NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, WV

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MEMORANDUM

To: VLBA Electronics Group

From: Roger D. Norrod

Subj: **Design Considerations for a 43 GHz Receiver**

1.0 Introduction

We now plan to construct one prototype 43 GHz receiver in 1989 and the remaining ten units in the following years. This memorandum will discuss some design considerations for the cryogenic package and the converter module. Several possible configurations are discussed and a proposed block diagram is presented. Selection of critical components and some unanswered questions are considered.

2.0 Possible Configurations

Basically, the receiver has to accept the dual-polarized output of the feed (circular waveguide of diameter 0.207 inch) and produce two 0.5-1.0 GHz IF outputs. It is desirable that the electrical and mechanical interfaces be as similar as possible to the other VLBA front-ends. There appears to be no reason that the basic dewar design used for the 4.8 to 23 GHz front-ends should not be used, so this will be the starting assumption.

The receiver as now conceived will consist of three physically separated assemblies: a dewar/cardcage package mounted at the feed output, a front-end interface module in the vertex room A-rack (likely identical to the F117 module used with the other front-ends), and a converter module in the vertex room B-rack. A first mix will be done at the dewar and a second mix will be performed in the converter module, producing the 0.5-1.0 GHz IF outputs.

The lower frequency front-ends have provisions to inject an externally generated phase-cal signal, a low-level noise cal, and a high-level noise cal into the signal paths. At present, it is felt unlikely that the high-level noise cal (intended primarily for solar observations) will be required, but the other two injected signals will be accommodated in the design.

The receiver should cover the SiO transitions with rest frequencies 42.5 to 43.4 GHz, and a methanol maser at 44.1 GHz. The VLBA project book defines the observing band as 42.3-43.5 GHz (precedes the discovery of the methanol maser). However, 10% bandwidth seems to be a reasonable spec for components in this band, so I have taken the frequency range 41-45 GHz as a working assumption.

2.1 Cryogenic Package

Figure 1 is a block diagram of the dewar package. The Polarizer/OMT will separate the two circular polarizations and will be cooled to 15 K. A specification for this component has been written (A53213N001) and an RFQ to several firms has produced two credible bids.

The signal paths will be in WR-22 waveguide from the outputs of the OMT to the inputs of the first mixers. The Phase Cal input will be combined with the output of a broadband noise source in a 3 dB coupler or a hybrid tee. Commercial WR-22 diode noise sources are available with 20 dB excess noise, which should be adequate for an injected cal level of 10 K. The combined cal is split at the 15 K station and injected into the two channels via 25 dB directional couplers.

A prototype 4-stage HEMT amplifier has been produced at NRAO (EDIR #282) with noise less than 50 K and gain greater than 25 dB from 42 to 44 GHz. Work is underway to produce two robust units for inclusion in the prototype receiver.

2.2 Frequency Conversions

Two techniques have been considered:

1. Use a fixed first LO, a Gunn oscillator phase-locked to a harmonic of the hydrogen maser reference frequency. The signal band is converted down to a broad first IF band (e.g., 4-8 GHz). The second conversion uses the 2-16 GHz LO synthesizer, and image-rejection mixers.

2. Use a harmonic of a 2-16 GHz synthesizer (a unit is available at the VLBA stations) as LO 1. LO 1 is then tunable, and a more narrow first IF band is acceptable. An existing (e.g., 8.4 GHz) converter module design can be used.

The advantage of the first approach is:

-- Adequate LO power can be obtained to drive both mixers at +10 dBm, meaning balanced, unbiased mixers can be used. The mixer conversion loss would be 5-6 dB. A gain of 25 dB preceding the mixer would be marginal, but adequate (~ 5 K noise contribution).

Disadvantages of the first approach are:

-- Image rejection mixers will be required at the second conversion (RF BW > 2 GHz). A cursory examination of vendor catalogs revealed none that would fit the bill, but something is probably available. However, 15-20 dB is probably all the image rejection that could be expected.

-- More NRAO engineering would probably be required to develop the phase-locked Ka-band source and the converter module.

The second approach, tunable LO1, has been considered in some detail. Table 1 and Figure 2 show the frequency coverage and block diagram of the configuration selected. Note that there is no coverage overlap at 42.15 and 43.65 GHz. To even achieve continuous coverage, the bandwidth of the first IF converter must cover 7.95-8.85 GHz. This bandwidth in practice will be set by the filters FL1, FL2 in Figure 1.

