filters ready to plug in. The full capacity can be obtained with 8 BBCs and 16 MHz filters for both sidebands. In order to divide these data rates of maximum 64 MBits/s from each BBC over 16 MBits/s tracks, the MKIV formatter employs fan out; data from a single stream is divided of more tracks on the tape. The acquisition rack can in principle provide more bandwidth, but to use these possibilities at 2 bit sampling requires two additional headstacks. In the tables below only the currently planned first two headstacks are taken into account. For one bit sampling the total bandwidth is limited by the maximum 16 channels in the formatter and station unit.

The large bandwidth are recorded with fan–out, the bit streams from a large baseband is written out over several tracks (2 or 4). For spectral line observing the MkIV system is also equipped with 4:1 and 2:1 fan–in; this means that when several small bandwidth signals are recorded simultaneously, they can be written to (and later read from) the same track

Another possibility is to record with the tape running at a slow speed and do the correlations faster than the real time. A large number of ranges in speed for the recorder at the telescopes are available. Recording at low speed has the advantage that there is a "speed–up" factor between recording and correlating. There are constraints here, however, because tape speeds at the correlator cannot be slower than 8 times the maximum. In addition, recirculation is not always possible simultaneously with speed–up.

A.2. Recording modes: VLBA

The VLBA has 8 BBCs which produce 16 × 16 MHz (upper and lower sideband. In addition there are filters for 8, 4, 2, 1, 0.5, 0.25, 0.125 and 0.0625 MHz. The formatter allows the writing of 32 tracks simultaneously, with a maximum rate of 8MBits/s, resulting in a maximum data rate of 256 Mbits/s. Doubling of this rate is planned by equipping all antennas with two tape drives. However, the current maximum allowed data rate is set by operational constraints to 128 MBits/s. This is the value that is used in the tables below; it results in a 32 MHz bandwidth in a 2 bit sampling mode. This can be achieved in a number of different ways, because fan–out can be set up to use either 2, 4, 8 or 16 basebands signals to the tape.

For small bandwidth observing the VLBA supports fan–in and oversampling. The VLBA has operates with only 3 tape speeds: 40, 80 and 160 ips, resulting in data rates of 2, 4 and 8 MB/s/tr. In addition the VLBA is in principle equipped with 4 IF systems, which makes it possible to record 2 Polarisations of two different observing frequencies possible.

A.3. MkIII

The MkIII format can record 28 × 2 MHz with the current acquisition rack. This is provided by 14 BBCs and one-to-one track assignment with 2 MHz/track and 1 bit sampling. A setup that uses this full capacity is called Mode A. In addition to Mode A there are number of other standard formatting modes defined. Mode B records half of the bandwidth, with all baseband coming from the same IF, thus one polarization. Mode C also has 28 MHz bandwidth, but establishes this by using only upper sideband and can hence record both circular polarizations. Mode D records only one SSB baseband, and in Mode E 7 basebands from one IF are recorded.

In combination with the different baseband filters this has resulted in some flexibility, although the spectral line modes are not easily accessed, because there is no oversampling possibility.

When MkIII modes are correlated there is a possible complication as MkIII mode A writes as much as 28 × 2 MHz bitstreams to tape. Because the correlator station units have only 16 output streams, the correlation needs to be done at two passes. On the other hand the data are only recorded at 2 MHz or 4 MSamp/s. So a factor 8 lower data rate than the correlator can handle (the fact that these are only 1 bit samples doesn't help in the correlator). The tapes at the correlator will run at twice the speed compared with normal MkIII recording **(Check! Just guessing)**, allowing MkIII experiments to be correlated in the equivalent of the observing time, but leaving space to apply recirculation.

