The Frequency Conversion System for the 23 GHz Band

A. R. Thompson

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In the VLBA receiving system for the 23 GHz band (21.7-24.1 GHz), the cryogenically-cooled input stages are located just below the bottom of the feed horn, about 4 meters above the top of the rack containing the IF and LO modules. The situation is similar for the other bands from 1.5 GHz upwards, but in the 23 GHz case the amplified signals are converted to a lower (intermediate) frequency before leaving the front-end package, so as to avoid the loss in 4-5 m of cable at 23 GHz. In the prototype system to be tested on the Pie Town antenna, a local oscillator tunable over the range 13.6-15.4 GHz, provided by a 2-16 GHz Synthesizer Module, is used to convert the signals down to the 8.0-8.8 GHz band, as shown in Figure 1. The loss in 5 m of cable (3/8-inch foam type) at this frequency is only 2.5 dB, and in the IF/LO rack the signals are processed by the same converter module that is used for the 8.4 GHz band, thereby saving a converter module (cost about $5k per antenna). A problem with this arrangement is that when the first local oscillator is set for the top end of the 23 GHz band, a spurious response resulting from the second harmonic of the local oscillator (at $2f_{LO} - f_{IF}$) falls within the low end of the signal band. This spurious response is about 16-20 dB below the wanted response of the mixer (for the mixers available: Honeywell 3MC1227/S1 and Spacek MM23-9). For continuum observations the unwanted frequency components are unlikely to cause problems, since at the correlator output they will be well separated in fringe frequency from the wanted signals. If strong water-line components are involved, as in some spectral line observations, the spurious response could be more troublesome.

Clearly, the unwanted response can be avoided by changing the first intermediate frequency, or by using a high-side local oscillator frequency. In the first of these options, the first IF must be increased rather than decreased because the 2-16 GHz Synthesizer will not tune above 15.9 GHz. Change of the first IF would require modification of the 8.4 GHz Converter Module or provision of an alternative converter to the 0.5-1.0 GHz IF. The second option, the use of a high-side local oscillator, would require another oscillator unit tunable over a few GHz near 32 GHz. If HEMT amplifiers rather than SIS mixers are used for the 43 GHZ front end, this oscillator could also be used as the first LO for the 43 GHz band, so it would not necessarily be an additional expense.

The effect of the LO and IF cables on the overall phase stability turns out to be the critical consideration in the choice between the two options outlined above. Figure 2 shows the mixer in the front-end package and the two cables running down to the IF/LO rack. Let f_S, f_{LO} and f_{IF} be the signal, local oscillator and intermediate frequencies respectively, and ϕ_S, ϕ_{LO} and ϕ_{IF} be the corresponding phases at the mixer.

If L is the length of the cables, the IF and LO phases at the rack, ϕ'_{LO} and ϕ'_{IF} are given by

$$\phi_{LO} = \phi'_{LO} - 2\pi f_{LO} L/c \quad (1)$$

and

$$\phi'_{IF} = \phi_{IF} - 2\pi f_{IF} L/c \quad (2)$$

For the lower-sideband case, $f_{IF} = f_S - f_{LO}$, and hence

$$\phi'_{IF} = \phi_S - \phi'_{LO} + 2\pi(f_{LO} - f_{IF}) L/c \quad (3)$$

For upper-sideband conversion, $\phi_{IF} = \phi_{LO} - \phi_S$, and

$$\phi'_{IF} = \phi'_{LO} - \phi_S - 2\pi(f_{LO} + f_{IF}) L/c \quad (4)$$

Representative frequency values are f_S = 23 GHz, f_{IF} = 9 GHz, f_{LO} = 14 GHz (lower sideband case) and f_{LO} = 32 GHz (upper sideband case). Thus in (3) $f_{LO} - f_{IF}$ = 5 GHz, whereas in (4) $f_{LO} + f_{IF}$ = 41 GHz. The dependence of the IF phase at the IF/LO rack on the stability of the cable lengths is greater by a factor of eight in the upper sideband case then in the lower. For a cable length of 5 m, and a fractional change in L of 3 X 10^{-5} (corresponding to about 1 deg C temperature change), the IF phase change is 0.9 deg for the lower sideband case and 7.3 deg for the upper sideband case. Clearly the lower sideband is the preferable choice. Note that the result is the same if the LO cable carries a subharmonic reference that is used to lock an oscillator at the mixer location.

