NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO

VLA Electronics Memorandum No. 137

MODIFICATION OF THE FREQUENCY CONVERSION SCHEME AT THE ANTENNAS

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This memorandum describes a modification of the scheme by which the signals in the 4·5 to 5·0 GHz band in the front end are converted to the four I.F. bands which go to the modem. The modification is introduced to eliminate a spurious response and to allow a reduction in the number of 2-4 GHz Synthesizer Modules and Fringe Generator Modules required. It also provides a convenient place for insertion of filters to limit the system bandpass at the antennas. It is intended to introduce the new scheme in the electronics for antennas 11 and onwards, and retrofit the first ten antennas at a later stage.

I. Spurious Response in the 4·5-5·0 GHz Mixer

In the prototype electronic system four 50 MHz-wide I.F. bands are selected from the 4·5-5·0 GHz output of the front end and converted to bands centered on 1325, 1425, 1575 and 1675 MHz. This occurs in the Frequency Converter Module, a block diagram of which is shown in Figure 1. The local oscillators for these conversions lie in the range 2850 to 3650 MHz and are derived from four 2-4 GHz Synthesizer Modules (L6), the outputs of which are tunable in alternate steps of 20 and 30 MHz. The center frequency of the wanted band in the 4·5-5·0 GHz range is given by

$$f_R = f_{LO} + f_{IF}$$

where f_{LO} is the output frequency of the synthesizer module and f_{IF} is 1325, 1425, 1575 or 1675 MHz. In addition, an unwanted response occurs at the mixer input resulting from the second harmonic of the local oscillator frequency. This unwanted frequency is given by

$$f_x = 2\,f_{LO} - f_{IF}$$

$$= 2\,f_R - 3\,f_{IF}$$

Figure 2 shows f_x as a function f_R for the four IF frequencies concerned and for 1025 MHz. Note that for the three highest IFs there are large ranges of f_R for which f_x falls within the 4·5-5·0 GHz range. The response at f_x is 20-30 dB below that at f_R so it is not likely to result in serious errors from astronomical signals, but it provides a possible channel for interference. This problem was realized when the prototype system was built (see VLA technical report No. 7 by S. Weinreb) and it was hoped to solve it later by some relatively simple modification such as using a better mixer, or a YIG-tuned preselector at the mixer input. Further investigation has shown these not to be very promising possibilities. The best solution appears to be to convert from 4·5 to 5·0 GHz to an I.F. for which the spurious response is well outside the input band and then to filter and reconvert to 1325, 1425, 1575 or 1675 MHz. A frequency of 1025 MHz has been chosen for this first I.F. because it is low enough to give freedom from the unwanted response without requiring a very steep sided filter response at 4·5 to 5·0 GHz, and it is within the range of the 1-2 GHz components in the Frequency Converter and so requires no changes to that module. Also the local oscillator frequencies required for the conversion from 4·5-5·0 GHz remain within the range of the 2-4 GHz Synthesizer Module, and the further conversions to 1325 MHz, etc., require oscillator frequencies that are multiples of 50 MHz and thus are relatively simple to generate from the oscillator system at the antennas.

Other spurious responses at the 4·5-5·0 GHz mixer were considered but all involve harmonics of the signal frequency. For an I.F. of 1025 MHz the only one that falls within the signal band is given by

$$2 f_y = 3 f_{LO} - f_{IF}$$

The input signal level at the mixer is -45 to -57 dBm in a 60 MHz-wide band and results from a gain of 48 dB from the front end inputs to the mixer (see VLA Technical Report No. 7). Interfering signals would thus have to be very strong to produce a harmonic response at the mixer, and this effect is not considered to be a problem.

The oscillator frequencies required for the conversion from 1025 MHz to the four next I.F. bands are given below:

CHANNEL	I.F.	L.O.
A	1325 MHz	300 MHz
B	1425 MHz	400 MHz
C	1575 MHz	550 MHz
D	1675 MHz	650 MHz

Harmonics of 300 and 400 MHz at 1200 and 1800 MHz can occur at the mixer output along with the wanted I.F. signals. The I.F. signals go to the I.F. Combiner Module (T2) where they are combined with standard reference signals at 1200 and 1800 MHz before going to the Modem (T1). At this point any harmonics of the 300 and 400 MHz oscillator frequencies should be about 54 dB below the reference signals in order that the resulting LO phase shift be $\leq 0.2^{o}$ at 1 GHz. The worst case is the third harmonic of 400 MHz which would be about -45 dBm at the output of a mixer such as a Relcom M1J driven by 400 MHz at 7 dBm. The 1425 MHz filter provides about 70 dB of rejection at 1200 MHz and the unwanted harmonic should thus be about 14 dB below the maximum tolerable level at the I.F. Combiner, so there should be no problem from the unwanted harmonics.

