CONCERNING VLA LOCAL OSCILLATOR SETTINGS

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Nel mezzo del cammin di nostra vita
Mi ritrovai per una selva oscura,
Che la diritta via era smarrita.

Dante Alighieri, L'Inferno I,1-3.

In the middle of the path of our life
I found myself in a dark wood,
Where the direct way was hidden.

In the past it has been alleged that only the computer can
determine at what frequency an observation will be made, and that it
is impossible for anyone to determine beforehand what will be
selected. If this was true in the past, it is even more true today.
With the introduction of a new Local Oscillator scheme on some
antennas, the chances even of a correct guess have receded.
Nil desperandum. The purpose of this opus is to try to prove that
there really is method behind the apparent madness.

In order to have a hope of understanding the software, it is
first necessary to have a rough idea of the hardware it controls.

1.0 HARDWARE

This is not an attempt to describe the Local Oscillator system
in detail, for that one should consult VLA Technical Report No. 29
and VLA Electronics Memorandum No. 137 both by A. R. Thompson.

The first stage of amplification of the received signal is a
cooled parametric amplifier at C-band (4.5-5.0 GHz: 6 cm). For

observations at other bands, the signal is converted to this band for amplification. At L-band (1.34-1.73 GHz: 22-17 cm) the signal first passes through a parametric upconverter; at K_u-band, also known, at the VLA only, as U-band (14.4-15.4 GHz: 2 cm) and K-band (22-24 GHz: 1.3 cm) through a cooled mixer.

There are four IF channels available - designated A, B, C, and D. Channels A and B come from one polarization, C and D from the other. After amplification, the signals are converted to frequencies of 1300-1350 MHz (A channel), 1400-1450 MHz (B), 1550-1600 MHz (C), and 1650-1700 MHz (D) for transmission through the waveguide to the control building.

The final conversion is from these frequencies to the baseband of the final filters, at which frequency the signals are digitized for further processing by the delay and multiplier system.

1.1 Current System

With the present Local Oscillator scheme, the center observing frequency is given by:

$$f_0 = f_1 \pm (f_{L6} + f_D + f_{BB}) \tag{1}$$

where:

f_1 is the frequency of the first LO, which is used to mix the RF to the 6 cm passband. This is set by the upconverter pump (F2 module) for L-band, by the 17-20 GHz Local Oscillator (F3 module) for K_u- and K-bands, and is zero for C-band;

$\pm$ indicates the sideband of the first LO mixer. The upper sideband is used for all bands except K_u-band;

f_{L6} is the frequency generated by the 2-4 GHz synthesizers (L6 module), which is used to mix the 4.5-5.0 GHz signal to the appropriate IF band.

f_D is one of the standard carriers 1200 MHz or 1800 MHz, which, when f_S is added or subtracted appropriately, mixes the IF band to the baseband of 0-50 MHz;

f_S is the frequency generated by the master Local Oscillator (L17 module) from the fine tuning synthesizers;

f_{BB} is the offset from zero of the center frequency of the final baseband filter.

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NOTES:

a) f_1 values for the four bands are as follows:

L	-3.2 GHz	fixed
C	0 GHz	fixed
K_u	19.6 GHz	standard
K	17.6 GHz	standard

The F3 module (for K_u- and K-bands) may be set to
any frequency between 17.0 GHz and 20.0 GHz satisfying
the following condition:

$$f_1 = 17.1 + N \times 0.3 \pm 0.1 \text{ GHz}$$

b) The sideband of the first mixer for each of the four
bands is as follows:

L	+	fixed
C	+	fixed
K_u	--	fixed
K	+	fixed

c) The L6 module may be set to any frequency between
2710 MHz and 4010 MHz which satisfies the following
condition:

$$f_{L6} = 2400 + N \times 50 \pm 10.1 \text{ MHz}$$

It will be noticed that, because of the difference between
$f_D + f_S$ for the different IF channels, to achieve the same
observing frequency for IF channels A and C, the L6
must be set 250 MHz higher for IF channel A.