Apendix B. Correlator configurations

B.1 Continuum configurations

N_t	t_{int} [s]	N_{pol}	V	mode tot–n–b	fan	rec [ips]	speed up	N_{intf}	BW [MHz]	N_{freq} (max)	out rate [Mb/s]
10	1	1,2	L	64–2–1	1:2	320	1	2	16	128	0.2
10	1	1,2	L	64–2–1	1:4	160	1	2	16	128	0.2
10	1	1,2	L	64–2–2	1:1	320	1	2	8	128	0.2
10	1	1,2	L	64–2–2	1:2	160	2	2	8	64	0.2
10	1	1,2	L	64–2–2	1:2	160	1	2	8	128	0.2
10	1	1,2	L	64–2–2	1:4	80	2	2	8	64	0.2
10	1	1,2	L	64–2–2	1:4	80	1	2	8	128	0.2
10	1	1,2	L	64–4–1	1:1	320	1	4	8	64	0.2
10	1	1,2	L	64–4–1	1:2	160	2	4	8	32	0.21
10	1	1,2	L	64–4–1	1:2	160	1	4	8	64	0.2
10	1	1,2	L	64–4–1	1:4	80	2	4	8	32	0.21
10	1	1,2	L	64–4–1	1:4	80	1	4	8	64	0.2
10	1	1,2	L	64–4–2	1:1	160	2	4	4	32	0.21
10	1	1,2	L	64–4–2	1:1	160	1	4	4	64	0.2
10	1	1,2	L	64–4–2	1:2	80	4	4	4	16	0.23
10	1	1,2	L	64–4–2	1:2	80	1	4	4	64	0.2
10	1	1,2	L	64–4–2	1:4	40	4	4	4	16	0.23
10	1	1,2	L	64–8–1	1:1	160	2	8	4	16	0.23
10	1	1,2	L	64–8–1	1:1	160	1	8	4	32	0.21
10	1	1,2	L	64–8–1	1:2	80	4	8	4	8	0.27
10	1	1,2	L	64–8–1	1:2	80	1	8	4	32	0.21
10	1	1,2	L	64–8–1	1:4	40	4	8	4	8	0.27
10	1	1,2	L	64–8–2	1:1	80	4	8	2	8	0.27
10	1	1,2	L	64–8–2	1:1	80	1	8	2	32	0.21
10	1	1,2	L	64–8–2	1:2	40	4	8	2	8	0.27
10	1	1,2	L	64–16–1	1:1	80	2	16	2	8	0.27
10	1	1,2	L	64–16–1	1:1	80	1	16	2	16	0.23
10	1	1,2	L	64–16–1	1:2	40	2	16	2	8	0.27
10	1	1,2	L	64–16–2	1:1	40	2	16	1	8	0.27
10	1	1,2	L	128–2–2	1:2	320	1	2	16	128	0.2
10	1	1,2	L	128–2–2	1:4	160	1	2	16	128	0.2
10	1	1,2	L	128–4–1	1:2	320	1	4	16	64	0.2
10	1	1,2	L	128–4–1	1:4	160	1	4	16	64	0.2
10	1	1,2	L	128–4–2	1:1	320	1	4	8	64	0.2
10	1	1,2	L	128–4–2	1:2	160	2	4	8	32	0.21
10	1	1,2	L	128–4–2	1:2	160	1	4	8	64	0.2
10	1	1,2	L	128–4–2	1:4	80	2	4	8	32	0.21
10	1	1,2	L	128–4–2	1:4	80	1	4	8	64	0.2
10	1	1,2	L	128–8–1	1:1	320	1	8	8	32	0.21
10	1	1,2	L	128–8–1	1:2	160	2	8	8	16	0.23
10	1	1,2	L	128–8–1	1:2	160	1	8	8	32	0.21
10	1	1,2	L	128–8–1	1:4	80	2	8	8	16	0.23

N_t	t_{int} [s]	N_{pol}	V	mode tot–n–b	fan	rec [ips]	speed up	N_{intf}	BW [MHz]	N_{freq} (max)	out rate [Mb/s]
10	1	1,2	L	128–8–1	1:4	80	1	8	8	32	0.21
10	1	1,2	L	128–8–2	1:1	160	2	8	4	16	0.23
10	1	1,2	L	128–8–2	1:1	160	1	8	4	32	0.21
10	1	1,2	L	128–8–2	1:2	80	4	8	4	8	0.27
10	1	1,2	L	128–8–2	1:2	80	1	8	4	32	0.21
10	1	1,2	L	128–8–2	1:4	40	4	8	4	8	0.27
10	1	1,2	L	128–16–1	1:1	160	2	16	4	8	0.27
10	1	1,2	L	128–16–1	1:1	160	1	16	4	16	0.23
10	1	1,2	L	128–16–1	1:2	80	2	16	4	8	0.27
10	1	1,2	L	128–16–1	1:2	80	1	16	4	16	0.23
10	1	1,2	L	128–16–1	1:4	40	2	16	4	8	0.27
10	1	1,2	L	128–16–2	1:1	80	2	16	2	8	0.27
10	1	1,2	L	128–16–2	1:1	80	1	16	2	16	0.23
10	1	1,2	L	128–16–2	1:2	40	2	16	2	8	0.27
10	1	1,2	L	256–4–2	1:2	320	1	4	16	64	0.2
10	1	1,2	L	256–4–2	1:4	160	1	4	16	64	0.2
10	1	1,2	L	256–8–1	1:2	320	1	8	16	32	0.21
10	1	1,2	L	256–8–1	1:4	160	1	8	16	32	0.21
10	1	1,2	L	256–8–2	1:1	320	1	8	8	32	0.21
10	1	1,2	L	256–8–2	1:2	160	2	8	8	16	0.23
10	1	1,2	L	256–8–2	1:2	160	1	8	8	32	0.21
10	1	1,2	L	256–8–2	1:4	80	2	8	8	16	0.23
10	1	1,2	L	256–8–2	1:4	80	1	8	8	32	0.21
10	1	1,2	L	256–16–1	1:1	320	1	16	8	16	0.23
10	1	1,2	L	256–16–1	1:2	160	2	16	8	8	0.27
10	1	1,2	L	256–16–1	1:2	160	1	16	8	16	0.23
10	1	1,2	L	256–16–1	1:4	80	2	16	8	8	0.27
10	1	1,2	L	256–16–1	1:4	80	1	16	8	16	0.23
10	1	1,2	L	256–16–2	1:1	160	2	16	4	8	0.27
10	1	1,2	L	256–16–2	1:1	160	1	16	4	16	0.23
10	1	1,2	L	256–16–2	1:2	80	2	16	4	8	0.27
10	1	1,2	L	256–16–2	1:2	80	1	16	4	16	0.23
10	1	1,2	L	512–8–2	1:2	320	1	8	16	32	0.21
10	1	1,2	L	512–8–2	1:4	160	1	8	16	32	0.21
10	1	1,2	L	512–16–1	1:2	320	1	16	16	16	0.23
10	1	1,2	L	512–16–1	1:4	160	1	16	16	16	0.23
10	1	1,2	L	512–16–2	1:1	320	1	16	8	16	0.23
10	1	1,2	L	512–16–2	1:2	160	2	16	8	8	0.27
10	1	1,2	L	512–16–2	1:2	160	1	16	8	16	0.23
10	1	1,2	L	1024–16–2	1:2	320	1	16	16	16	0.23