The X-band power amp (A7, Figure 2) must provide +17 dBm at each tripler input. Amps that can do this appear to be available commercially (e.g., Avantek APT-12057). One vendor (Spacek) has provided a budgetary quote on the tripler, BPF, mixer assembly. The mixer quoted is a biased (starved LO), balanced unit with about 7.5 dB conversion loss. The BPF is required to remove higher harmonics of LO_x that would produce intermod products in the IF_1 passband. Another potentially troublesome intermod product (3•LO1-2•RF) is said to be down by more than 45 dB.

The noise temp of these mixers, including the contribution of IF amps A5 and A6, is likely to be 2600 K. This means greater than 27 dB preceding gain is required to get the noise contribution below 5 K. The best way to achieve this seems to be to add a fifth stage to the cryogenic amplifiers. This means that the expensive Q-band room temperature amps (A3, A4, Fig. 1) will not be required.

2.3 Recommended Configuration

On balance, the LO configuration shown in Figure 2 seems to be the better. The component cost will be about the same, except that the fixed LO scheme will require a new converter module type and the other scheme can probably use an existing converter. (See the next section.) Image rejection with the fixed LO configuration could be a problem, and more engineering will be required.

Table 2 is an estimate of the total receiver component costs (excluding the converter and interface modules).

3.0 System Considerations

Reference to a block diagram of the electronics system (D58001K001, sheet 1) may make this section more understandable. Each antenna has three 2-16 GHZ synthesizers. No. 3 can be switched (S10) between the 8.4 GHz Converter Module or the 23 GHz front-end. An unused port on S10 can be used to switch it to the 43 GHz front-end.

The 8.4 GHz Converter (Block Diagram C53500K009) has internal two-position input switches to select between the outputs of the 8.4 GHz and 23 GHz front-ends. If it is decided to use the existing modules with the 43 GHz front-end, three possibilities occur to me: Modify the existing design to incorporate a three-position switch; add a second two-position switch in the rack preceding the converter input; or build an identical or simplified 8.4 GHz converter dedicated to use with the 43 GHz front-end. The last option has some attraction as the two modules could serve as hot spares for each other.

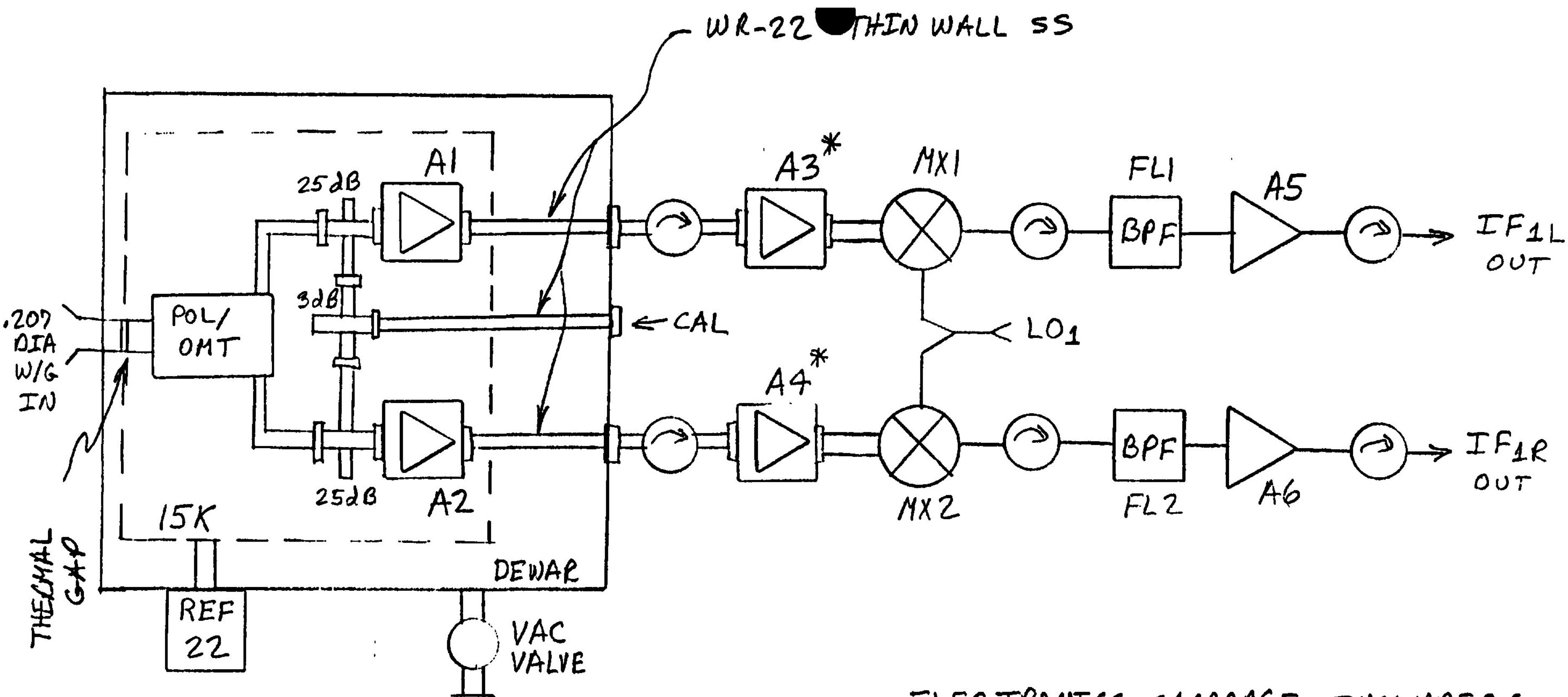
The Q-band tripler/mixers will likely be fairly sensitive to the LO_x input level. A manual adjustment process when the receiver or synthesizer is installed would be possible, but a simple leveling loop around A7 might be preferable.