Reconsideration was also given at this stage to the choice of the four intermediate frequencies of 1325, 1425, 1575 and 1675 MHz. The I.F. band edges should have adequate clearance from the 1200 and 1800 MHz reference signals so as not to add noise to them. With the present choice, shown in Figure 3, adequate clearance of the reference bands would be obtained even if the I.F. bandwidths were increased to 100 MHz at some future time. Tests to date have indicated no problems with intermoudlation products and it is not apparent that the present choice for these frequencies can be improved.

II. Block Diagrams of New System

Figure 4 shows a block diagram of a new module, tentatively named the I.F. Offset Module, that will be connected between P5 and P6 in Figure 1 to replace the external filter used in the prototype system. The local oscillator at P3 in Figure 1 will then be tuned to convert the desired signal band to 1025 MHz. In Figure 4 the I.F. signal first goes through one of four selectable filters which determine the bandwidth, and is then converted to one of the four next I.F. bands before returning to the Frequency Converter Module. The overall gain in the I.F. Offset Module is approximately unity and the amplifier provides 10 dB of gain to compensate for mixer and filter losses.

The three selectable filters shown allow considerable flexibility in limiting the bandwidth at the antenna to avoid interference. Note that the center frequency of the passband at the front-end input can only be tuned in the 20 and 30 MHz steps of the 2-4 GHz Synthesizer Module, so if it is desired to center the response on some specific line it may be necessary to choose the center frequency of the filter appropriately. In the case of the hydrogen line 1026 MHz can be tuned to 1416 MHz (upconverter pump at 3200 MHz and 2-4 GHz Synthesizer at 3590 MHz) so the 1026/12 filter covers 1410 to 1422 MHz at the -3 dB points which should be a good choice for much hydrogen line work. Note that it may be necessary to use cavity bandpass filters for bandwidths less than 20 MHz (percentage bandwidth less than 2%). Provision can be made to add an external filter for special requirements using the fourth switch position. Figure 6 shows the interference threshold curve for the 18-21 cm band using the data described in VLA Electronics Memorandum No. 129.

The physical implementation of the new module has not yet been finalized but one channel can be incorporated in a unit-width module or two in a double-width module. Control signals for the switching will be provided by the Front End Control Module (F5). Figure 5 shows a scheme for producing the required oscillator signals for the conversion of the 1025 MHz signals. This can be implemented in a unit-width module or incorporated with the I.F. Offset components. Tables I and II give approximate cost estimates for these units.

III. Reduction in the Number of 2-4 GHz Synthesizer and Fringe Generator Modules

The prototype scheme incorporates four 2-4 GHz Synthesizers Modules at each antenna. Four different oscillator frequencies are required even when only two different observing frequencies are in use because the four signal channels are converted to four different I.F. bands. In the new system, however, all four channels will be converted to 1025 MHz, and only two synthesizer modules are required for two-frequency operation, one for channels A and C, one for channels B and D. (Channels A and B come from the front end system for one polarization and channels C and D from that for the opposite polarization.) It seems likely that two-frequency operation will be the most commonly used mode with the VLA since it applies to polarization measurements and to cases where the maps with opposite polarizations are simply averaged to maximize the sensitivity. Provision of just two 2-4 GHz Synthesizer Modules at each antenna would result in a cost saving of approximately $7,700 per antenna since each synthesizer costs $3,050 and requires a separate Fringe Generator Module costing $800. Providing only two of each of these modules at each antenna would result in the following restrictions on the operation.

