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To: VLBA Data Acquisition Group

From: John C. Webber and Dorsey L. Thacker

Subject: Matched mixer pairs for SSB mixers

Alan Rogers kindly supplied us with the mixer test fixture of VLBA data acquisition memo #183 and lent us 5 LMX-149 mixers for test. We have conducted tests of mixer compatibility for 25 LMX- 113 and 9 LMX-149 mixers. We conclude that the match of the higher-priced LMX-149's is statistically no better than that of the LMX-113's. Using matched pairs of LMX-113's in actual mixers produces good results, although meeting the specifications above 900 MHz still appears difficult.

The test setup consisted of two signal sources, a Wavetek 2520 synthesizer for the LO, the tracking generator output of an Avantest R3361B spectrum analyzer for the RF, the test fixture, and a Tektronix 2225 oscilloscope. For each mixer type, one mixer was adopted as a standard and all comparisons were made with respect to it. All mixers were assigned arbitrary serial numbers. The standard was kept in the same physical position in the test fixture and the same input and output cables used throughout each series of measurements. This is important, since the environment has noticeable non-repeatable effects on the results. The video frequency chosen was 5 MHz, but tests showed the results to be independent of video frequency. Each measurement consisted of setting the LO to 500, 750, or 1000 MHz, setting the RF 5 MHz higher, and observing the output on the oscilloscope. The LO level supplied to the test fixture was +10 dBm and the RF level was -10 dBm. The relative amplitudes and phases were measured as Y and X displacements of the traces. Removing a mixer from the fixture and replacing it showed that the repeatability was about $\pm 1\%$ in amplitude and $\pm 1^\circ$ in phase. The oscilloscope channels were well matched and the results were the same with the two inputs reversed.

The advantage of measuring the mixers this way is that, given n mixers, only $n - 1$ pairs have to be measured. One can predict the relative amplitude and phase responses of any given pair and thus predict the worst-case image rejection due to such errors (see data acquisition memo #162).

The raw data for the LMX-113 and LMX-149 pairs tested is appended. Note that the mismatch of some pairs at 1000 MHz can be as great as 30% in amplitude and 12° of phase, which would limit the image rejection to 15 dB!

The usefulness of these data was checked by taking mixer pairs selected by this process and testing them against each other in the test fixture. Typical results are shown in the following table.

Comparison of mixers 102 and 112

LO Freq	Predicted		Measured	
(MHz)	Amplitude (%)	Phase (degrees)	Amplitude (%)	Phase (degrees)
500	-2.0	-2.0	-2.0	-1.8
750	-2.4	1.2	-1.8	1.8
1000	-2.6	2.3	-0.9	0.3

The agreement between the values predicted by measurements against the standard is best at 500 and worst at 1000 MHz, but the difference even at 1000 MHz is only 1.7% in amplitude and 2.0° of phase.

A FORTRAN program was written to use the measured values of amplitude and phase relative to the standard in order to select pairs of mixers for which the predicted image rejection ratio due to mixer mismatch is better than 30 dB. Four situations were analyzed for each possible pair: no adjustments, adjustment of amplitude on one side, constant phase adjustment, and phase adjustment with a linear slope in frequency. For the 12 possible pairs (excluding the comparison standard), 5 pairs were found for which no adjustments should be needed. For 3 additional pairs, a match was possible with amplitude adjustment only. For 2 additional pairs, amplitude and constant phase would suffice; there was no significant improvement if a linear phase term was available, apparently because the mixer phases are not linear with frequency. Two mixers (#106 and #110) had good matches within the set but no candidates were left after the selection process. Two mixers (#100 and #119) were so bizarre that they were unmatchable within this set.

Two of the selected matched pairs (#112, #102) and (#104, #123) were mounted in SSB mixers and tested. At the frequencies of 500, 750, and 900 MHz, they meet the image rejection criterion of 23 dB at all video frequencies and the average image rejection across the 16 MHz bandpass exceeds 26 dB. This was achieved with only minor adjustment of the input lead length. Above 900 MHz, the worst case found was 21 dB at 1000 MHz and 16 MHz video frequency; the average image rejection at 1000 MHz was 23 dB. We conclude that evaluating mixers in this fashion is adequate to meet our needs.

A comparison of the 9 available LMX-149's (the 5 from Haystack and 4 we ordered for testing) shows that, although the LMX-149's have less amplitude rolloff at 1000 MHz, they are not any better matched than the LMX-113's and thus do not justify the price premium in this application.