B.2 Standard line configurations

N_t	t_{int} [s]	N_{pol}	V	mode tot–n–b	fan	rec [ips]	speed up	N_{intf}	BW [MHz]	N_{freq} (max)	out rate [Mb/s]
10	10	1,2	G	2–1–1	1:1	40	4	1	1	1024	0.31
10	10	1,2	G	4–1–1	1:1	80	2	1	2	2048	0.31
10	10	1,2	G	4–1–1	1:1	80	1	1	2	4096	0.31
10	10	1,2	G	4–1–2	1:1	40	4	1	1	1024	0.31
10	10	1,2	G	4–2–1	1:1	40	4	2	1	512	0.31
10	10	1,2	G	8–1–1	1:1	160	1	1	4	4096	0.31
10	10	1,2	G	8–1–2	1:1	80	2	1	2	2048	0.31
10	10	1,2	G	8–1–2	1:1	80	1	1	2	4096	0.31
10	10	1,2	G	8–2–1	1:1	80	2	2	2	1024	0.31
10	10	1,2	G	8–2–1	1:1	80	1	2	2	2048	0.31
10	10	1,2	G	8–2–2	1:1	40	4	2	1	512	0.31
10	10	1,2	G	8–4–1	1:1	40	4	4	1	256	0.32
10	10	1,2	G	16–1–2	1:1	160	1	1	4	4096	0.31
10	10	1,2	G	16–2–1	1:1	160	1	2	4	2048	0.31
10	10	1,2	G	16–2–2	1:1	80	2	2	2	1024	0.31
10	10	1,2	G	16–2–2	1:1	80	1	2	2	2048	0.31
10	10	1,2	G	16–4–1	1:1	80	2	4	2	512	0.31
10	10	1,2	G	16–4–1	1:1	80	1	4	2	1024	0.31
10	10	1,2	G	16–4–2	1:1	40	4	4	1	256	0.32
10	10	1,2	G	32–2–2	1:1	160	1	2	4	2048	0.31
10	10	1,2	G	32–4–1	1:1	160	1	4	4	1024	0.31
10	10	1,2	G	32–4–2	1:1	80	2	4	2	512	0.31
10	10	1,2	G	32–4–2	1:1	80	1	4	2	1024	0.31

