BBDev Memo 041.2

SX Observations using a Broadband Receiver and RDBE: Revised frequencies

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1. Introduction

(The frequencies are revised to allow the use of all USB channels in X-band.)

An important component of the VLBI2010 development is the ability to observe simultaneously with both the legacy systems utilizing S-band and X-band and with the broadband systems. The current challenge to making the observations is the correlation of the individually placed 8 MHz or 16 MHz channels of the legacy systems that are using either a Mark4 or a DDC-capable digital back end with the contiguous 32 MHz channels of the digital backends having PFB output.

This memo provides the UDC and channel frequencies for using the RDBE/Mark6 system (GGAO12M and Westford at this time) to acquire S- and X-band data to be correlated with data from Mark4/Mark5B systems or DDC-capable digital backends on other IVS antennas. This requires two RDBEs for X-band and one RDBE for S-band. Frequencies for the fourth RDBE are set for C-band (5-5.5 GHz) in order to provide good frequency coverage for the broadband-only stations. The settings for this band may be revised in the future after more study of the optimum value given the frequency coverage of the available stations.

A major consideration in assigning the band and channel frequencies for the broadband systems is to avoid having the 8-MHz legacy channels cross a 32-MHz boundary in the broadband setup. This requires careful consideration of the band frequencies and the channels selected within those bands.

2. Setup

2.1 Mark4

The polarization for the legacy stations is right circular (standard geodetic SX hardware). The polarizations for the broadband systems are dual linear.

The observing 'frequence' is the R1 frequency sequence with track assignment for 2-bit sampling giving 512 Mbps. The frequencies are given in the $CODES section for a recent R1 or for CONT14.

The lower and upper edges (in frequency space) of the 8 MHz channels are as follows (character labels are included for convenience of referencing):

S-band	a	2225.99	2233.99	upper sideband
	b	2245.99	2253.99	upper sideband
	c	2265.99	2273.99	upper sideband
	d	2295.99	2303.99	upper sideband
	e	2345.99	2353.99	upper sideband
	f	2365.99	2373.99	upper sideband
X-band	A	8204.99	8212.99	LOWER SIDEBAND
	B	8212.99	8220.99	upper sideband
	C	8252.99	8260.99	upper sideband
	D	8352.99	8360.99	upper sideband
	E	8512.99	8520.99	upper sideband

F	8732.99	8740.99	upper sideband
G	8852.99	8860.99	upper sideband
J	8912.99	8920.99	upper sideband
I	8924.99	8932.99	LOWER SIDEBAND
J	8932.99	8940.99	upper sideband

2.2 Broadband System using RDBE

There are two goals for the broadband frequency assignments.

a) the LOs for all bands must be separated by a multiple of 32 MHz;

b) no 8 MHz channel should cross a 32-MHz boundary.

In order to decide how to set the UDC values for the S and the X bands Roger plotted the positions of the legacy channels within a 32-MHz band (i.e. calculate lower and upper channel frequencies modulo 32 MHz).

The channels that are lowest in the modulo-32 interval are D and E, for which the lower edges are 0.99 MHz and the upper edges are 8.99 MHz. The next lowest are J (4.99-12.99) and b (5.99-13.99).

All other channels have a lower edge of 9.99 MHz (channel e) or greater.

The lower edge of channel a is at 17.99 MHz in the modulo-32 interval.

Thus if the UDC frequency is selected such that a 32 MHz boundary in the PFB output from the resulting LO is in the interval 8.99 – 9.99 MHz relative to a multiple of 32 MHz, only channels b and J will be intersected by a multiple of 32 MHz relative to the PFB boundaries.

To set channel a (with lower edge of 2225.99 MHz) near the lower edge of the Nyquist zone,

Define the lowest frequency of the PFB in the second Nyquist zone relative to the LO as f_NZ2_lower:

f_NZ2_lower = f_LO_S + 1024 + 16 - 512 MHz = f_LO_S + 528 MHz.

This frequency should be in the range 2225.99 – (17.99 – 8.99) to 2225.99 – (17.99 – 9.99) MHz, ie 2216.99 – 2217.99 MHz. Thus f_LO_S should be in the range 1688.99 – 1689.99 MHz.

The UDC frequency for a specific LO is derived as

$$f\_UDC = (f\_LO + 22500)/4$$

so the allowed values are between 6047.25 and 6047.5 MHz, but must be a multiple of 0.1 MHz. Selecting 6047.3 MHz for f_UDC_S (arbitrarily, but it is within the range of acceptable values) gives f_LO_S = 1689.2 MHz.

The requirement that all PFB channels must lie a multiple of 32 MHz apart sets a constraint on the X-band and C-band UDC settings.

