Notes on Gain Distribution in the VLBA Front End and Converter Systems

Erich Schlecht

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In VLBA Electronics Memo No. 39, A. R. Thompson drew up a general plan for the gain and power level distribution in the front-end and converter subsystems of the VLBA receivers above 1 GHz. This outline took into account the specifications included in Larry D'Addario's VLBA Electronics Memo No. 30, as well as the desire to minimize the receiver noise added after the front-end.

The values shown in Memo No. 39 must be revised somewhat in light of more detailed information derived from the design and testing of the converter modules. Figure 1 is an updated version of Memo No. 39's Figure 1 and includes values expected for the various losses and gains in the system for each band.

Gain and Power Handling Limitations

The two primary, conflicting constraints in designing receiver gain distribution are gain compression in the mixer and receiver noise temperature. A third consideration is gain flatness over the specified frequency range. Referring to Figure 1, the maximum input power to the mixer which causes it to have no more than 1% gain compression, $P_{MXR,max}$, is a strong function of mixer LO power. The numbers shown are based on mixer tests and estimates, and are only approximate, but include several dB of safety margin. Table 1, which lists the conclusions of this memo, shows the maximum front-end gain as $G_{FE,max}$, which, in dB, is $P_{MXR,max}$ minus the maximum input power, $P_{A,max}$, plus the losses between the front-end and the mixer.

The minimum front-end gain, $P_{FE,min}$ in Table 1 is that required to keep the noise added by the post front-end subsystems to less than 1 deg K. The noise figure of the post front-end subsystems includes the losses between the front-end and the IF amplifier as well as that of the IF amplifier itself.

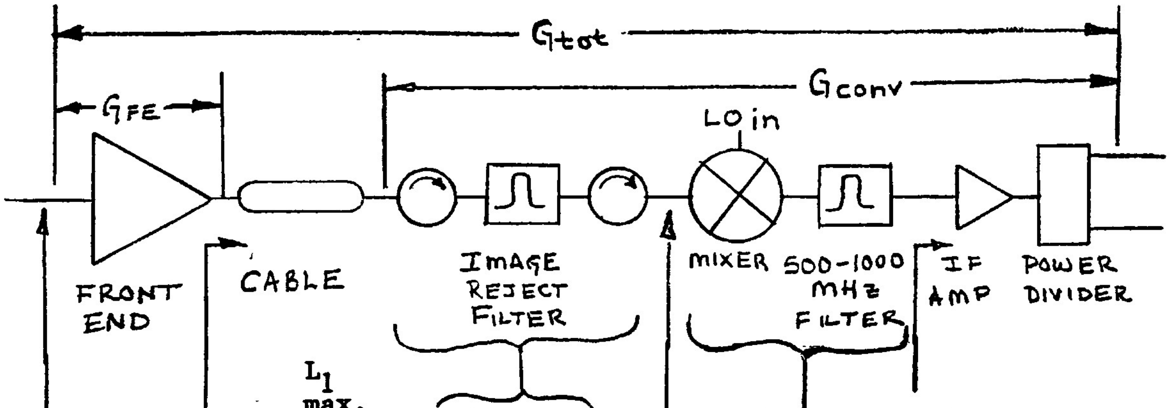
The recommended front-end gains shown in Table 1, $G_{FE,rec}$, are simply reasonable compromises between $G_{FE,min}$ and $G_{FE,max}$ These are somewhat higher than those shown in Memo 39, due to several factors. First, the 1.5 GHz mixer has more loss than originally thought. This is due to the LO being relatively far in frequency from the RF input (the manufacturer specified up to an IF of 500 MHz only). Second, I have here taken into account the maximum 3 dB loss in the cable connecting front-end to converter. Third, all bands except 15 GHz will use higher power mixers than originally thought (13 dBm for 1.5 GHz, 10 dBm for 4.8 and 10.7 GHz). This allows a higher input power to the mixer, hence more front-end gain.