B.3 Extra line configurations from oversampling

N_t	t_{int} [s]	N_{pol}	V	mode tot–n–b	fan	rec [ips]	speed up	N_{intf}	BW [MHz]	N_{freq} (max)	out rate [Mb/s]
10	10	1,2	G	2–1–1 (×2)	1:1	40	4	1	0.5	1024	0.31
10	10	1,2	G	2–1–1 (×4)	1:1	40	4	1	0.25	1024	0.31
10	10	1,2	G	4–1–1 (×2)	1:1	80	2	1	1	2048	0.31
10	10	1,2	G	4–1–1 (×2)	1:1	80	1	1	1	4096	0.31
10	10	1,2	G	4–1–1 (×4)	1:1	80	2	1	0.5	2048	0.31
10	10	1,2	G	4–1–2 (×2)	1:1	40	4	1	0.5	1024	0.31
10	10	1,2	G	4–1–2 (×4)	1:1	40	4	1	0.25	1024	0.31
10	10	1,2	G	4–2–1 (×2)	1:1	40	4	2	0.5	512	0.31
10	10	1,2	G	4–2–1 (×4)	1:1	40	4	2	0.25	512	0.31
10	10	1,2	G	8–1–1 (×2)	1:1	160	1	1	2	4096	0.31
10	10	1,2	G	8–1–1 (×4)	1:1	160	1	1	1	4096	0.31
10	10	1,2	G	8–1–2 (×2)	1:1	80	2	1	1	2048	0.31
10	10	1,2	G	8–1–2 (×2)	1:1	80	1	1	1	4096	0.31
10	10	1,2	G	8–1–2 (×4)	1:1	80	2	1	0.5	2048	0.31
10	10	1,2	G	8–2–1 (×2)	1:1	80	2	2	1	1024	0.31
10	10	1,2	G	8–2–1 (×2)	1:1	80	1	2	1	2048	0.31
10	10	1,2	G	8–2–1 (×4)	1:1	80	2	2	0.5	1024	0.31
10	10	1,2	G	8–2–2 (×2)	1:1	40	4	2	0.5	512	0.31
10	10	1,2	G	8–2–2 (×4)	1:1	40	4	2	0.25	512	0.31
10	10	1,2	G	8–4–1 (×2)	1:1	40	4	4	0.5	256	0.32
10	10	1,2	G	8–4–1 (×4)	1:1	40	4	4	0.25	256	0.32
10	10	1,2	G	16–1–2 (×2)	1:1	160	1	1	2	4096	0.31
10	10	1,2	G	16–1–2 (×4)	1:1	160	1	1	1	4096	0.31
10	10	1,2	G	16–2–1 (×2)	1:1	160	1	2	2	2048	0.31
10	10	1,2	G	16–2–1 (×4)	1:1	160	1	2	1	2048	0.31
10	10	1,2	G	16–2–2 (×2)	1:1	80	2	2	1	1024	0.31
10	10	1,2	G	16–2–2 (×2)	1:1	80	1	2	1	2048	0.31
10	10	1,2	G	16–2–2 (×4)	1:1	80	2	2	0.5	1024	0.31
10	10	1,2	G	16–4–1 (×2)	1:1	80	2	4	1	512	0.31
10	10	1,2	G	16–4–1 (×2)	1:1	80	1	4	1	1024	0.31
10	10	1,2	G	16–4–1 (×4)	1:1	80	2	4	0.5	512	0.31
10	10	1,2	G	16–4–2 (×2)	1:1	40	4	4	0.5	256	0.32
10	10	1,2	G	16–4–2 (×4)	1:1	40	4	4	0.25	256	0.32
10	10	1,2	G	32–2–2 (×2)	1:1	160	1	2	2	2048	0.31
10	10	1,2	G	32–2–2 (×4)	1:1	160	1	2	1	2048	0.31
10	10	1,2	G	32–4–1 (×2)	1:1	160	1	4	2	1024	0.31
10	10	1,2	G	32–4–1 (×4)	1:1	160	1	4	1	1024	0.31
10	10	1,2	G	32–4–2 (×2)	1:1	80	2	4	1	512	0.31
10	10	1,2	G	32–4–2 (×2)	1:1	80	1	4	1	1024	0.31
10	10	1,2	G	32–4–2 (×4)	1:1	80	2	4	0.5	512	0.31