A summary of UDC settings and channel_select values is given in section 3.

2.2.1 S-band (Band A)

The Luff value (UDC frequency) for S-band is:

f_luff_S= 6048.6 (was 6047.3)

f_L0_S (RF frequency that goes to 0) corresponds to 1694.4 MHz.

The channel select values for the S-Band RDBE are:
[1 5 8 11 12 13 14 15]

The lower and upper edges (in RF space, MHz) of the 32 MHz channels for S-band are as follows:

2670.4	2702.4
2542.4	2574.4
2446.4	2478.4
2350.4	2382.4
2318.4	2350.4
2286.4	2318.4
2254.4	2286.4
2222.4	2254.4

The phasecal offset used in the RDBE is 4.4 MHz (mod(f_LO_S+1024,5)).

The channels are recorded as lower sideband.

A representation of the channels is shown in Figure 1.

2.2.2 C-band (Band B)

From simulations Bill Petrachenko determined that the third band should have as the lower edge frequency 5010 MHz, given that the other three bands are fixed for S/X coverage. I have called this C-band.

The Luff value (UDC frequency) for C-band is:

f_luff_C = 6752.6 (was 6751.3)

f_LO_C corresponds to 4510.4 MHz.

The channel select values for the C-Band RDBE are:
[1 2 4 6 9 13 14 15]

These are chosen arbitrarily to give a minimum-redundancy array, but a better array may be chosen given more time and a better-defined criterion for choosing the frequencies.

The lower and upper edges (in RF space, MHz) of the 32 MHz channels for C-band are as follows:

5486.4	5518.4
5454.4	5486.4
5390.4	5422.4
5326.4	5358.4
5230.4	5262.4
5102.4	5134.4
5070.4	5102.4
5038.4	5070.4

The phasecal offset used in the RDBE is 0.4 MHz.

The channels are recorded as lower sideband.

A representation of the channels is shown in Figure 2.

2.2.3 X-band (Bands C and D)

The Luff values (UDC frequencies) arrived at for X-band are:

f_luff_Xlo = 7544.6 corresponds to f_LO_Xlo of 7678.4 MHz Band C

f_luff_Xhi = 7672.6 corresponds to f_LO_Xhi of 8190.4 MHz Band D

f_LO_Xlo and f_LO_Xhi are the RF LO frequencies generated by the UDCs.

The channel select values for the X-band RDBEs (Bands C and D) are

Xlo (Band C): [1,2,4,6,11,13,14,15].
Xhi (Band D): [1,2,6,9,11,13,14,15].

The lower and upper edges (in RF space, MHz) of the 32 MHz channels for X_lo are as follows:

8654.4 8686.4
8622.4 8654.4
8558.4 8590.4
8494.4 8526.4
8334.4 8366.4
8270.4 8302.4
8238.4 8270.4
8206.4 8238.4

The lower and upper edges (in RF space, MHz) of the 32 MHz channels for X_hi are as follows:

9166.4 9198.4
9134.4 9166.4
9006.4 9038.4
8910.4 8942.4
8846.4 8878.4
8782.4 8814.4
8750.4 8782.4
8718.4 8750.4

The phasecal offsets used in the RDBE are

Band C 4.4 MHz.

Band D 0.4 MHz.

The channels are recorded as lower sideband.

A representation of the channels is shown in Figure 3.

3. Summary of UDC frequencies and RDBE channels

pcal offsets corrected 16/02/17 even though BEC gave me the information (in email folder bbdSX) on 2015/12/11.

Band	UDC freq (MHz)	LO from UDC	channel select	pcal offset
A (S)	6048.6	1694.4	[1,5,8,11,12,13,14,15].	~~4.4~~ 3.4e6
B (C)	6752.6	4510.4	[1,2,4,6,9,13,14,15]	~~0.4~~ 4.4e6
C (X-lo)	7544.6	7678.4	[1,2,4,6,11,13,14,15]	~~4.4~~ 2.4e6
D (X-hi)	7672.6	8190.4	[1,2,6,9,11,13,14,15]	~~0.4~~ 4.4e6

