VGOS MEMO #044

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To: IVS VGOS Technology and Operations Groups
From: A. E. Niell
Subject: VGOS Band and Channel Frequency Configuration

This note describes the configuration of the four bands and the frequency channels within each band for the VGOS broadband observing as used for the GGAO12M – Westford observations. The configuration has been stable for the sequence of observations called VGOS Demonstration Series (VDS) that has been in progress since 2014 December.

The frequency configuration contains four bands of 512 MHz that span 3000.4 MHz to 10680.4 MHz (low edge of lowest recorded 32 MHz channel to high edge of highest recorded channel).

The GGAO-Westford four-RDBE-G/one-Mark6 systems make use of complex samples recorded in VDIF format, and that configuration is described first below. However, prior to implementation of the complex sample/VDIF configuration the recording was done on four Mark5Cs using real samples in Mark5B format. That layout is also provided. It is hoped that stations using Mark5B format can provide their data as described below in hopes of minimizing both effort and possible confusion at the correlator.

Backend, recorder, sample type, and recorded format (as of 2017 January):

GGAO12m, Kokee12m, and Westford:

Digital back end:	RDBE-G (one for each band)
Recorder:	Mark6
Samples:	Complex (how to specify more accurately?)
Format:	VDIF

(Please advise which of the following is correct. The information for other stations can be added)

Wettzell South

Digital back end:	two DBBC2s (two bands per DBBC2)
Recorder:	Mark6
Samples:	Real
Format:	VDIF

Yebes13m (as of 2017 January)

Digital back end:	RDBE-G (one for each band)
Recorder:	Mark6
Samples:	Complex
Format:	VDIF

Ishioka

Digital back end:	ADS3000+ (one for each band)
Recorder:	K6
Samples:	Real
Format:	VDIF

BAND AND CHANNEL FREQUENCIES:

The following table gives the frequencies associated with the four bands of the Broadband setup that is in use for the VGOS sessions involving GGAO12m and Westford and expected to be used for Kokee12m. Some of the details of the setup for the UpDown converters and RDBEs as used at GGAO12m and Westford are also included. The information has been left in this table in case questions come up regarding how the local oscillator frequencies (LOs) are derived.

All recorded channels are used in fourfit to calculate the single-band and multi-band delay. To obtain the best Delay Resolution Function, the lower edge of all channels should be a multiple of 32 MHz (the width of each PFB channel) above that of the lowest channel. The value of this multiple is shown in column 8.

Column 9 gives the frequency of the first phase cal tone in the sampled Nyquist zone relative to the sample frequency (f_LO + f_sampler with f_sampler = 1024 MHz for the RDBE). This is needed only for phase cal extraction in the RDBE-G.

				f_LO	f_sample	lower edge	ch 15 DC freq	diff mod(32) relative to lowest lower edge	pcal offset	high- or low-band	
Band	UDC		4* UDC	-22500	+1024	-496	32			GGAO	Westford
A	6243.1		24972.4	2472.4	3496.4	3000.4	3032.4	0	1.4	low	low
B	6803.1	*	27212.4	4712.4	5736.4	5240.4	5272.4	70	1.4	high	high
C	7083.1		28332.4	5832.4	6856.4	6360.4	6392.4	105	1.4	high	high
D	8043.1		32172.4	9672.4	10696.4	10200.4	10232.4	225	1.4	high	high

For each recorded channel of each of the four bands, the following table lists a) the frequency that goes to DC for recording, b) the channel number within the PFB (the channels are numbered 0-15), and c) the polarization. The IF label (0 or 1, in column 1) is the convention that is in use for the GGAO12m-Westford hardware.

Frequency that goes to DC for each channel

IF	channel*	The 32MHz channels are lower sideband. Subtract 32MHz from each value for the low frequency edge of the channel. A	B	C	D	Polarization**
0	1	3480.4	5720.4	6840.4	10680.4	H(X)
0	2	3448.4	5688.4	6808.4	10648.4	H(X)
0	4	3384.4	5624.4	6744.4	10584.4	H(X)
0	6	3320.4	5560.4	6680.4	10520.4	H(X)
0	9	3224.4	5464.4	6584.4	10424.4	H(X)
0	13	3096.4	5336.4	6456.4	10296.4	H(X)
0	14	3064.4	5304.4	6424.4	10264.4	H(X)
0	15	3032.4	5272.4	6392.4	10232.4	H(X)
1	1	3480.4	5720.4	6840.4	10680.4	V(Y)
1	2	3448.4	5688.4	6808.4	10648.4	V(Y)
1	4	3384.4	5624.4	6744.4	10584.4	V(Y)
1	6	3320.4	5560.4	6680.4	10520.4	V(Y)
1	9	3224.4	5464.4	6584.4	10424.4	V(Y)
1	13	3096.4	5336.4	6456.4	10296.4	V(Y)
1	14	3064.4	5304.4	6424.4	10264.4	V(Y)
1	15	3032.4	5272.4	6392.4	10232.4	V(Y)

*PFB channels are numbered 0-15; ch 0 spans +16MHz to -16MHz about f_sample

** H and V are physical orientation of the polarization; X and Y are labels for DiFX and fourfit

Total data rate: 8192 Mbps

The frequency selection and placement of the channels within the VDIF packet (and for Mark5B) are shown in Figures 1 and 2, at the end of the note.