B.4 Extra line configurations from Fan–In

N_t	t_{int} [s]	N_{pol}	V	mode tot–n–b	fan	rec [ips]	speed up	N_{intf}	BW [MHz]	N_{freq} (max)	out rate [Mb/s]
10	10	1,2	G	0.5–1–1	4:1	40	4	1	0.25	1024	0.31
10	10	1,2	G	1–1–1	4:1	80	2	1	0.5	2048	0.31
10	10	1,2	G	1–1–1	4:1	80	1	1	0.5	4096	0.31
10	10	1,2	G	1–1–1	2:1	40	4	1	0.5	1024	0.31
10	10	1,2	G	1–1–2	4:1	40	4	1	0.25	1024	0.31
10	10	1,2	G	1–2–1	4:1	40	4	2	0.25	512	0.31
10	10	1,2	G	2–1–1	4:1	160	1	1	1	4096	0.31
10	10	1,2	G	2–1–1	2:1	80	2	1	1	2048	0.31
10	10	1,2	G	2–1–1	2:1	80	1	1	1	4096	0.31
10	10	1,2	G	2–1–2	4:1	80	2	1	0.5	2048	0.31
10	10	1,2	G	2–1–2	4:1	80	1	1	0.5	4096	0.31
10	10	1,2	G	2–1–2	2:1	40	4	1	0.5	1024	0.31
10	10	1,2	G	2–2–1	4:1	80	2	2	0.5	1024	0.31
10	10	1,2	G	2–2–1	4:1	80	1	2	0.5	2048	0.31
10	10	1,2	G	2–2–1	2:1	40	4	2	0.5	512	0.31
10	10	1,2	G	2–2–2	4:1	40	4	2	0.25	512	0.31
10	10	1,2	G	2–4–1	4:1	40	4	4	0.25	256	0.32
10	10	1,2	G	4–1–1	2:1	160	1	1	2	4096	0.31
10	10	1,2	G	4–1–2	4:1	160	1	1	1	4096	0.31
10	10	1,2	G	4–1–2	2:1	80	2	1	1	2048	0.31
10	10	1,2	G	4–1–2	2:1	80	1	1	1	4096	0.31
10	10	1,2	G	4–2–1	4:1	160	1	2	1	2048	0.31
10	10	1,2	G	4–2–1	2:1	80	2	2	1	1024	0.31
10	10	1,2	G	4–2–1	2:1	80	1	2	1	2048	0.31
10	10	1,2	G	4–2–2	4:1	80	2	2	0.5	1024	0.31
10	10	1,2	G	4–2–2	4:1	80	1	2	0.5	2048	0.31
10	10	1,2	G	4–2–2	2:1	40	4	2	0.5	512	0.31
10	10	1,2	G	4–4–1	4:1	80	2	4	0.5	512	0.31
10	10	1,2	G	4–4–1	4:1	80	1	4	0.5	1024	0.31
10	10	1,2	G	4–4–1	2:1	40	4	4	0.5	256	0.32
10	10	1,2	G	4–4–2	4:1	40	4	4	0.25	256	0.32
10	10	1,2	G	8–1–2	2:1	160	1	1	2	4096	0.31
10	10	1,2	G	8–2–1	2:1	160	1	2	2	2048	0.31
10	10	1,2	G	8–2–2	4:1	160	1	2	1	2048	0.31
10	10	1,2	G	8–2–2	2:1	80	2	2	1	1024	0.31
10	10	1,2	G	8–2–2	2:1	80	1	2	1	2048	0.31
10	10	1,2	G	8–4–1	4:1	160	1	4	1	1024	0.31
10	10	1,2	G	8–4–1	2:1	80	2	4	1	512	0.31
10	10	1,2	G	8–4–1	2:1	80	1	4	1	1024	0.31
10	10	1,2	G	8–4–2	4:1	80	2	4	0.5	512	0.31
10	10	1,2	G	8–4–2	4:1	80	1	4	0.5	1024	0.31
10	10	1,2	G	8–4–2	2:1	40	4	4	0.5	256	0.32

N_t	t_{int} [s]	N_{pol}	V	mode tot–n–b	fan	rec [ips]	speed up	N_{intf}	BW [MHz]	N_{freq} (max)	out rate [Mb/s]
10	10	1,2	G	16–2–2	2:1	160	1	2	2	2048	0.31
10	10	1,2	G	16–4–1	2:1	160	1	4	2	1024	0.31
10	10	1,2	G	16–4–2	4:1	160	1	4	1	1024	0.31
10	10	1,2	G	16–4–2	2:1	80	2	4	1	512	0.31
10	10	1,2	G	16–4–2	2:1	80	1	4	1	1024	0.31
10	10	1,2	G	32–4–2	2:1	160	1	4	2	1024	0.31

B.5 Extra line configurations from slow replay tape speeds

N_t	t_{int} [s]	N_{pol}	V	mode tot–n–b	fan	rec [ips]	speed up	N_{intf}	BW [MHz]	N_{freq} (max)	out rate [Mb/s]
10	10	1,2	G	2–1–1	1:1	40	1	1	1	4096	0.31
10	10	1,2	G	4–1–2	1:1	40	1	1	1	4096	0.31
10	10	1,2	G	4–2–1	1:1	40	1	2	1	2048	0.31
10	10	1,2	G	8–2–2	1:1	40	1	2	1	2048	0.31
10	10	1,2	G	8–4–1	1:1	40	1	4	1	1024	0.31
10	10	1,2	G	16–4–2	1:1	40	1	4	1	1024	0.31