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d) f_D values for the four IF channels are as follows:

A	1200 MHz	fixed
B	1200 MHz	fixed
C	1800 MHz	fixed
D	1800 MHz	fixed

e) f_S ranges for the four IF channels are as follows:

A	100 to 150 MHz	tunable
B	200 to 250 MHz	tunable
C	-250 to-200 MHz	tunable
D	-150 to-100 MHz	tunable

These frequencies are actually generated from four 100 to 150 MHz synthesizers. In order to produce f_S, the synthesizers are set to:

A	$f_S(A)$
B	$f_S(B)/2$
C	$-f_S(C)/2$
D	$-f_S(D)$

It will be noticed that, since the synthesizers are tunable in 1 Hz steps, IF channels A and D are tunable in steps of 1 Hz, but B and C in steps of 2 Hz.

For polarization measurements, it is essential that the local oscillators of channels A and C and also B and D be locked. This is done in the synthesizer phase lock (L17) module, which forces the following relationships:

$$f_S(A) - f_S(C) = 350 \text{ MHz}$$

$$f_S(B) - f_S(D) = 350 \text{ MHz}$$

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It is possible to override these restraints by setting
the L17 module in independent mode.

f) The values of f_{BB} for the currently available filters
are:

Bandwidth	f_{BB}	
50 MHz	25 MHz	fixed
12 MHz	40 MHz	fixed
1.5 MHz	40 MHz	fixed

1.2 Interim System

With the new Local Oscillator system, the center observing
frequency is given by:

$$f_0 = f_1 \pm (f_{L6} - f_A + f_D + f_S + f_{BB}) \qquad (2)$$

where all terms are exactly as defined before except:

f_A is an offset frequency which may be regarded as being
subtracted from f_{L6}. The 4.5-5.0 GHz signal is actually mixed
down to 1000-1050 MHz, and then mixed up using f_A to the appropriate
IF band.

NOTES:

g) f_A values for the four IF channels are:

A	300 MHz	fixed
B	400 MHz	fixed
C	550 MHz	fixed
D	650 MHz	fixed

It will be noticed that, because of this additional
offset frequency, that the L6 setting to achieve the

same observing frequency on IF channels A and C is
now the same for both channels; but different from
both settings in the current system.

1.3 Final System

The final version of the Local Oscillator system is expected to be
similar to the interim system. There will, however, be three
major differences.

1) In the current system, there are only two IF channels –
   A and C. For each channel there is one 2-4 GHz synthesizer
   (L6 module). In the final system, however, all four
   IF channels will exist; but still only two L6's.
   One of these will control IF channels A and C, the other
   B and D. So, while channels A and C are independent
   now, in the final system they will not be.

2) In the current system, observations on all IF channels
   must be made in the same band. In the final system,
   there will be one possible exception to this restriction:
   a dichroic reflector over the K_u-band feed will allow
   simultaneous observation at K_u- and C-bands.

3) There will be a total of 8 selectable final IF filters.

The final center observing frequency will be:

$$f_0 = f_1 \pm (f_{L6} - f_A + f_D + f_S + f_{BB}) \qquad (3)$$

where all terms are exactly as defined before.

NOTES:

h) The values of f_{BB} for the filters in the final system
   will be:

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Bandwidth	f_{BB}		Code
50 MHz	25 MHz	fixed	0
25 MHz	12.5 MHz	fixed	1
12.5 MHz	6.25 MHz	fixed	2
6.25 MHz	3.13 MHz	fixed	3
3.13 MHz	1.56 MHz	fixed	4
1.56 MHz	0.78 MHz	fixed	5
0.78 MHz	0.39 MHz	fixed	6
0.22 MHz	0.29 MHz	fixed	8

These are not strictly speaking the filter bandwidths, but the bandwidths of the sampled signal. The 3 dB filter bandwidths will be about 8% narrower. The user will be able to specify $0 \leq n \leq 9$ for the bandwidth code such that the sampled bandwidth is:

$$\frac{50}{2^n} \text{ MHz}$$

It will be noticed that n=7 and n=9 are not listed. These bandwidths will be implemented in the correlator and are deliberately omitted at present, since the hardware itself and the software implementation are not yet complete.

2.0 SOFTWARE

In order to understand new conventions, it is sometimes instructive to try to understand the old. In this case, however, it would probably only add to the confusion. The original software was written with the projected final configuration in mind, and is, in consequence, completely wrong in places. The new software, on the other hand, was written with the new projected final configuration in mind. When this is available it may function simply; in the meantime, however...