(1) When operating in one wavelength band (i.e., without the dichroic reflector) it would be possible to tune the 50 MHz-wide bands to only two different frequencies within the 500 MHz bandwidth of the front end, since channels A and C would be on the same frequency and so would channels B and D. With four synthesizers all four bands could be tuned to different frequencies, which might be useful for some spectral investigations if the effects of polarization could be accounted for. Note that in the two-synthesizer case, when narrow bandwidths are used in the final I.F. stages, it would be possible to center two of these on different parts of the 50 MHz band in channels A and C and similarly for channels B and D. Four frequency operation would thus still be possible in this more restricted manner.

(2) When the dichroic reflector is used for simultaneous observations in the 2 cm and 6 cm wavelength bands, only one 50 MHz-wide signal band would be usable for each of these wavelengths. This is because there would only be two Fringe Generators at each antenna so only two fringe rates could be accommodated. Note that the dichroic mode of operation is somewhat restrictive in any case since only one polarization can be used with each wavelength band even with four synthesizers at each antenna.

IV. Summary

The scheme described above incorporating the I.F. Offset Modules is required to remove a possible channel for interference which could be troublesome, especially when operating in the 18-21 cm band where there are many other spectrum users. It has also been planned for some time to incorporate bandwidth selection filters at the antennas to match the system passbands to the radio astronomy bands and to provide better selectivity when working outside the radio astronomy bands. Implementation of the above modifications allows the possibility of reducing the number of 2-4 GHz Synthesizer Modules and Fringe Generator Modules.

It must be decided whether removing the restrictions in Section III is worth the $216K required to equip 28 systems with four Synthesizers and Fringe Generators at each antenna rather than two. It would, of course, be possible to implement the cheaper scheme for initial operation and have the option of adding the extra modules in the late stages of construction of the array when the final cost is accurately known.

Table I APPROXIMATE COST OF I.F. OFFSET MODULE (Figure 4)

Two 4-way coaxial switches (Transco 144C70100)	$ 460
Three tubular bandpass filters, 6-pole	210
One cavity bandpass filter	250
Amplifier (Avantek UTO 1501)	100
Mixer (Relcom M1J)	110
Switch control circuitry	20
Packaging	150
Total per (I.F. Channel)	$1,300
Total per antenna	$5,200

Table II APPROXIMATE COST OF L.O. COMPONENTS (Figure 5)

Two 2-way power dividers (Merrimac PDM-20-250, PDM-20-500)	$ 135
Two mixers (Relcom M1J)	220
Frequency doubler (Anzac D-1-4)	55
Four tubular bandpass filters, 4-pole	240
Four amplifiers (Avantek GPD 402, 403)	200
Packaging	150
Total (per antenna)	$1,000