Mark5B format

The layout for Mark5B format is taken from the vex description of our earlier use of Mark5B/real formatted data from the RDBE-Gs that were recorded on Mark5Cs. Four Mark5Cs were used, one for each RDBE-G. The following vex language describes how this layout was used at the correlator.

```
   def DBE-X4-XX01_full_NZ2_polfreq_A;
     chan_def = &X : 3480.40 MHz : L : 32.000 MHz : &Ch01 : &BBC01 : &L_cal;
     chan_def = &X : 3448.40 MHz : L : 32.000 MHz : &Ch02 : &BBC02 : &L_cal;
     chan_def = &X : 3384.40 MHz : L : 32.000 MHz : &Ch03 : &BBC03 : &L_cal;
     chan_def = &X : 3320.40 MHz : L : 32.000 MHz : &Ch04 : &BBC04 : &L_cal;
     chan_def = &X : 3224.40 MHz : L : 32.000 MHz : &Ch05 : &BBC05 : &L_cal;
     chan_def = &X : 3096.40 MHz : L : 32.000 MHz : &Ch06 : &BBC06 : &L_cal;
     chan_def = &X : 3064.40 MHz : L : 32.000 MHz : &Ch07 : &BBC07 : &L_cal;
     chan_def = &X : 3032.40 MHz : L : 32.000 MHz : &Ch08 : &BBC08 : &L_cal;
     chan_def = &X : 3480.40 MHz : L : 32.000 MHz : &Ch09 : &BBC09 : &L_cal;
     chan_def = &X : 3448.40 MHz : L : 32.000 MHz : &Ch10 : &BBC10 : &L_cal;
     chan_def = &X : 3384.40 MHz : L : 32.000 MHz : &Ch11 : &BBC11 : &L_cal;
     chan_def = &X : 3320.40 MHz : L : 32.000 MHz : &Ch12 : &BBC12 : &L_cal;
     chan_def = &X : 3224.40 MHz : L : 32.000 MHz : &Ch13 : &BBC13 : &L_cal;
     chan_def = &X : 3096.40 MHz : L : 32.000 MHz : &Ch14 : &BBC14 : &L_cal;
     chan_def = &X : 3064.40 MHz : L : 32.000 MHz : &Ch15 : &BBC15 : &L_cal;
     chan_def = &X : 3032.40 MHz : L : 32.000 MHz : &Ch16 : &BBC16 : &L_cal;
     sample_rate = 64.0 Ms/sec;
   enddef;

def Mk34112-XX01_full;
     fanout_def = A : &Ch01 : sign : 1 : 02;
     fanout_def = A : &Ch01 : mag  : 1 : 03;
     fanout_def = A : &Ch02 : sign : 1 : 04;
     fanout_def = A : &Ch02 : mag  : 1 : 05;
     fanout_def = A : &Ch03 : sign : 1 : 06;
     fanout_def = A : &Ch03 : mag  : 1 : 07;
     fanout_def = A : &Ch04 : sign : 1 : 08;
     fanout_def = A : &Ch04 : mag  : 1 : 09;
     fanout_def = A : &Ch05 : sign : 1 : 10;
     fanout_def = A : &Ch05 : mag  : 1 : 11;
     fanout_def = A : &Ch06 : sign : 1 : 12;
     fanout_def = A : &Ch06 : mag  : 1 : 13;
     fanout_def = A : &Ch07 : sign : 1 : 14;
     fanout_def = A : &Ch07 : mag  : 1 : 15;
     fanout_def = A : &Ch08 : sign : 1 : 16;
     fanout_def = A : &Ch08 : mag  : 1 : 17;
     fanout_def = A : &Ch09 : sign : 1 : 18;
     fanout_def = A : &Ch09 : mag  : 1 : 19;
     fanout_def = A : &Ch10 : sign : 1 : 20;
     fanout_def = A : &Ch10 : mag  : 1 : 21;
     fanout_def = A : &Ch11 : sign : 1 : 22;
     fanout_def = A : &Ch11 : mag  : 1 : 23;
     fanout_def = A : &Ch12 : sign : 1 : 24;
     fanout_def = A : &Ch12 : mag  : 1 : 25;
     fanout_def = A : &Ch13 : sign : 1 : 26;
     fanout_def = A : &Ch13 : mag  : 1 : 27;
     fanout_def = A : &Ch14 : sign : 1 : 28;
     fanout_def = A : &Ch14 : mag  : 1 : 29;
     fanout_def = A : &Ch15 : sign : 1 : 30;
     fanout_def = A : &Ch15 : mag  : 1 : 31;
     fanout_def = A : &Ch16 : sign : 1 : 32;
     fanout_def = A : &Ch16 : mag  : 1 : 33;
enddef;
```