y

4. Figures

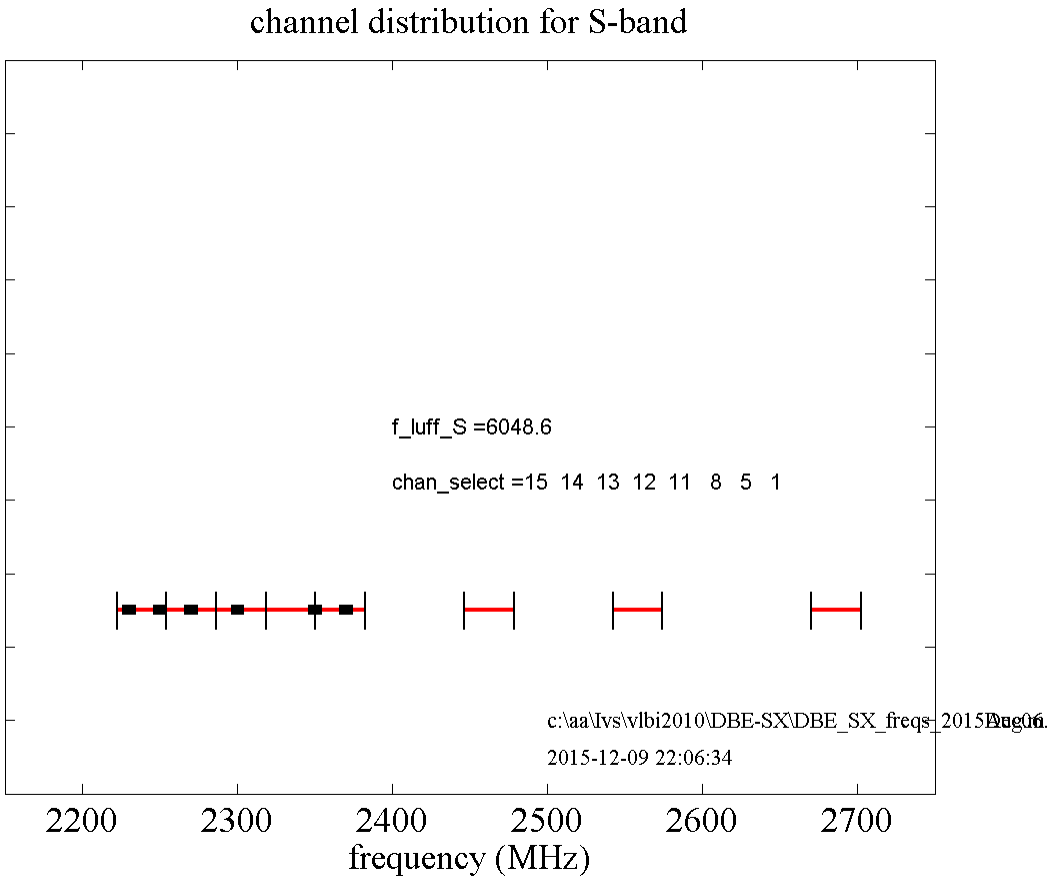

Figure 1. These are the frequencies to be used for S-band for the RDBE and Mark4: Black channels are Mark4 8 MHz frequency bands: red channels are S-band RDBE channels. RDBE channels count from right to left and are selected (dbe_chan_select) as [1,5,8,11,12,13,14,15].