B.6 Complete line configurations

N_t	t_{int} [s]	N_{pol}	V	mode tot–n–b	fan	rec [ips]	speed up	N_{intf}	BW [MHz]	N_{freq} (max)	out rate [Mb/s]
10	10	1,2	G	0.5–1–1	4:1	40	8	1	0.25	512	0.31
10	10	1,2	G	0.5–1–1 (×2)	4:1	40	8	1	0.125	512	0.31
10	10	1,2	G	1–1–1	4:1	80	4	1	0.5	1024	0.31
10	10	1,2	G	1–1–1	2:1	40	8	1	0.5	512	0.31
10	10	1,2	G	1–1–1 (×2)	4:1	80	4	1	0.25	1024	0.31
10	10	1,2	G	1–1–1 (×2)	2:1	40	8	1	0.25	512	0.31
10	10	1,2	G	1–1–1 (×4)	2:1	40	8	1	0.125	512	0.31
10	10	1,2	G	1–1–2	4:1	40	8	1	0.25	512	0.31
10	10	1,2	G	1–1–2 (×2)	4:1	40	8	1	0.125	512	0.31
10	10	1,2	G	1–2–1	4:1	40	8	2	0.25	256	0.32
10	10	1,2	G	1–2–1 (×2)	4:1	40	8	2	0.125	256	0.32
10	10	1,2	G	2–1–1	4:1	160	2	1	1	2048	0.31
10	10	1,2	G	2–1–1	4:1	160	1	1	1	4096	0.31
10	10	1,2	G	2–1–1	2:1	80	4	1	1	1024	0.31
10	10	1,2	G	2–1–1	2:1	80	1	1	1	4096	0.31
10	10	1,2	G	2–1–1	1:1	40	8	1	1	512	0.31
10	10	1,2	G	2–1–1	1:1	40	1	1	1	4096	0.31
10	10	1,2	G	2–1–1 (×2)	4:1	160	2	1	0.5	2048	0.31
10	10	1,2	G	2–1–1 (×2)	2:1	80	4	1	0.5	1024	0.31
10	10	1,2	G	2–1–1 (×2)	1:1	40	8	1	0.5	512	0.31
10	10	1,2	G	2–1–1 (×4)	2:1	80	4	1	0.25	1024	0.31
10	10	1,2	G	2–1–1 (×4)	1:1	40	8	1	0.25	512	0.31
10	10	1,2	G	2–1–1 (×8)	1:1	40	8	1	0.125	512	0.31
10	10	1,2	G	2–1–2	4:1	80	4	1	0.5	1024	0.31
10	10	1,2	G	2–1–2	2:1	40	8	1	0.5	512	0.31
10	10	1,2	G	2–1–2 (×2)	4:1	80	4	1	0.25	1024	0.31
10	10	1,2	G	2–1–2 (×2)	2:1	40	8	1	0.25	512	0.31
10	10	1,2	G	2–1–2 (×4)	2:1	40	8	1	0.125	512	0.31
10	10	1,2	G	2–2–1	4:1	80	4	2	0.5	512	0.31
10	10	1,2	G	2–2–1	2:1	40	8	2	0.5	256	0.32
10	10	1,2	G	2–2–1 (×2)	4:1	80	4	2	0.25	512	0.31
10	10	1,2	G	2–2–1 (×2)	2:1	40	8	2	0.25	256	0.32
10	10	1,2	G	2–2–1 (×4)	2:1	40	8	2	0.125	256	0.32
10	10	1,2	G	2–2–2	4:1	40	8	2	0.25	256	0.32
10	10	1,2	G	2–2–2 (×2)	4:1	40	8	2	0.125	256	0.32
10	10	1,2	G	2–4–1	4:1	40	8	4	0.25	128	0.32
10	10	1,2	G	2–4–1 (×2)	4:1	40	8	4	0.125	128	0.32
10	10	1,2	G	4–1–1	4:1	320	1	1	2	4096	0.31
10	10	1,2	G	4–1–1	2:1	160	2	1	2	2048	0.31
10	10	1,2	G	4–1–1	2:1	160	1	1	2	4096	0.31
10	10	1,2	G	4–1–1	1:1	80	4	1	2	1024	0.31
10	10	1,2	G	4–1–1	1:1	80	1	1	2	4096	0.31