The Local Oscillator settings are controlled in the Synchronous Computer system by means of the //LO card, and the final IF filter is selected on the source request card. For a more detailed description

one should consult VLA Computer Memorandum No. 131 by B. G. Clark and VLA Computer Memorandum No. 133 by E. Raimond.

The //LO card is read by the NEW program in FORTRAN in the following format:

READ (15,100) LOTAB, LOTCD, F1AB, F1CD, L6A, L6B, L6C, L6D, FSA, FSB

100 FORMAT (4X, 2I1, 2F7.1, 4I5, 2F10.0)

where:

LOTAB, LOTCD are the tuning digits for the upconverter (L-band) or first mixer (K_u-and K-bands) bias control in the front end, and they do not play any part in the LO frequency calculations;

F1AB, F1CD are the f_1 frequencies for IF channels A & B and C & D respectively;

L6A, L6B, L6C, L6D are the f_{L6} frequencies for the four IF channels;

FSA, FSB are the f_S frequencies for IF channels A and B respectively.

NOTES:

A) All frequencies are entered in MHz, except for F1AB and F1CD, which are given in GHz.

B) The L6A, etc. frequencies are always given as a multiple of 10 MHz; the 0.1 MHz is added or subtracted by the software to produce the appropriate f_{L6}.

C) The possibility of observing with the fine tuning synthesizers unlocked will not be supported by the software. Thus it is not necessary to define f_S for channels C and D. These are calculated by the software as in note e).

2.1 Final System

The software will hopefully work smoothly as advertised. The only change will be that L6C and L6D need not be specified; they will be ignored, since the L6 module for channels A and B will also control channels C and D respectively.

2.2 Current and Interim System

What follows may seem to the casual reader to be a mess. Rest assured - it is. We have tried to make the software able to support transitions from the current system to the interim to the final. This is, of course, impossible. However, the software as it is at present will require minimum modifications along the way.

1) For the transition from the current to the interim system, the only change is the L6 frequency setting. Since there are four L6 frequencies read from the //LO card, we have adopted the convention that L6A and L6C are used to set the L6's of current antennas. For the antennas with the new L6 system, the A and C channels are set using the values L6B and L6D respectively. Thus for observations with the mixed system, the following must be made true:

L6B = L6A + 300 MHz.

L6D = L6C + 550 MHz.

It will be noticed that the difference is exactly f_A. As explained in note c), for observation at the same frequency on both IF channels with the current system,

L6C = L6A - 250 MHz.

For the purposes of computation of the observing frequency in the computer, the "new" L6 settings are used. Thus even if an antenna with the new L6 system is not being used for an observation, L6B and L6D must still be given correctly.

2) Simultaneous observations using frequencies in two different bands is only possible using the dichroic reflector, which may only be installed on antennas 1 and 2 at present. Unless this observation mode is being used, f_1 for all IF channels must be the same, even at K_u- and K-bands, there being only one F3 module. Thus

an additional restriction is:

F1CD = F1AB.

3) The quantity that is used to calculate the observing
   frequency is the Signed Sum of the LO's.
   This is the observing frequency corresponding to zero
   frequency at baseband, and is therefore the same as
   equations (1), (2), and (3) removing the f_{BB} term. From
   the //LO card, two Signed Sums are calculated:

   $FX = F1AB \pm (L6MB + FSA + 900)$,

   $FY = F1CD \pm (L6MD + FSB + 800)$.

   where:

   L6MA etc. are the L6A etc. with the additional 0.1
   MHz added or subtracted as appropriate:

   The constant terms are $f_D - f_A$ for A and B channels.
   In the final system, FX and FY will be the baseband
   frequency for channels A and B respectively. In the
   current and interim systems, however, they are in fact
   used for channels A and C respectively. Thus to control
   channel C, one must enter the equivalent f_S for channel
   B. To observe at the same frequency on IF channels A
   and C it must be true that:

   FSB = FSA + 100 MHz

   as it will be in the final system for channels A and B.

4) In the final system channels A and C will not be tunable
   independently by the software. As present, however, it
   is possible. Normally, the fine tuning synthesizer
   setting for channel C is:

   $f_F(C) = (350 - FSA)/2$.

   The setting of this synthesizer is at present governed
   by FY, which has the normal setting for channel B. Using
   this value, the setting for channel A would be:

   $f_F(A) = FSB - 100$.

