OPERATING MODES OF GMRT CORRELATOR

CR Subrahmanya/21Mar-27Jun91

This note gives a brief description of various options planned in the GMRT Correlator System. Rather than tabulating all possible options together, attempt is made to list the options under various groups depending on the subsystem where they are implemented in the system.

1. THE GMRT RF/IF SIGNALS

In the GMRT, there will be two streams of analog signals of bandwidth 32 MHz coming from each antenna. If a single-frequency feed is selected, these two will correspond to R and L polarizations centred at the desired frequency. However, in the case of dual-frequency feeds, these two will correspond to a single circular polarization signal for each of the two frequencies simultaneously available. For convenience, these two will simply be referred to as R and L in this document, although this terminology is inappropriate for dual-frequency observation.

The R and L streams mentioned above will then be split into two streams of 16 MHz bandwidth each, thus resulting in 4 channels for each antenna. Each of these 4 channels has a 16 MHz bandwidth. At this stage, it is possible to select independent filters for upper and lower sidebands which will limit the bandwidth to one of 9 possible values: 16, 8, 4, 2, ... 0.064 MHz.

It should thus be remembered that the upper and lower sidebands for each polarization correspond to the same RF signal of a broader bandwidth. This implies, for instance, the Walsh demodulation and noise-switching will be identical for the upper and lower sidebands of a given polarization.

2. SAMPLER CARD

The sampler card has no useful user-selectable option. The sampler in GMRT is always driven at the same rate for all channels, at 32 Ms/s irrespective of observing modes. The sampler will output 4-bit samples to the Data Preparation Card (DPC) which provides for various user-selectable options.

3. DATA PREPARATION CARD (DPC)

The options provided by the DPC are crucial to the observing modes supported by the correlator system. The functions of the DPC are explained in a separate document. They include Walsh demodulation, effective sampling rate selection, channel selections related to polarization modes, synchronous detection of total power for noise-calibration, delay setting, etc.

Sampling Options: Effective sampling interval can be selected independently for each station. There are two possible sampling intervals which can be selected for each station - corresponding to the two IF sidebands of maximum bandwidth 16 MHz each. The sampling frequency can be any one of 9 possible values, 32, 16, 8, ..., 0.128 Ms/s. It may be noted that this selection does not affect the sampler cards, which always output 4-bit samples at 32 Ms/s. The effective sampling rate is provided in the Data Preparation Card (DPC) which ignores the samples which do not occur at the times expected on the basis of the desired sampling rate.

The DPC requires that the same sampling rate be chosen for R and L channels of the same sideband. While this is the obvious choice for single-frequency observations, it is an unavoidable restriction for the dual-frequency observations. In such cases, the two "polarizations" strictly correspond to

38 MHz. One would normally be using a much narrower filter for the lower frequency than for the higher frequency. Since DPC forces effective sampling rate to be the same, the sampling interval will correspond to the broader bandwidth. This makes the signal of narrower bandwidth to be oversampled and thus be processed with much worse spectral resolution than feasible with the selected FFT size.

Channel Selection: Channel selection is an important option to be understood by the user since it is linked with polarization and 16/32 MHz choices. There are 4 FFT engines for each antenna, to which the DPC sends 4-bit samples. These streams are grouped as two R/L pairs, each pair corresponding to the same sideband (lower or upper). Selection of both pairs will result in 32 MHz bandwidth, for which only RR/LL products are possible without any cross-polarization products. Full polarization is only feasible when only one of the two sidebands is processed. Channel select option enables choice of either (for polarization) or both the sidebands.

Overlapped Windows: The correlator system groups the 4-bit samples in each channel into blocks of 512 consecutive samples at the desired effective sampling interval. At the maximum sampling rate of 32 Ms/s, DPC forms these blocks such that adjacent blocks correspond to contiguous streams of data. However, when lower sampling rate is chosen, adjacent blocks will overlap each other such that the net rate of data entering the FFT engine is always at 32 Ms/s. Thus, if the data are required to be sampled at 32/n Ms/s, adjacent blocks of 512 samples received by the FFT engine will have 512(1-1/n) values in common.

The overlap factor is not independently selectable by user, since it is linked with the sampling rate. However, it is an important feature to be noticed by the users wanting to use the facility of time-domain window offered during the FFT to reduce the spectral sidelobes. If such a window is required, it is essential to overlap adjacent blocks to avoid significant loss of sensitivity.

Walsh Modulation and Gain Calibration: Both these are implemented within the DPC, synchronously with the antenna feed electronics. Details of implementation will be discussed elsewhere. The user has the option to enable or disable the switching, but otherwise there is no user-definable parameter controlling these features.