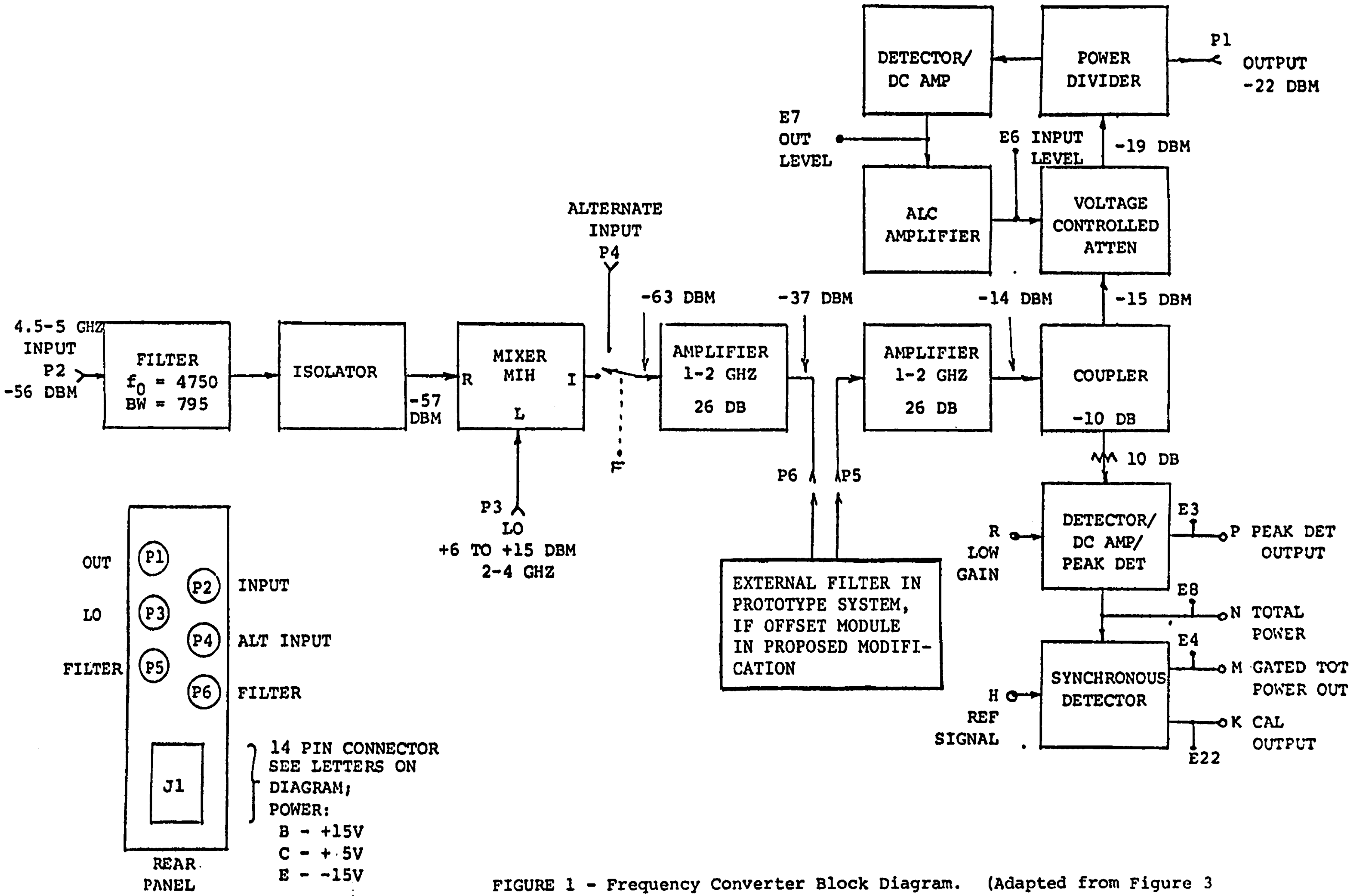

FIGURE 1 - Frequency Converter Block Diagram. (Adapted from Figure 3 of VLA Technical Report No. 7 by S. Weinreb.)