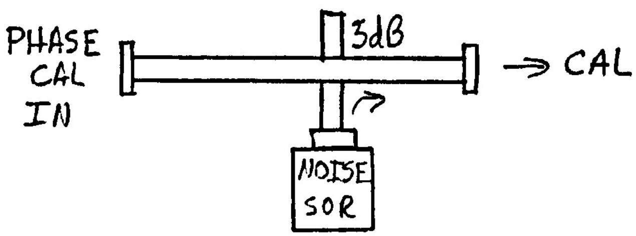
The need for five cryogenic amplifier stages to get enough gain preceding the mixers will require a third bias card. Hence, a non-standard dewar card-cage will be required, but probably would be needed anyway to accommodate the waveguide components.

The X-band power amp will require about 1.5 A at 12-15 V. It might be desirable to mount a power supply on or near the front-end rather than run wires up from the racks.

4.0 Summary

Figures 1 and 2 and Table 2 defines the receiver configuration suggested here. Comments would be appreciated. Comments on the options mentioned in section 3 are especially needed.





ELECTRONICS CARDCAGE INCLUDES:

– AMP BIAS CARDS	D53200A002
– SENSOR CARD	D53200A003
– CONTROL CARD	D53200A004
– MONITOR CARD	D53200A006

* A3 and A4 may not be required. See text.