4. FFT OPTIONS

The FFT options are implemented within the FFT card - each FFT card consists of 4 FFT engines and is dedicated for a specific antenna. The information related to various options is communicated by the online computer to the FFT control card, which also performs many of the control/interface functions for a group of FFT cards. These details may not concern the user, but it is important to know certain inter-relationships which exist among the FFT engines within the same card, i.e., among various channels of a single antenna. The parameters of each antenna can, however, be chosen independently of those of any other antenna.

Fringe Rotation: Fringe rotation is implemented by multiplying each 4-bit sample by a exp(i.fringe_angle), where fringe_angle is updated at the rate specified by the online computer. The fringe rates can be independently specified for each FFT engine, although one usually would chose them to be identical for both polarizations of a given frequency band and a given antenna.

FFT Size: There is a restriction that all the FFT engines of a given antenna perform FFTs of the same size. The FFT sizes of different antennas could be specified independently of each other. The available

FFT sizes are 512,256, or 32 points. Note that the number of spectral channels is half the FFT size because of the Hermitian symmetry of the Fourier transform of a real function. The low-resolution is provided to increase the time-resolution. It is possible to combine adjacent channels before data acquisition to achieve different number of channels than those listed above.

The maximum number of spectral channels is 128 if polarization is required, but could be 256 if polarization information is not needed (only RR,LL products will be available in that case.) The spectral resolution, however, depends on the effective sampling rate chosen at the DPC.

Fractional Sample Time Correction(FSTC): Delay errors in fractions of effective sampling time interval are introduced in the spectra as phase gradients. This is done in the last stage of the FFT by multiplying by the frequency-dependent phase factor. The fractional delay error is specified as the equivalent slope of the phase ramp in the spectra. The number-controlled-oscillator in the FX chip is used to update the phase for each FFT output on the basis of this slope.

5. MULTIPLIER OPTIONS

Polarization modes: There are 3 polarization modes, depending upon the channel select option exercised at the DPC before the FFT card. The number of spectral channels is decided by the size of FFT chosen at the FFT card. For the sake of clarity, we list the polarization modes here, although the necessary user parameters would have been specified in DPC and FFT. There are three distinct modes, out of which only one mode will result in full polarization observations (all 4 Stokes parameters are available.) There are two non-polarization modes(RR,LL only recorded) - (a) single sideband (upto 16 MHz) & upto 256 spectral channels; (b) full band (upto 32 MHz bandwidth) and upto 128 spectral channels in each sideband. In effect, the maximum number of spectral channels is 128 or 256 depending on whether polarization information is desired or not, but the spectral resolution depends on the bandwidths of filters used before sampler, and the effective sampling rate chosen at the DPC.

In sub-array implementations, it will be assumed that the polarization mode of 16 baselines within a single multiplier card will be the same. The modes can be independently chosen for different multiplier cards.

Integration Options: The short-term-accumulation (STA) - the on-chip accumulation of cross-correlation values - is restricted to a maximum interval of 128 ms. For longer STA intervals, there will be loss of precision due to the limited number of bits used to represent the numbers in the multiply-accumulate mode. It is possible to read out samples at a faster rate, but the resulting data rates would be too fast to handle in subsequent operations. In principle, the correlator system can allow a time-resolution as low as 4 ms in high resolution and 0.5 ms in low-resolution (16 channel) mode, but rest of the system is not designed to take this load. Our system is modular and we plan to leave open the challenging option open for a future data acquisition system to provide such high time resolutions.

In the current design, the highest time-resolution is 128 ms for full spectral resolution, and 8 ms for the low resolution mode with 16 channels.

The integration time options available are 8, 16, 32, 64 and 128 ms. Among these, 128 ms (default mode) is special, being the only mode in there is no loss of data at any bandwidth. However, it should be noted that the net time-resolution will be limited by the LTA and Data Acquisition system which are initially being planned to support only the default 128 ms STA option.

The STA integration option will be common to the entire array. Apparent differences for different baselines must be implemented in the software related to data acquisition.

6. DATA ACQUISITION OPTIONS

The options for data acquisition are implemented in two stages - the Long Term Accumulator (LTA) and the Data Acquisition System (DAS). The LTA will have the capability of reading all the 238080 (complex) correlator channels every 128 ms. The design has not been finalised, and it may be possible to support faster speeds. However, the archival speeds available in the DAS will be much slower, limited by the speeds supported by archival media. Our current plan is to use the Exabyte 8mm cartridges. The Exabyte drive available with us can pack 2.3 GB of data into one cartridge, and can sustain transfer rates of about 128 kB/s. This will lead to the recording of all 238080 channels every few seconds.