The lowest frequency band for a first IF for the 23 GHz band that permits use of the 2-16 GHz Synthesizer as a first local oscillator, and also avoids spurious responses of the form $(2f_{LO} - f_{IF})$ and $(3f_{LO} - f_{IF})$, is about 9.4 - 9.9 GHz. It is therefore proposed to modify the design of the 8.4 GHz Converter Module to accept the band 9.4- 9.9 GHz as well as 8.0-8.8 GHz, so that it will perform the second conversion for the 23 GHz band in addition to the first conversion for the 8.4 GHz band.

Discussions with Larry D'Addario and Erich Schlecht were helpful in this analysis, especially as the large difference in the phase sensitivity in the two cases was not intuitively obvious.

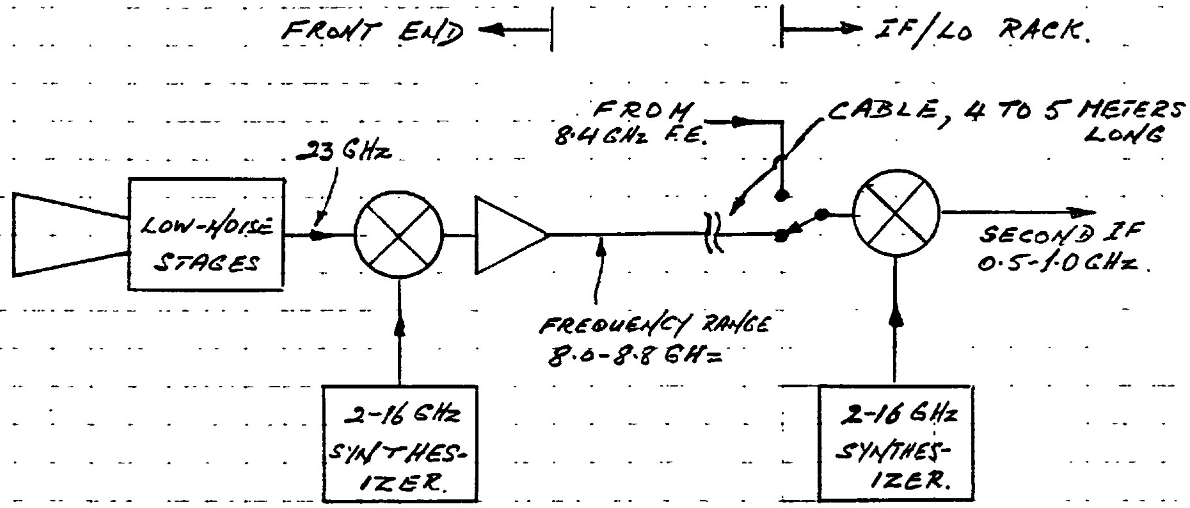

Fig. 1 23 GHz conversion scheme using 8.4 GHz converter input as first IF stage.

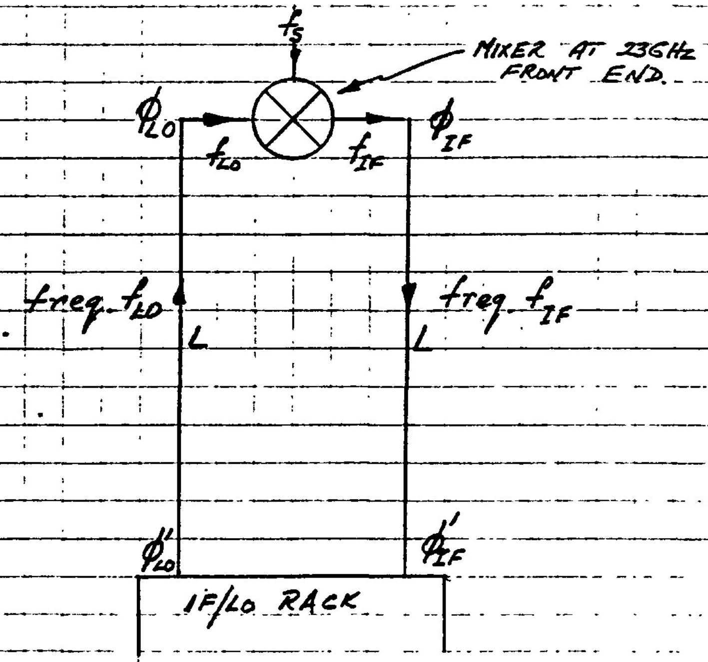

Fig. 2 LO and IF phases at the front end and IF/LO rack.