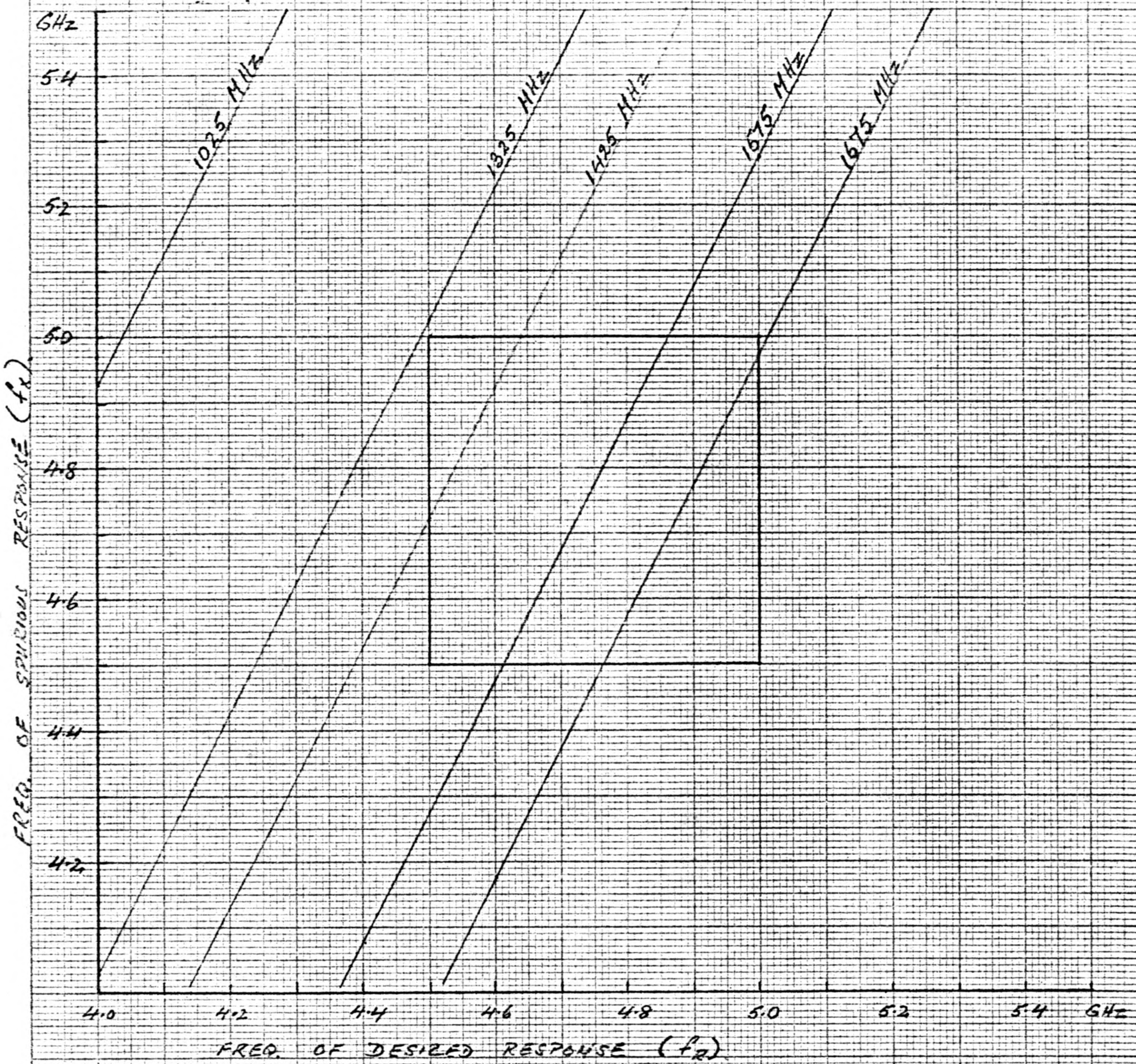

Fig 2 f_x as a function of f_R for five intermediate frequencies.

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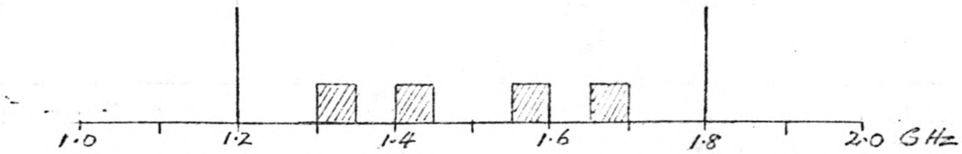

Fig 3. Spectrum of IF bands (shaded) and reference signals at 1·2 and 1·8 GHz.

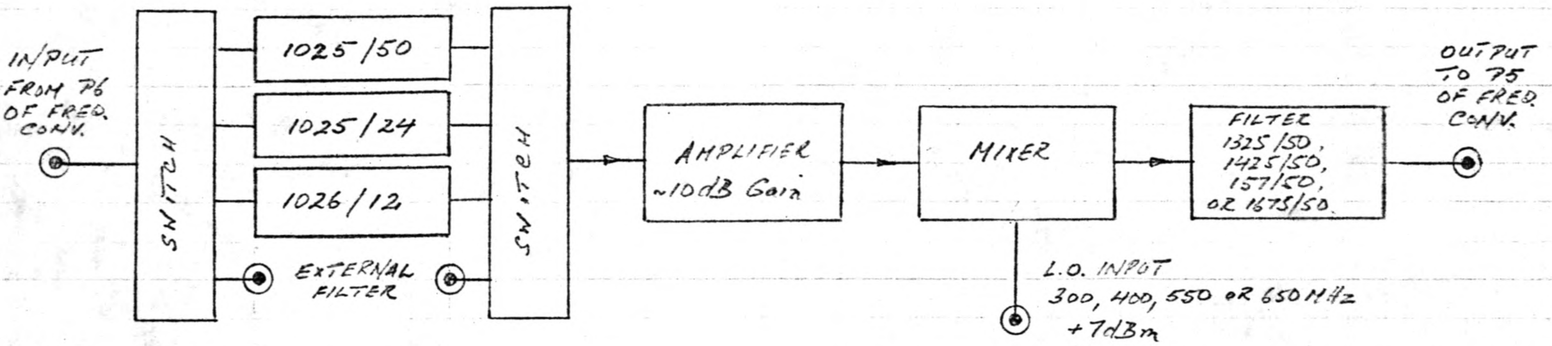

Fig. 4 Block diagram of proposed IF Offset Module.