The flatness of the converter modules so far tested, 1.5 GHz and 15 GHz was found to be worse than expected. The problem derives from various mismatches in the IF area, and it seemed at first necessary to insert a 3 dB attenuator between the IF output of the mixer and the IF filter. However, after redesigning the layout of the amplifier chain, this no longer seems to be necessary. Additionally, in the future a better matched set of IF amplifiers will be used. Figures 2 and 3 compare the Avantek IF amplifier set currently used and the Watkins-Johnson set to be used from now on.

Conclusion

The front end gains recommended here are guidelines, and the performance of various receiver subsystems as tabulated can only be taken as approximate. The specifications are still somewhat flexible, therefore, although the overall design is complete. A more complete account of converter performance based on measurements of the completed units will come out in the near future.

Figure 1. Front End and Converter Block Diagram



Band (GHz)	$P_{A,max}$[1] (dBm)	nf_c[2] (dB)	L_1 max. cable loss (dB)	BW[3] (GHz)	L_2 loss (dBm)	$P_{MXR,max}$[5] (dBm)	L_3 loss (dB)	nf_{IF}[6] (dB)
15	-54.7	19.5	3	1.23	1.6	-10	8.3	6.6
10.7	-54.7	19.2	3	1.23	1.3	-7	8.3	6.6
4.8	-58.1	19.6	3	.56	1.7	-7	8.3	6.6
1.5	-58.1	19.8	3	~.56[4]	0.4[4]	-4	9.8	6.6

Notes:

1. 200,000 deg K in the bandwidth of the pre-mixer filter (BW).
2. Noise figure into the top of the front end to converter cable.
3. Approximate noise bandwidth of pre-mixer image reject filter.
4. First isolator and filter not installed - included in front end.
5. Maximum power to the mixer which keeps the gain compression at less than 1%.
6. Noise figure into the IF amplifier assuming the output looks into a noise figure of 10 dB.

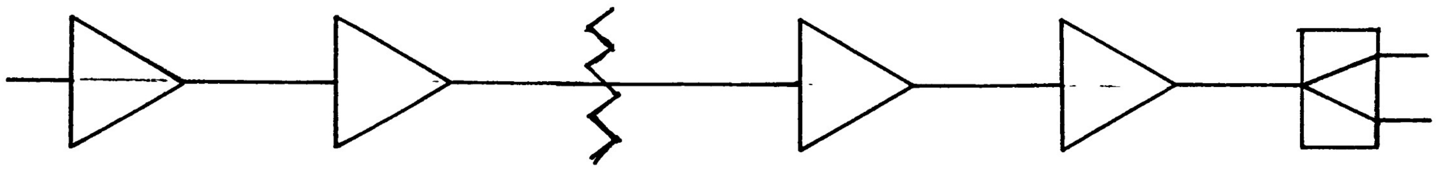
Table 2. Gain Analysis

Band	nf_c	$G_{FE,min}$ [1]	$G_{FE,max}$ [2]	$G_{FE,rec}$	$T_{R,PFE}$ [3]	G_{tot} [4]	G_{conv} [5]
(GHz)	(dB)	(dB)	(dB)	(dB)	deg K	(dB)	(dB)
15	19.5	44	49	46	.6	56	13
10.7	19.2	44	52	46	.6	57	14
4.8	19.6	44	56	47	.5	58	14
1.5	19.8	45	59	47	.5	59	15

Notes:

1. Minimum gain across the band for <= 1 deg K added noise.
2. Maximum average gain for <= 1% increase in mixer conversion loss. $P_{FE,max} = P_{MXR,max} - P_{A,max} + L_1 + L_2$.
3. Noise temperature contribution of circuitry following the front end at the recommended front end gain.
4. Total gain required to amplify the standard system noise level (T_{sl} of Table A-1 in Memo 30) to the -65 dBm in 1 MHz level specified in Memo 30.
5. Converter gain, equal to $G_{tot} - G_{FE,rec} + L_1$.

Figure 2.



Avantek UTO-1044 UTO-1005 UTF-025 UTO-1044 UTO-1044

WJ A18-1 A19 G1 A18-1 A19

Figure 3.

Examples of the gain flatness for the Avantek and Watkins-Johnson amplifier sets.