N_t	t_{int} [s]	N_{pol}	V	mode tot–n–b	fan	rec [ips]	speed up	N_{intf}	BW [MHz]	N_{freq} (max)	out rate [Mb/s]
10	10	1,2	G	4–1–1 (×2)	4:1	320	1	1	1	4096	0.31
10	10	1,2	G	4–1–1 (×2)	2:1	160	2	1	1	2048	0.31
10	10	1,2	G	4–1–1 (×2)	2:1	160	1	1	1	4096	0.31
10	10	1,2	G	4–1–1 (×2)	1:1	80	4	1	1	1024	0.31
10	10	1,2	G	4–1–1 (×2)	1:1	80	1	1	1	4096	0.31
10	10	1,2	G	4–1–1 (×4)	2:1	160	2	1	0.5	2048	0.31
10	10	1,2	G	4–1–1 (×4)	1:1	80	4	1	0.5	1024	0.31
10	10	1,2	G	4–1–1 (×8)	1:1	80	4	1	0.25	1024	0.31
10	10	1,2	G	4–1–2	4:1	160	2	1	1	2048	0.31
10	10	1,2	G	4–1–2	4:1	160	1	1	1	4096	0.31
10	10	1,2	G	4–1–2	2:1	80	4	1	1	1024	0.31
10	10	1,2	G	4–1–2	2:1	80	1	1	1	4096	0.31
10	10	1,2	G	4–1–2	1:1	40	8	1	1	512	0.31
10	10	1,2	G	4–1–2	1:1	40	1	1	1	4096	0.31
10	10	1,2	G	4–1–2 (×2)	4:1	160	2	1	0.5	2048	0.31
10	10	1,2	G	4–1–2 (×2)	2:1	80	4	1	0.5	1024	0.31
10	10	1,2	G	4–1–2 (×2)	1:1	40	8	1	0.5	512	0.31
10	10	1,2	G	4–1–2 (×4)	2:1	80	4	1	0.25	1024	0.31
10	10	1,2	G	4–1–2 (×4)	1:1	40	8	1	0.25	512	0.31
10	10	1,2	G	4–1–2 (×8)	1:1	40	8	1	0.125	512	0.31
10	10	1,2	G	4–2–1	4:1	160	2	2	1	1024	0.31
10	10	1,2	G	4–2–1	4:1	160	1	2	1	2048	0.31
10	10	1,2	G	4–2–1	2:1	80	4	2	1	512	0.31
10	10	1,2	G	4–2–1	2:1	80	1	2	1	2048	0.31
10	10	1,2	G	4–2–1	1:1	40	8	2	1	256	0.32
10	10	1,2	G	4–2–1	1:1	40	1	2	1	2048	0.31
10	10	1,2	G	4–2–1 (×2)	4:1	160	2	2	0.5	1024	0.31
10	10	1,2	G	4–2–1 (×2)	2:1	80	4	2	0.5	512	0.31
10	10	1,2	G	4–2–1 (×2)	1:1	40	8	2	0.5	256	0.32
10	10	1,2	G	4–2–1 (×4)	2:1	80	4	2	0.25	512	0.31
10	10	1,2	G	4–2–1 (×4)	1:1	40	8	2	0.25	256	0.32
10	10	1,2	G	4–2–1 (×8)	1:1	40	8	2	0.125	256	0.32
10	10	1,2	G	4–2–2	4:1	80	4	2	0.5	512	0.31
10	10	1,2	G	4–2–2	2:1	40	8	2	0.5	256	0.32
10	10	1,2	G	4–2–2 (×2)	4:1	80	4	2	0.25	512	0.31
10	10	1,2	G	4–2–2 (×2)	2:1	40	8	2	0.25	256	0.32
10	10	1,2	G	4–2–2 (×4)	2:1	40	8	2	0.125	256	0.32
10	10	1,2	G	4–4–1	4:1	80	4	4	0.5	256	0.32
10	10	1,2	G	4–4–1	2:1	40	8	4	0.5	128	0.32
10	10	1,2	G	4–4–1 (×2)	4:1	80	4	4	0.25	256	0.32
10	10	1,2	G	4–4–1 (×2)	2:1	40	8	4	0.25	128	0.32
10	10	1,2	G	4–4–1 (×4)	2:1	40	8	4	0.125	128	0.32