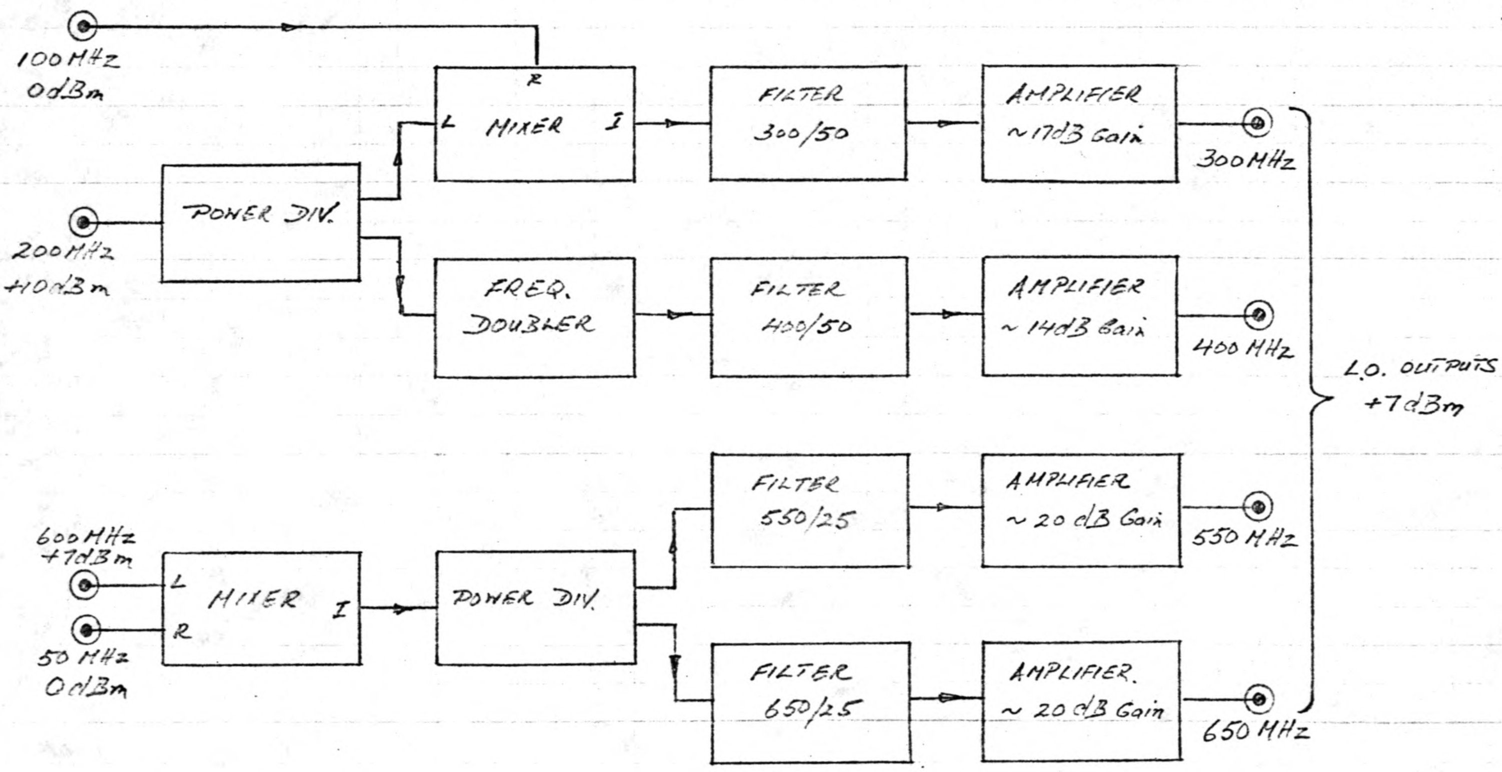

Fig. 5 Proposed block diagram for generating required L.O. signals.

