

DYNAMIC RANGE AND INTERFERENCE THRESHOLDS  
IN THE  
FRONT-END AND IF UNITS

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The power levels of the system noise at various points in the receiving system, and the range over which the signal level can vary while the response remains linear, are of particular importance for observations of the sun and observations in the presence of interfering signals. A discussion and some specifications of the power levels are given in VLBA Electronics Memo No. 30. The present memorandum is concerned with the gains and power levels of the front end and frequency converter units, to ensure that they can accommodate solar observations, and to specify the levels of interfering signals at which gain compression occurs. The interfering signals with which we are concerned here are ones which occur within the passband of the front end or IF amplifiers, but not within the receiving passband of the baseband amplifiers.

Gains and Signal Levels

A schematic diagram of the typical front-end and IF system for one of the receiving bands in the range 1.5 to 15 GHz is shown in Fig. 1. Since the precise noise figures, gain compression levels and other characteristics of the components are not known at the time, we shall consider typical values which are representative of most of the receiving bands.

Some general considerations should first be mentioned. Filters or attenuators that are inserted to prevent overload on strong signals should preferably be located in the equipment room of the site building rather than the antenna vertex room, since the temperature will be more stable in the building. Also the signals will have passed through the band selection switches before reaching the building, so it is then necessary to provide only one set of filters or attenuators for each of the four IF cables, rather than one for each polarization of each receiving band. These considerations suggest that the gain of the equipment within the vertex room should not be too high, so that special filtering will not be required there. On the other hand, the consideration of possible pickup of interference in the cables from the vertex room to the equipment room suggests that the signal levels at the cable input should not be too low. At this time, with no specific evidence that cable pickup will be a problem, we shall assume that minimizing the possibility of gain compression within the vertex room is the more important consideration.

The front end consists of a cryogenically-cooled amplifier and a post amplifier as shown in Fig. 1. The gain of the cooled amplifier is typically 30 dB. The gain of the post amplifier can be chosen as required, and the 1-dB compression point for this amplifier is typically 10 dBm at the output. (This figure is obtained from the specifications of the 8.4 GHz Mitec amplifiers given in VLBA Technical Report No. 1, p. 36, and from the specification for the Mitec amplifier for the 1.5 GHz band.) In the VLBA we prefer not to exceed 1% gain compression, and will here assume that this occurs typically at a level of 12 dB below the 1 dB compression point, i.e. -2 dBm for the post amplifier. The figures used here apply to overloading by a single sinusoidal signal, and the corresponding overload levels for Gaussian noise are believed to be higher, but we shall ignore this difference.

A minimum value of the gain for the front end is set by the requirement that the noise added by succeeding stages should be kept small. The noise figure of the mixer at the input of the frequency converter module is estimated to be 12 dB (mixer conversion loss 7 dB, filter loss 0.5 dB, noise figure of 500-1000 MHz amplifier 4.5 dB). The 12 dB figure should apply to most of the bands in the 1 to 15 GHz range. The loss in the cable from the front end to the frequency converter (about 4 m of 0.375-inch semi-rigid coax) varies from 0.5 to 3 dB over the various bands. If we take the noise figure at the input of the cable following the front end to be 15 dB, and require no more than 2K contribution to the system temperature from the cable and following stages, the front end gain must be no less than 36 dB. For 1K contribution the gain must be no less than 39 dB. In Fig. 1, 39 dB is obtained from 30 dB in the cooled stages, 15 dB in the post amplifier, and a 6 dB attenuator to allow some gain margin and to improve the match to the cable.

With 45 dB of gain to the output of the post amplifier, a system temperature of 200,000 K (as recommended in VLBA Electronics Memo No. 30 for estimation of solar-observation levels) in a bandwidth of 1 GHz produces a signal level of -11 dBm. This level is well within the -2 dBm level estimated above for the 1% compression point.