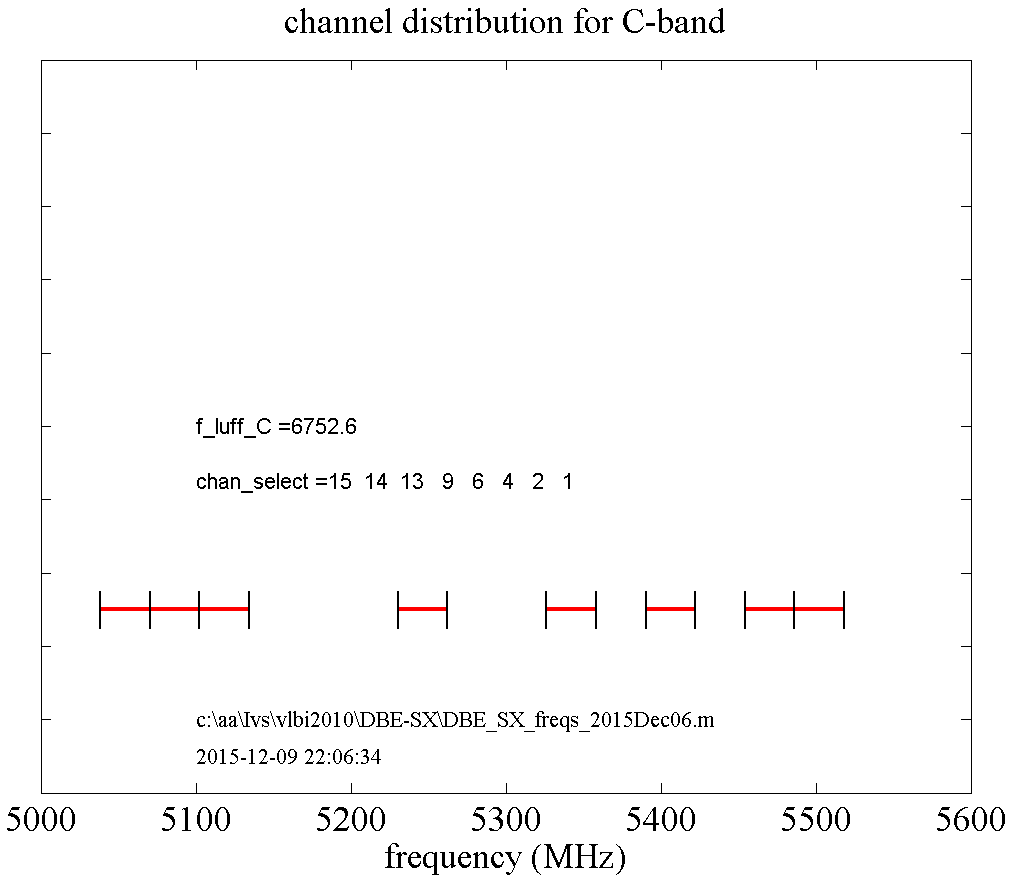

Figure 2. These are the frequencies to be used for C-band for the RDBE. RDBE channels count from right to left and are selected (dbe_chan_select) as [1,2,4,6,9,13,14,15].

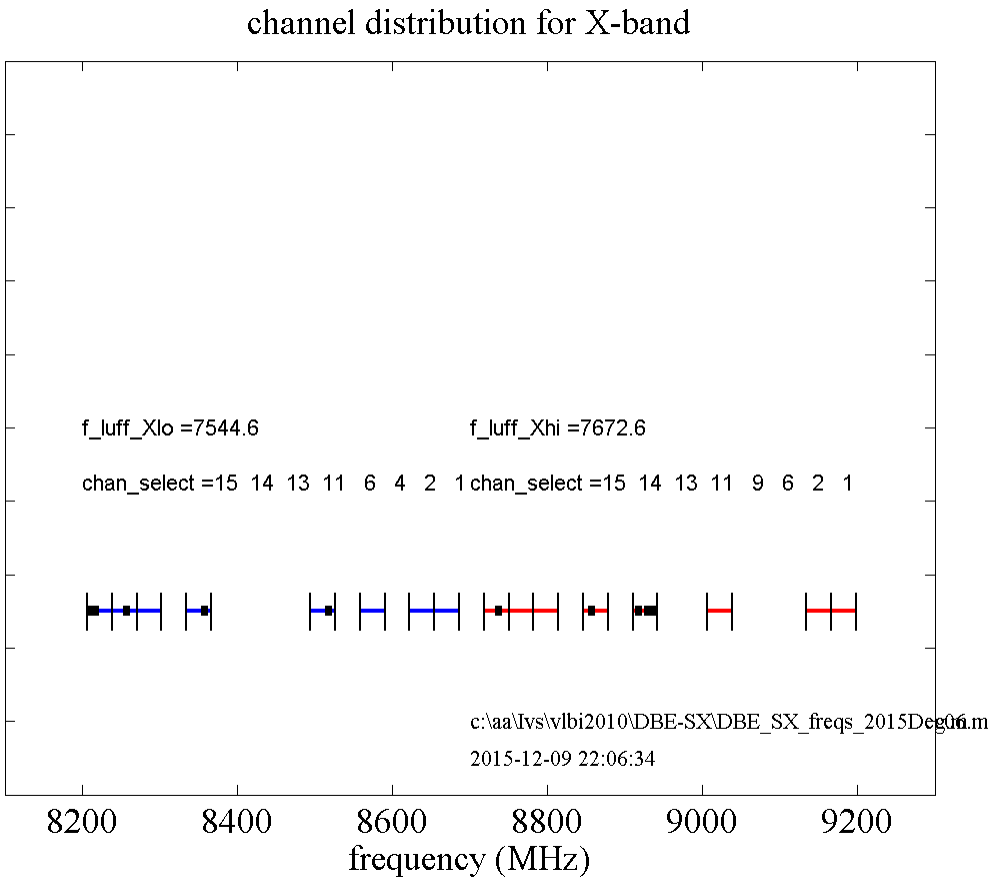

Figure 3. These are the frequencies to be used for X-band for the RDBE and Mark4: Black channels are Mark4 frequency bands: blue channels are X_lo RDBE channels; red channels are X_hi RDBE channels. RDBE channels count from right to left and are selected (dbe_chan_select) as [1,2,4,6, 11,13,14,15] for Xlo and [1,2,6,9,11,13,14,15] for Xhi.