VLBA ACQUISITION MEMO #219

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To: VLBA Data Acquisition Group

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Subject: Spurious signals in the BBC

L.O. sidebands in their conversion to baseband

There are 10 KHz sidebands on the BBC at level of -40 dBc or lower (if the BBC is in spec). These sidebands can be carried out of the BBC and returned with a different delay to produce 10 KHz in the baseband. Without a delay the sidebands exactly cancel each other. The maximum expected level for this spurious 10 KHz is given by the following:

Level of 10 KHz sideband on L.O.	-30 dBm
Isolation from osc. to SSB mixer input	-25 dB
Reverse isolation of 4-way switch	-25 dB
Reflection coefficient at IFD output	-10 dB
Phase difference of reflected (20 ns at 10 KHz)	-58 dB relative to 1 radian
Maximum BBC gain at 2 MHz BW	64 dB
Max expected 10 KHz level in baseband	-84 dBm

While this is a very low level (well below the -54 dBm level seen on some BBCs when running in DAR) it could be further reduced by increasing the reverse isolation of the 4-way switch module. This mechanism for generating 10 KHz has been tested on a MKIII converter and BBC. In this case (the MKIII) it was necessary to remove the input isolation amplifier and use a long cable with open end in order to raise the level sufficiently to observe the 10 KHz.

Amplitude modulation of L.O.

Any sidebands on the L.O. which are the result of amplitude modulation (as opposed to phase modulation) will be detected by the mixers and coupled into the baseband. Amplitude modulation of the L.O. can occur via noise or spurious signals on the D.C. power lines which are not adequately filtered. For example, if there is a 1 mV 10 KHz signal on the -15 volt bias to the oscillator FET the expected level is given by the following:

1 mV out of 15 v would produce L.O. sidebands of	-73 dBm
Isolation between L.O./R.F. in mixer	-25 dB
Maximum baseband gain at 2 MHz Bw	64 dB
Expected level of 10 KHz	-34 dBm

This example shows the extreme importance of filtering the FET and buffer amplifier bias. Inadequate D.C. power filtering was found to be the primary cause of the 10 KHz spurious in BBC, Serial #27, recently tested on the bench at Haystack.

Another method of amplitude modulation of the L.O. is by the digital divider. If the divider presents a modulated VSWR the amplitude sidebands can be coupled back into the mixer via the reverse path through the oscillator buffer. Tests on a BBC however, show a more surprising path. The L.O. and sidebands leak out through the 5 MHz cable and are coupled back through the I.F. input cable. The levels are approximately as follows:

Level of L.O. leakage back through 5 MHz cable	-40 dBm
Amplitude modulation sidebands	-50 dB
Coupling between 5 MHz and I.F> cables	-45 dB
Maximum BBC gain at 2 MHz BW	64 dB
Attenuation to front panel	<u>10 dB</u>
10 KHz level at front panel	-81 dBm

<u>Other spurious signals</u>

a] 5 MHz

The 5 MHz is directly in the passband for bandwidths greater than 4 MHz and can be coupled into the video via DC power lines and ground currents. Another path through the IF and straight through to the mixer. This path could be attenuated by decreasing the RF coupling capacitors in the 4-way switch.

b] 11.05 MHz

The microprocessor clocks are strong signals in the BBC and like the 5 MHz can be coupled into the baseband. In this case, coupling through the digital control lines to the active filters and Bw gain compensation is the predominant mechanism.

c] MCB communications

The MCB communications are strong signals entering and leaving the BBC and could get coupled in the same way as the 5 and 11.05 MHz. Although tests show that this is not a significant problem.

<u>Measurement of spurious signals (bench tests of BBC #27)</u>

Signal	VLBA BBC Front Panel Monitor	MKIII	Notes
10 KHz in video	-75 dBm (≈-85 dBm)	<-100 dBm	1
5 MHz in video	-75 dBm (-85 dBm)	-86 dBm	2
μP clock in video	-60 dBm (-70 dBm)	-67 dBm	3
L.O. leakage from adjacent conv.	Not yet measured	-64 dBm	4

Notes:

a] Front panel outputs are 10 dB lower than video going to sampler - MKIII at 36 dB gain, VLBA BBC at 64 dB gain.

1] Not measurable in MKIII. -54 dBm has been observed with BBC in DAR.
2] MKIII Bw = 4 MHz, VLBA BBC Bw = 16 MHz.
3] 9.224 MHz for MKII, 1105 MHz for BBC.
4] Leakage of L.O. from one converter into the adjacent converter.
5] Numbers in () are measurements after making the modifications listed below.

Modifications needed to improve D.C. power filtering

a] Add 220 μH inductors (Nytronics WEE-220) in series D.C. power lines to oscillator (+15v and -15v) and oscillator buffer (-15v). Solder one end of inductor to feed-thru and other end to supply wires. Use heat sink tubing to insulate the end connected to the supply wires. Alternately mount a solder lug terminal strip for mounting inductors.

b] Add 33 μF (25v) across +15v inside oscillator buffer.

The inductors have small enough resistance to prevent excessive voltage drop and enough inductance to give 30 dB attenuation at 10 KHz (when combined with 33 μF).

c] Add 0.1 μF across +6v and -6v to SSB mixer submodule.

Further tests with a complete DAR are needed to be sure that these changes are necessary and sufficient to reduce the spurious signals to an acceptable level. The coupling between 5 MHz cables and I.F. cables was quite severe in the bench test set-up owing to the use of an extender with single shielded coax. If the coupling is a problem in the DAR rack efforts will have be made to reduce the L.O. leakage path out of the digital divider. Tests on BBC Serial #27 show that PC board grounding is poor and the leakage can be reduced by adding an extra mounting screw between the L.O. and 5 MHz input.

Summary

The spurious signal levels in the BBC are much worse than in the MKIII video converter because the BBC has about 30 dB more gain than the MKIII converter. However, additional D.C. power filtering and other minor changes can reduce the level of spurious signals to an acceptable level. Further tests of the DAR as a system will be needed to finalize the modifications required for adequate reduction of the spurious levels.