The recording of data will be limited to meaningful correlations; e.g., correlations between antennas belonging to different sub-arrays will not be recorded. User will be provided with the option of merging adjacent spectral channels or selecting any subset of spectral channels. When such options are exercised, the recording limitation of 128 kB/s may correspond time intervals much less than a few sec. For instance, if only 16 spectral channels and all four Stokes parameters are required, it will be possible to record data every half a second.

In addition to the archival of raw visibilities, the data acquisition system will also be able to write the data on the disk of the online file server. Online monitoring or other programs will be able to access the data through the file server. Since all the monitored data base and other data logging is being done on the file server, it should be possible to do on-line calibration of data after the data reach the file server. This is part of a wish-list whose details have not been worked out yet.

Baselines available in MAC cards:

The 30 antennas are denoted by the numbers 1,2,...9 followed the letters a,b,c,...,u where the upper case is used for "L" in order to avoid confusion with the digit "1". Each multilier card has upto 16 baselines derived from upto 8 antennas as listed below. The entire multiplier system consists of two sets of 32 cards - one for each sideband - with the baselines as listed below.

There are 3 types of cards - (A) 6 baselines with 4 antennas (4 x 2 cards); (B) 30 baselines with 6 antennas (7 x 2 cards); (C) 16 baselines with 8 antennas (21 x 2 cards)

11	..	..	..	99	..	..	..	hh	..	..	..	pp	..	..	..
21	22	..	..	a9	aa	..	..	ih	ii	..	..	qp	qq	..	..
..	..	55	..	..	..	dd	..	..	..	LL	..	..	..	tt	..
..	..	65	66	..	..	ed	ee	..	..	mL	mm	..	..	ut	uu
31	32	33	..	71	72	73	74	75	76	77	..	b1	b2	b3	b4
41	42	43	44	81	82	83	84	85	86	87	88	c1	c2	c3	c4
51	52	53	54	91	92	93	94	95	96	97	98	d1	d2	d3	d4
61	62	63	64	a1	a2	a3	a4	a5	a6	a7	a8	e1	e2	e3	e4
b5	b6	b7	b8	b9	ba	bb	..	f1	f2	f3	f4	f5	f6	f7	f8
c5	c6	c7	c8	c9	ca	cb	cc	g1	g2	g3	g4	g5	g6	g7	g8
d5	d6	d7	d8	d9	da	db	dc	h1	h2	h3	h4	h5	h6	h7	h8
e5	e6	e7	e8	e9	ea	eb	ec	i1	i2	i3	i4	i5	i6	i7	i8
f9	fa	fb	fc	fd	fe	ff	..	j1	j2	j3	j4	j5	j6	j7	j8
g9	ga	gb	gc	gd	ge	gf	gg	k1	k2	k3	k4	k5	k6	k7	k8
h9	ha	hb	hc	hd	he	hf	hg	L1	L2	L3	L4	L5	L6	L7	L8
i9	ia	ib	ic	id	ie	if	ig	m1	m2	m3	m4	m5	m6	m7	m8
j9	ja	jb	jc	jd	je	jf	jg	jh	ji	jj	..	n1	n2	n3	n4
k9	ka	kb	kc	kd	ke	kf	kg	kh	ki	kj	kk	o1	o2	o3	o4
L9	La	Lb	Lc	Ld	Le	Lf	Lg	Lh	Li	Lj	Lk	p1	p2	p3	p4
m9	ma	mb	mc	md	me	mf	mg	mh	mi	mj	mk	q1	q2	q3	q4
n5	n6	n7	n8	n9	na	nb	nc	nd	ne	nf	ng	nh	ni	nj	nk
o5	o6	o7	o8	o9	oa	ob	oc	od	oe	of	og	oh	oi	oj	ok
p5	p6	p7	p8	p9	pa	pb	pc	pd	pe	pf	pg	ph	pi	pj	pk
q5	q6	q7	q8	q9	qa	qb	qc	qd	qe	qf	qg	qh	qi	qj	qk
nL	nm	nn	..	r1	r2	r3	r4	r5	r6	r7	r8	r9	ra	rb	rc
oL	om	on	oo	s1	s2	s3	s4	s5	s6	s7	s8	s9	sa	sb	sc
pL	pm	pn	po	t1	t2	t3	t4	t5	t6	t7	t8	t9	ta	tb	tc
qL	qm	qn	qo	u1	u2	u3	u4	u5	u6	u7	u8	u9	ua	ub	uc
rd	re	rf	rg	rh	ri	rj	rk	rL	rm	rn	ro	rp	rq	rr	..
sd	se	sf	sg	sh	si	sj	sk	sL	sm	sn	so	sp	sq	sr	ss
td	te	tf	tg	th	ti	tj	tk	tL	tm	tn	to	tp	tq	tr	ts
ud	ue	uf	ug	uh	ui	uj	uk	uL	um	un	uo	up	uq	ur	us