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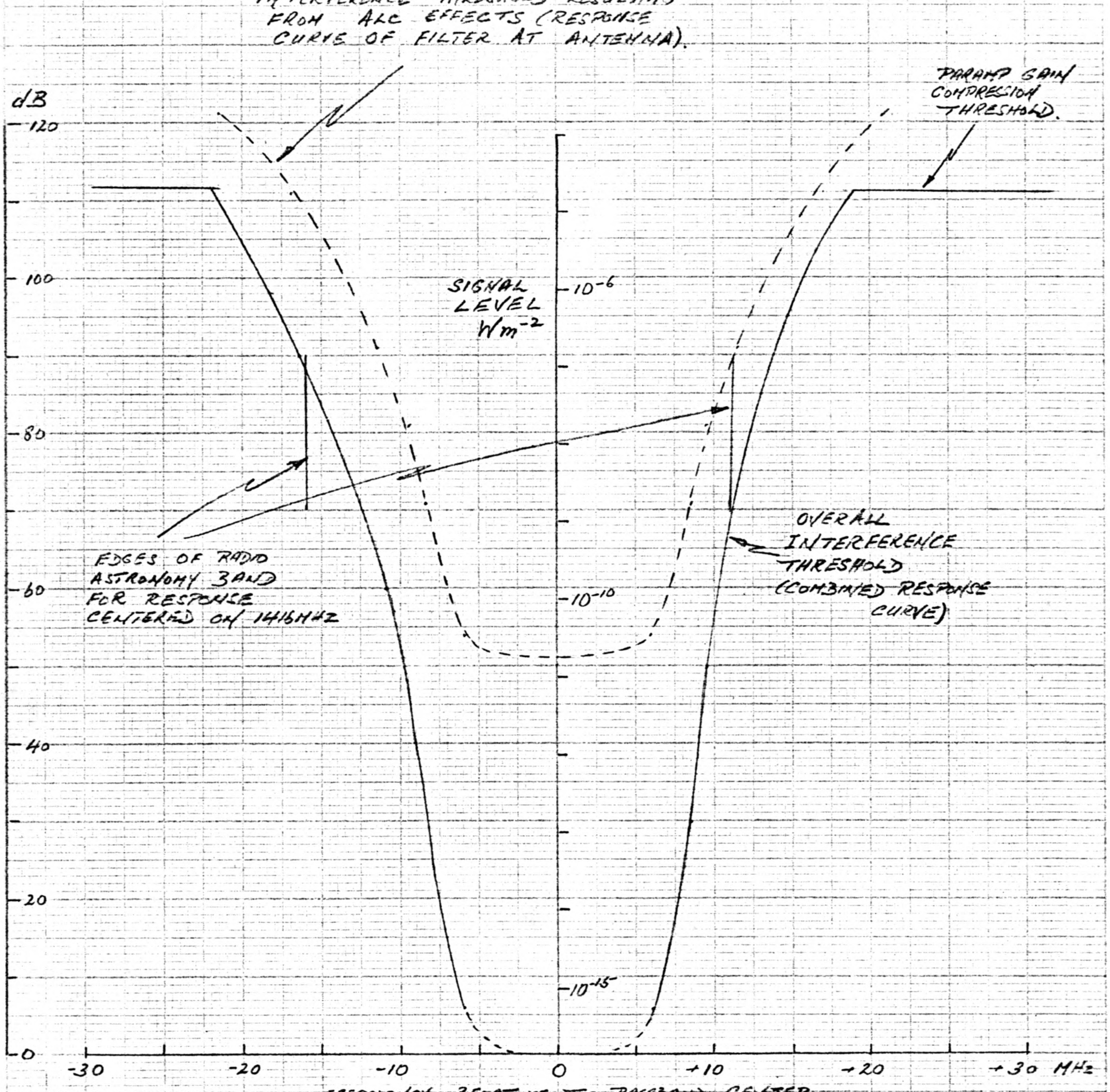

Fig 6. Frequency response with interference threshold levels for the 18-21 cm wavelength band with a 6-pole, 12 MHz-bandwidth filter at the antenna (1026/12 in fig 4) and a 4-pole, 12 MHz-bandwidth filter in the I.F. Receiver Module. Curves are typical data from filter catalogs and threshold figures are from VLA Electronics Memorandum # 129.