N_t	t_{int} [s]	N_{pol}	V	mode tot–n–b	fan	rec [ips]	speed up	N_{intf}	BW [MHz]	N_{freq} (max)	out rate [Mb/s]
10	10	1,2	G	4–4–2	4:1	40	8	4	0.25	128	0.32
10	10	1,2	G	4–4–2 (×2)	4:1	40	8	4	0.125	128	0.32
10	10	1,2	G	8–1–1	2:1	320	1	1	4	4096	0.31
10	10	1,2	G	8–1–1	1:1	160	2	1	4	2048	0.31
10	10	1,2	G	8–1–1	1:1	160	1	1	4	4096	0.31
10	10	1,2	G	8–1–1 (×2)	2:1	320	1	1	2	4096	0.31
10	10	1,2	G	8–1–1 (×2)	1:1	160	2	1	2	2048	0.31
10	10	1,2	G	8–1–1 (×2)	1:1	160	1	1	2	4096	0.31
10	10	1,2	G	8–1–1 (×4)	2:1	320	1	1	1	4096	0.31
10	10	1,2	G	8–1–1 (×4)	1:1	160	2	1	1	2048	0.31
10	10	1,2	G	8–1–1 (×4)	1:1	160	1	1	1	4096	0.31
10	10	1,2	G	8–1–1 (×8)	1:1	160	2	1	0.5	2048	0.31
10	10	1,2	G	8–1–2	4:1	320	1	1	2	4096	0.31
10	10	1,2	G	8–1–2	2:1	160	2	1	2	2048	0.31
10	10	1,2	G	8–1–2	2:1	160	1	1	2	4096	0.31
10	10	1,2	G	8–1–2	1:1	80	4	1	2	1024	0.31
10	10	1,2	G	8–1–2	1:1	80	1	1	2	4096	0.31
10	10	1,2	G	8–1–2 (×2)	4:1	320	1	1	1	4096	0.31
10	10	1,2	G	8–1–2 (×2)	2:1	160	2	1	1	2048	0.31
10	10	1,2	G	8–1–2 (×2)	2:1	160	1	1	1	4096	0.31
10	10	1,2	G	8–1–2 (×2)	1:1	80	4	1	1	1024	0.31
10	10	1,2	G	8–1–2 (×2)	1:1	80	1	1	1	4096	0.31
10	10	1,2	G	8–1–2 (×4)	2:1	160	2	1	0.5	2048	0.31
10	10	1,2	G	8–1–2 (×4)	1:1	80	4	1	0.5	1024	0.31
10	10	1,2	G	8–1–2 (×8)	1:1	80	4	1	0.25	1024	0.31
10	10	1,2	G	8–2–1	4:1	320	1	2	2	2048	0.31
10	10	1,2	G	8–2–1	2:1	160	2	2	2	1024	0.31
10	10	1,2	G	8–2–1	2:1	160	1	2	2	2048	0.31
10	10	1,2	G	8–2–1	1:1	80	4	2	2	512	0.31
10	10	1,2	G	8–2–1	1:1	80	1	2	2	2048	0.31
10	10	1,2	G	8–2–1 (×2)	4:1	320	1	2	1	2048	0.31
10	10	1,2	G	8–2–1 (×2)	2:1	160	2	2	1	1024	0.31
10	10	1,2	G	8–2–1 (×2)	2:1	160	1	2	1	2048	0.31
10	10	1,2	G	8–2–1 (×2)	1:1	80	4	2	1	512	0.31
10	10	1,2	G	8–2–1 (×2)	1:1	80	1	2	1	2048	0.31
10	10	1,2	G	8–2–1 (×4)	2:1	160	2	2	0.5	1024	0.31
10	10	1,2	G	8–2–1 (×4)	1:1	80	4	2	0.5	512	0.31
10	10	1,2	G	8–2–1 (×8)	1:1	80	4	2	0.25	512	0.31
10	10	1,2	G	8–2–2	4:1	160	2	2	1	1024	0.31
10	10	1,2	G	8–2–2	4:1	160	1	2	1	2048	0.31
10	10	1,2	G	8–2–2	2:1	80	4	2	1	512	0.31
10	10	1,2	G	8–2–2	2:1	80	1	2	1	2048	0.31

$N_{\rm t}$	$t_{\rm int}$ [s]	$N_{\rm pol}$	V	mode tot–n–b	fan	rec [ips]	speed up	$N_{\rm intf}$	BW [MHz]	$N_{\rm freq}$ (max)	out rate [Mb/s]
10	10	1,2	G	8–2–2	1:1	40	8	2	1	256	0.32
10	10	1,2	G	8–2–2	1:1	40	1	2	1	2048	0.31
10	10	1,2	G	8–2–2 (×2)	4:1	160	2	2	0.5	1024	0.31
10	10	1,2	G	8–2–2 (×2)	2:1	80	4	2	0.5	512	0.31
10	10	1,2	G	8–2–2 (×2)	1:1	40	8	2	0.5	256	0.32
10	10	1,2	G	8–2–2 (×4)	2:1	80	4	2	0.25	512	0.31
10	10	1,2	G	8–2–2 (×4)	1:1	40	8	2	0.25	256	0.32
10	10	1,2	G	8–2–2 (×8)	1:1	40	8	2	0.125	256	0.32
10	10	1,2	G	8–4–1	4:1	160	2	4	1	512	0.31
10	10	1,2	G	8–4–1	4:1	160	1	4	1	1024	0.31
10	10	1,2	G	8–4–1	2:1	80	4	4	1	256	0.32
10	10	1,2	G	8–4–1	2:1	80	1	4	1	1024	0.31
10	10	1,2	G	8–4–1	1:1	40	8	4	1	128	0.32
10	10	1,2	G	8–4–1	1:1	40	1	4	1	1024	0.31
10	10	1,2	G	8–4–1 (×2)	4:1	160	2	4	0.5	512	0.31
10	10	1,2	G	8–4–1 (×2)	2:1	80	4	4	0.5	256	0.32
10	10	1,2	G	8–4–1 (×2)	1:1	40	8	4	0.5	128	0.32
10	10	1,2	G	8–4–1 (×4)	2:1	80	4	4	0.25	256	0.32
10	10	1,2	G	8–4–1 (×4)	1:1	40	8	4	0.25	128	0.32
10	10	1,2	G	8–4–1 (×8)	1:1	40	8	4	0.125	128	0.32
10	10	1,2	G	8–4–2	4:1	80	4	4	0.5	256	0.32
10	10	1,2	G	8–4–2	2:1	40	8	4	0.5	128	0.32
10	10	1,2	G	8–4–2 (×2)	4:1	80	4	4	0.25	256	0.32
10	10	1,2	G	8–4–2 (×2)	2:1	40	8	4	0.25	128	0.32
10	10	1,2	G	8–4–2 (×4)	2:1	40	8	4	0.125	128	0.32