The first eight channels are horizontal polarization (defined as X as used in the DiFX correlator and in fourfit). The second eight channels are vertical (Y) polarization, as described in the following IF/BBC section:

```
def DBE-X4-XX01_pol;
  if_def = &IF_1N : 3N : X : 8080.0 MHz : U : 5 MHz : 0 Hz;
  if_def = &IF_3N : 3N : Y : 8080.0 MHz : U : 5 MHz : 0 Hz;
enddef;
```

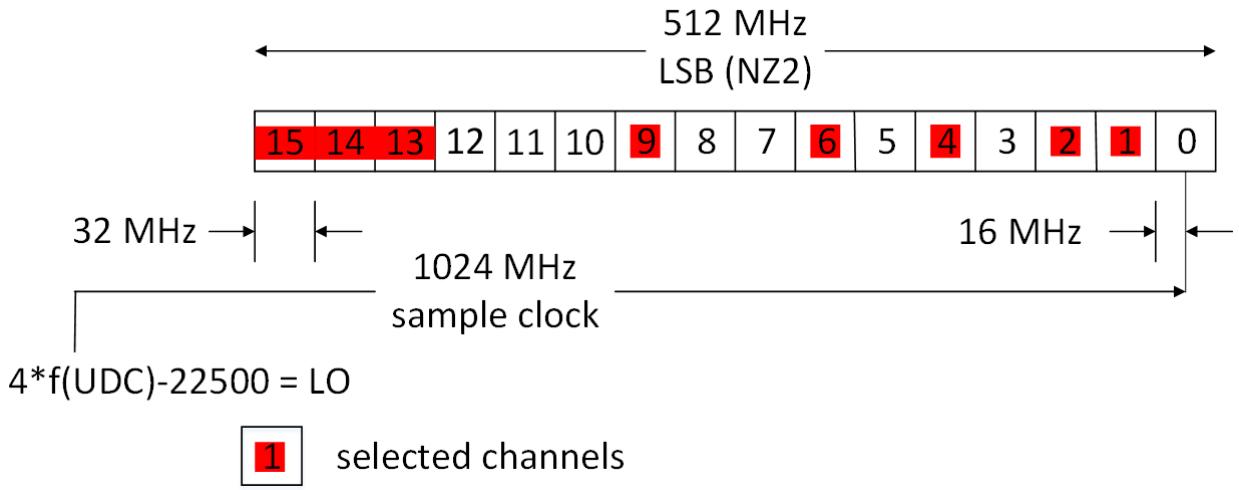

Figure 1: Location of the PFB channels in frequency space relative to the local oscillator and sample clock. The eight channels that are selected to be recorded are shown in red.

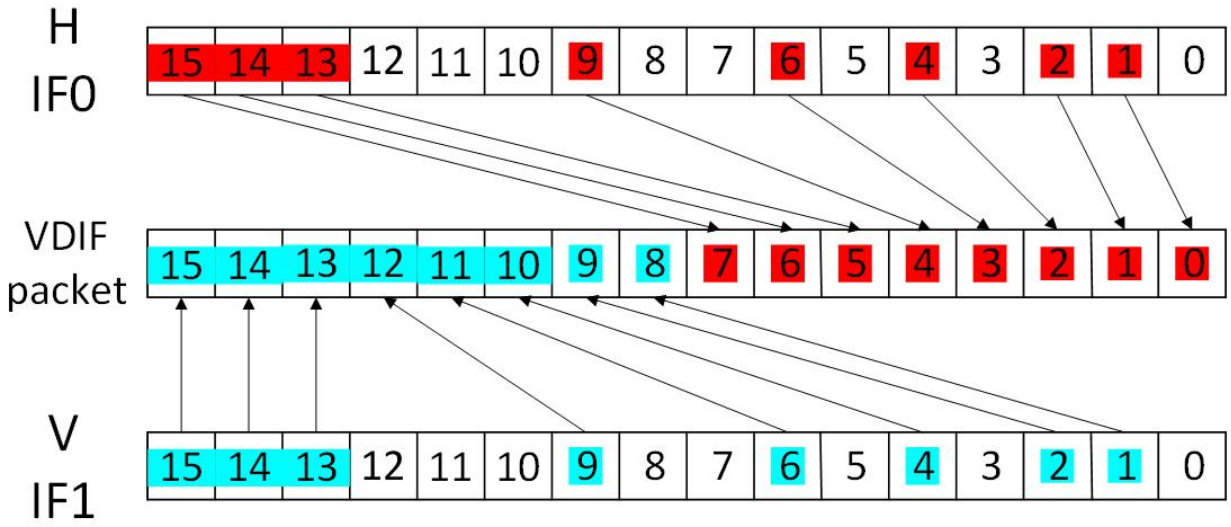

Figure 2: Assignment of channels to VDIF packet by polarization. The VDIF header and other information precede channel 0.