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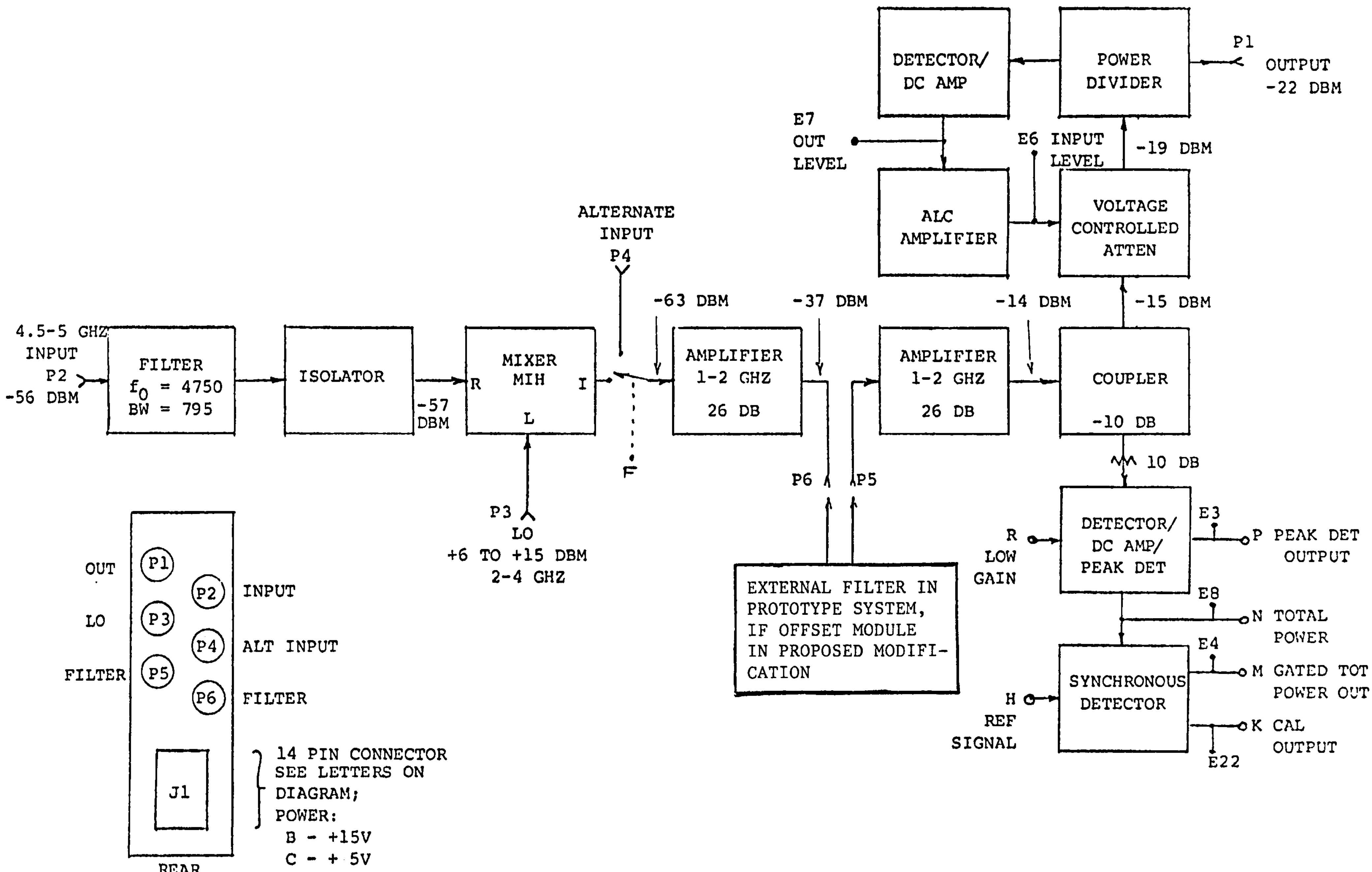

FIGURE 1 - Frequency Converter Block Diagram. (Adapted from Figure 3 of VLA Technical Report No. 7 by S. Weinreb.)