FIGURE 1
43 GHZ FRONT-END

2/17/89

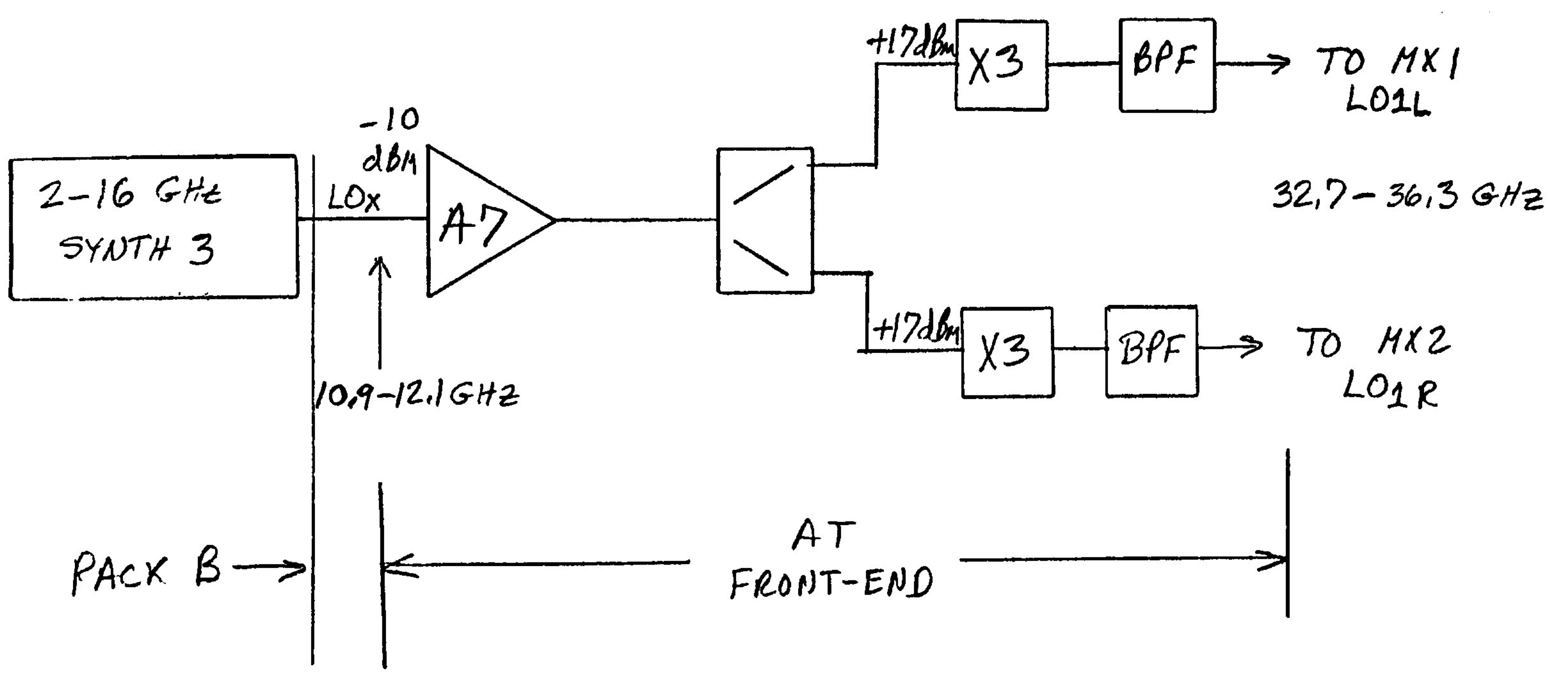


FIGURE 2

FIRST LO CHAIN (TUNABLE)

2/17/89

TABLE 1
LO FREQUENCIES

Fsyn	LO1 3 X Fsyn	LO1+7.95	LO1+8.85	LO2	Fsky @ IF2=0.5	Fsky @ IF2=1.0
10.9	32.7	40.65	41.55	7.40	40.60	41.10
				7.60	40.80	41.30
				9.40	41.60	41.10
11.1	33.3	41.25	42.15	7.40	41.20	41.70
				7.60	41.40	41.90
				9.40	42.20	41.70
11.4	34.2	42.15	43.05	7.40	42.10	42.60
				7.60	42.30	42.80
				9.40	43.10	42.60
11.6	34.8	42.75	43.65	7.40	42.70	43.20
				7.60	42.90	43.40
				9.40	43.70	43.20
11.9	35.7	43.65	44.55	7.40	43.60	44.10
				7.60	43.80	44.30
				9.40	44.60	44.10
12.1	36.3	44.25	45.15	7.40	44.20	44.70
				7.60	44.40	44.90
				9.40	45.20	44.70

TABLE 2

Estimated Component Cost
43 GHz Receiver

Item	Cost
Refrigerator, Model 22	$3,600
Polarizer/OMT	4,200
Cal Coupler (2)	1,200
3 dB Coupler (2)	1,400
Cryo Amp Materials (2)	3,000
W/G Isolator (2)	1,700
W/G Mixer/Tripler/BPF (2)	9,500
LO Medium-Power Amp	1,800
X-Band Isolator (4)	600
X-Band Low-Noise Amp (2)	5,000
X-Band BPF (2)	400
Miscellaneous Waveguide Flanges, etc.	500
Total	**$32,900**