In the 500-1000 MHz IF range the available selection of amplifiers is greater than that for most of the post amplifiers which operate at the input signal frequency. Of the modular amplifiers for the IF range, Avantek UTO 1004 is one of the higher level units with 1 dB compression at 20 dBm output. We interpret this as +8 dBm for the 1% compression point, which is 10 dB higher than for the post amplifier. For a 200,000 K system temperature and IF bandwidth of 500 MHz, 1% compression occurs at 67 dB of gain relative to the front-end input. In non-solar observing a system temperature of 30 K is roughly representative of the bands from 1.5 to 15 GHz, and the corresponding noise power level is 38 dB below that for 200,000 K. Thus the usual

(non-solar) power level at the output of the IF amplifier in the vertex room could be as high as -30 dBm (which is the 1% compression level less 38 dB) in 500 MHz bandwidth. If, however, the system is designed so that the RF post amplifier and the IF amplifier reach the 1% compression points for the same signal level at the antenna, the IF amplifier gain should be reduced by about 10 dB to give a (non-solar) level of -40 dBm at the IF amplifier output. In Fig. 1 we have chosen an intermediate level of -35 dBm, which corresponds to a gain of 62 dB relative to the front end input.

#### Interference Levels for 1% Compression of Gain

For the system in Fig. 1, a narrowband interfering signal of level -54 dBm (-84 dBW) at the antenna output would produce 1% gain compression in the IF amplifier: thus the threshold for harmful interference from this mechanism can be defined as -84 dBW in an isotropic antenna. The corresponding values for flux density are given in Table 1. Values for the 330 MHz, 610 MHz, 23 GHz and 43 GHz bands should be regarded as tentative since the system that will be used for these bands will differ in some details from that in Fig. 1. At 330 MHz and 610 MHz post amplifiers of higher dynamic range, and additional filtering, can be provided. At 23 and 43 GHz there will be two frequency conversions in going from the signal frequency to the 500-1000 MHz IF.

TABLE 1. Estimated Flux Density Levels of Interfering Signals for 1% Gain Compression

Frequency Band	Collecting Area for 0 dB gain, $\lambda^2/4\pi$	Flux Density for 1% Compression
GHz	dB m <sup>2</sup>	dB Wm <sup>-2</sup>
0.33	-11.8	-72*
0.61	-17.1	-67*
1.5	-25	-59
2.3	-29	-55
4.8	-35	-49
6.1	-37	-47
8.4	-40	-44
10.7	-42	-42
15	-45	-39
23	-49	-35*
46	-54	-30*