   Hence the correct synthesizer setting for channel C is:

   $f_F(C) = (350 - [FSB - 100])/2$
   $= (450 - FSB)/2$,

and for channel A is:

$$f_F(A) = FSA.$$

These frequencies are at present automatically set by the software.

3.0 PREPARING TO OBSERVE

To determine the Local Oscillator settings necessary for observation, it is best to start at the feeds and work down to the baseband.

3.1 Conversion From Observing Frequency to Paramp Passband

At C-band the signal passes directly into the paramps, so there is no first Local Oscillator. At L-band, the first Local Oscillator is fixed at 3.2 GHz. At K- and K_u-bands, however, there is a choice: any observing frequency may be mixed with two or four possible F3 settings to produce a frequency in the paramp passband. At the moment, there is no preference for any one of these. Eventually, it may be possible to determine by observation that certain combinations of F3 and L6 frequencies function better than others.

3.2 Conversion From Paramp Passband to IF Band

For all narrow bandwidths, there are two possible L6 settings to mix the signal down to the IF band. With the current system, the higher one must be used. Using 25 MHz bandwidth, there are some frequencies in the passband at which it is not possible to observe. Using 50 MHz bandwidth, observations are only possible at a discrete number of frequencies - those that can be mixed down to the exact center of the IF band.

3.3 Conversion From IF Band to Baseband

The final Local Oscillator frequency may now simply be computed from equation (2). It will be noticed that, with the current and interim systems, this often comes outside the stated tuning range. Because of the 40 MHz offset in the narrower

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filters, the L17 frequency for channel A often falls in the range 80 to 100 MHz. This does not matter for most observations, since the fine tuning synthesizers can be set as low as 80 MHz. However, the L17 itself may not lock the A and C channel synthesizers using this setting, rendering polarization measurements impossible. In the final system, this problem will not arise. If the higher L6 setting were not used, a value of 60 MHz would be required from the synthesizers, which is outside their usable tuning range.

There is now a Local Oscillator Service program (LOSER) on the DEC-10, which will perform these conversions, and list all possible combinations of frequency settings.

3.4 Examples

1)Possible Local Oscillator settings for 22450.100 MHz, using a bandwidth of 12 MHz with the current system.

//LO	17.5	17.5	3610	3910	3360	3910	100.0000	200.0000
//LO	17.5	17.5	3640	3940	3390	3940	70.2000	170.2000
//LO	17.6	17.6	3510	3810	3260	3810	100.0000	200.0000
//LO	17.6	17.6	3540	3840	3290	3840	70.2000	170.2000
//LO	17.8	17.8	3310	3610	3060	3610	100.0000	200.0000
//LO	17.8	17.8	3340	3640	3090	3640	70.2000	170.2000
//LO	17.9	17.9	3210	3510	2960	3510	100.0000	200.0000
//LO	17.9	17.9	3240	3540	2990	3540	70.2000	170.2000

NOTE:

Only the options with 100 MHz for FSA may be used. For observation using the final system, FSA and FSB will be higher by 33.75 MHz (the difference between f_{BB} in the two configurations), and therefore all eight possible combinations will be valid.

2) Possible Local Oscillator settings for 14584.100 MHz, using a bandwidth of 50 MHz with the current system.

```
//LO    19.3    19.3    3390    3690    3140    3690    100.0000    200.0000
//LO    19.4    19.4    3490    3790    3240    3790    100.0000    200.0000
```

NOTE:

These are the only two possible settings. They are also
valid for the final system.

3)   Local Oscillator settings for 1665.000 MHz, using a
bandwidth of either 1.5 MHz or 12 MHz with the current system.

```
//LO    -3.2    -3.2    3540    3840    3290    3840    85.1000    185.1000
```

4)   Local Oscillator settings for 1720.000 MHz, using
a bandwidth of either 1.5 MHz or 12 MHz with the current system.

```
//LO    -3.2    -3.2    3590    3890    3340    3890    90.1000    190.1000
```

5)   Local Oscillator settings for 1665.000 MHz on channel
A and 1720.000 MHz on channel C, using a bandwidth of either
1.5 MHz or 12 MHz with the current system.

```
//LO    -3.2    -3.2    3540    3840    3340    3890    85.1000    190.1000
```


E quindi uscimmo a riveder le stelle.

Dante Alighieri, L'Inferno XXXIV, 139.

And thence we emerged, once again to see the stars.