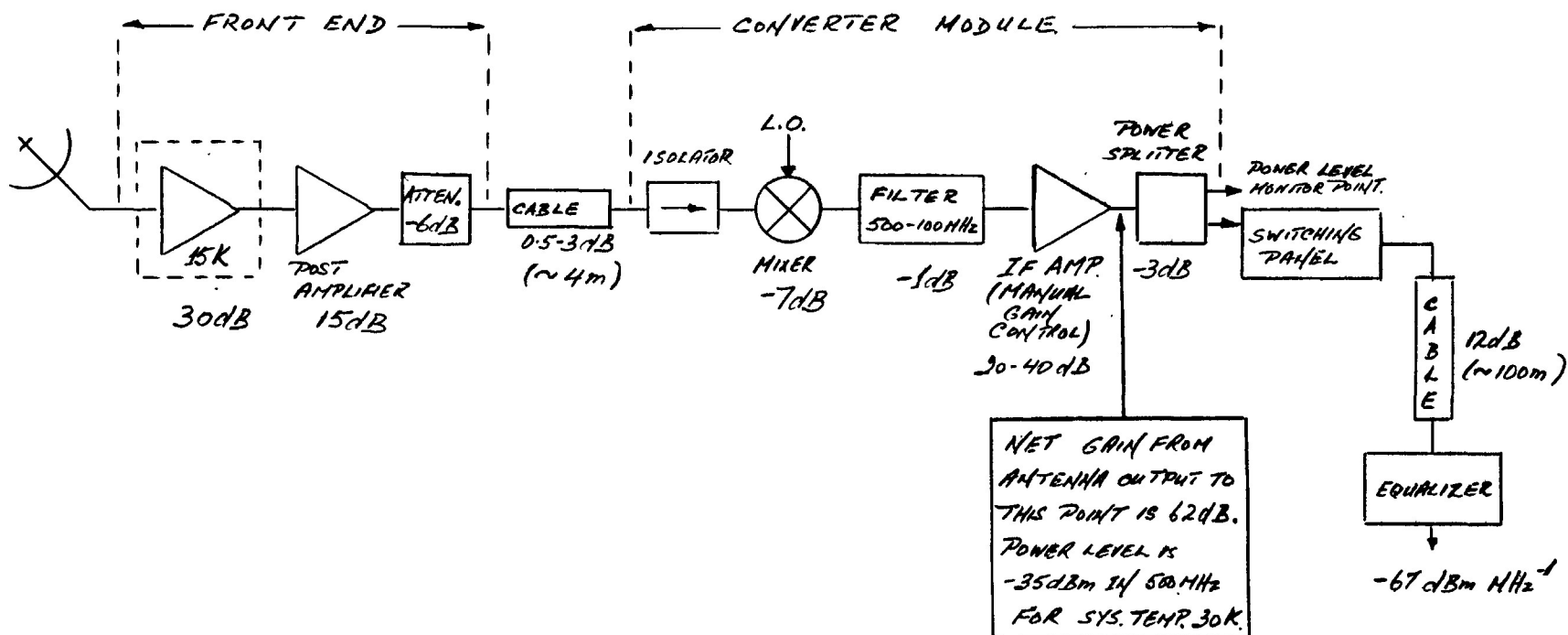
\* Approximate only

The flux density values in Table 1 represent strong signals, and except for the 610 MHz band are greater than the values encountered in the site testing: see VLBA Memos No. 383, 401, 407, 415, 423 and 433. The strong signal at 1717 MHz at Los Alamos is approximately  $-75 \text{ dBWm}^{-2}$ . Thus the gains and power levels indicated in Fig. 1 appear to be satisfactory. Fig. 2 shows a proposed design for the 500-1000 MHz amplifier which contains a manual gain adjustment to allow the level to be set at the monitor output point in the vertex room. This adjustment can accommodate differences in front end gains, cable losses, etc. The level at the monitor point will be measurable with a power meter and calibrated preamplifier which will be installed in the IF/LO rack in each vertex room.

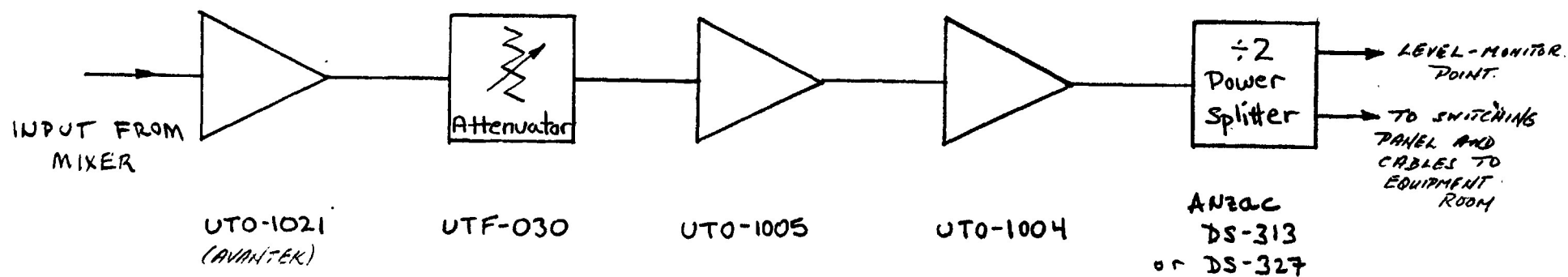
The design of the cable equalizer unit, which also incorporates a signal amplifier to bring the level up to  $-67 \text{ dBm MHz}^{-1}$  as specified in VLBA Electronics Memo No. 30, will depend upon the attenuation of the cables between the vertex room of the antenna and the equipment room of the site building. The value of 12 dB shown in Fig. 1 corresponds approximately to 70 m of 3/8" semi-rigid cable from the equipment room to the base of the antenna, and 30 m of RG9 flexible cable from the base to the vertex room, for a frequency of 750 MHz. Attenuator pads may also be inserted at the ends of the cables to improve the matching.

### Conclusion

The gains and signal levels discussed above and shown in Fig. 1 provide adequate dynamic range for solar observing, and to avoid non-linearity on most interfering signals, except, perhaps the strong UHF television signals in the 610 MHz band. However, a special superheterodyne filter system is being developed to provide the necessary selectivity in the 610 MHz band. An IF amplifier of the type shown in Fig. 2 should be appropriate for use in the converter modules for almost all of the different frequency bands.



**Fig. 1** Front end and IF system with typical parameters for receiving bands in the 1.5-15 GHz range.



**Fig. 2** Proposed 0.5-1.0 GHz IF amplifier.