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Richard F. Bradley and Shing-Kuo Pan

NRAO Central Development Laboratory
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Introduction

The atmospheric opacity and stability data obtained recently from the Millimeter Array site survey instrumentation located near San Pedro de Anacama, Chile suggest that this site may be suitable for astronomical observations at submillimeter wavelengths. These preliminary data include 225 GHz opacity measurements acquired from the currently available tipping radiometer and 12 GHz phase stability measurements acquired from a portable interferometer. Opacity measurements at 690 GHz, using a new tipping radiometer designed specifically for this band, would enhance our understanding of the atmospheric opacity as a function of frequency and therefore provide a more complete assessment of site suitability. This memorandum will examine the technical and cost issues involved in the development of this new 690 GHz radiometer system.

Design Issues

The proposed 690 GHz radiometer will be based, in part, on the existing 225 GHz system described by Liu [1]. A block diagram of the new 690 GHz system is presented in Figure 1. The overall operation and control of both systems would be quite similar. The following issues must be considered carefully when designing the new system:

Optics

The rotatable mirror assembly, chopper assembly, and fixed mirror can be made smaller than the corresponding items used currently in the 225 GHz system. The surface accuracy of the mirrors and chopper blades needs to be improved slightly. Although the material used for the reference and hot loads at 225 GHz may not function effectively at 690 GHz, there is suitable material readily available for this purpose. The physical temperatures of the reference and hot loads may need to be adjusted to provide adequate noise power for system calibration at 690 GHz, where the receiver temperature will be somewhat higher than what is measured currently at 225 GHz. The wiring scheme for the rotatable mirror should be redesigned and improvements should be made to the chopper wheel synchronization technique to improve blade tracking.

Local Oscillator Injection

The cavity-type local oscillator (LO) injection scheme used at 225 GHz cannot be used at 690 GHz due to the much higher losses that would be present in such a structure. The cavity would also be much more difficult to fabricate and tune. However, a Martin-Puplett interferometer or perhaps the more compact Mach-Zender interferometer may be used for LO injection. In either case, the interferometer would be located in the signal path between the fixed mirror and the focusing lens. It can be fabricated either by NRAO or purchased from a commercial vender. The feed horn, which was part of the injection cavity at 225 GHz, will be integrated into the 690 GHz mixer block.

Local Oscillator

The local oscillator for this system requires greater than 0.5 mW for optimum performance. A complete LO chain, which will deliver a maxium power of 0.5 mW, can be purchased from Zimmermann [2], but the overall performance of the mixer may be compromised. To achieve optimum performance, the LO would most likely consist of a 115 GHz Gunn oscillator with an output power of 120 mW followed by a balanced doubler to 230 GHz with an efficiency of 20 percent. This doubler would then be followed by a tripler to 690 GHz with an efficiency of about 3 percent, yielding a power of 0.72 mW. A feed and lens assembly would be used to couple this power into the diplexing interferometer. The Gunn oscillator and tripler can be purchased. However, the balanced doubler is not commercially available and must be developed at NRAO. This work would be a natural extension of the frequency multiplier projects currently underway at the Central Development Laboratory for use in the 3 mm receiver on the 12m telescope. All of the components in the LO chain must have adequate temperature stability. The dc power requirements for this LO will be comparable to that used currently at 225 GHz.

690 GHz Mixer

A room temperature planar Schottky diode mixer has been developed by us [3] for use in the 580-700 GHz band. Recent laboratory measurements on the prototype unit have demonstrated a mixer temperature of 3610 K at 690 GHz with a conversion loss of 10.2 dB. The mixer block has an integrated diagonal-type feed horn making it well suited for the tipping radiometer application. Acceptable mixing performance requires an LO power between 0.5 to 1.0 mW. The IF, which should be centered at 1.5 GHz with a bandwidth of 1.0 GHz, is compatible with the existing 225 GHz system.

IF Amplifier and Square-Law Detector

Room temperature IF amplifiers, having less than 0.35 dB noise figure (24 K) in the 1.0-2.0 GHz band, are now available from commercial vendors. The square-law detector [4] used in the 225 GHz radiometer can also be used with the 690 GHz system. However, proper operation of this detector in the 1.0-2.0 GHz band should be verified since replacement diodes must now be used in place of the original detector diodes which are no longer available. A coaxial-type detector followed by sufficient dc gain is an alternative that should also be considered.

Logic Family

Since this equipment will be powered by solar cells, every attempt should be made to minimize the dc power requirements. It is worth examining the existing synchronous detector, reference generator, and motor control circuitry to see if CMOS technology has any advantages over the low-power Schottky technology used in the 225 GHz radiometer. The two schemes should be evaluated on the basis of power consumption, temperature stability, and lightening-induced overvoltage sensitivity.

Computer and Interface

The VLBA Monitor and Control card used in the 225 GHz system should be replaced with a commercial unit. Several vendors now supply compact interface modules or cards that link directly to laptop computers. Vendors also supply software modules to aid in the programming effort. Furthermore, a small internal computer, used in place of the external unit, should also be considered.

Cost Estimate

At least six months of both engineering and technician time will be required for the design, fabrication, and evaluation of this project. The cost of materials is summarized below:

Description	Est. Cost	Notes
Martin-Puplett Diplexer	$ 4,000	NRAO or Commercial
Lenses (2)	$ 1,000	NRAO
Calibration Loads	$ 200	NRAO and Commercial
Planar Diode Mixer	$ 5,000	NRAO and UVa
Complete LO System	$ 40,000	NRAO and Commercial
Low Noise Amp, 1-2 GHz	$ 1,000	Commercial
IF Amplifier, 1-2 GHz	$ 400	Commercial
Filter, 1-2 GHz Bandpass	$ 200	Commercial
Square-Law Detector	$ 200	NRAO
Computer	$ 3,000	Commercial
All Other Components	$ 5,000	NRAO and Commercial
TOTAL	$ 60,000	

Acknowledgements

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References

[1] Liu, Zhong-Yi. "225 GHz Atmospheric Receiver - Users Manual," *NRAO Electronics Division Internal Report*, No. 271, August 1987.

[2] Zimmermann, Peter, Ralph, and Rudiger. "All Solid-State Radiometers for Environmental Studies to 700 GHz," *Third International Symposium on Space Terahertz Technology*, Ann Arbor, MI", March, 1992, pp. 706-723.

[3] Hesler, J., T. Crowe, R. Bradley, S-K Pan, and G. Chattopadhyay. "The Design, Construction and Evaluation of a 585 GHz Planar Schottky Mixer," *Sixth International Symposium on Space THz Technology*," Pasadena, CA, March 1995, (to be published).

[4] Weinreb, S. "Square-Law Detector Tests," *NRAO Electronics Division Internal Report*, No. 214, May 1981.

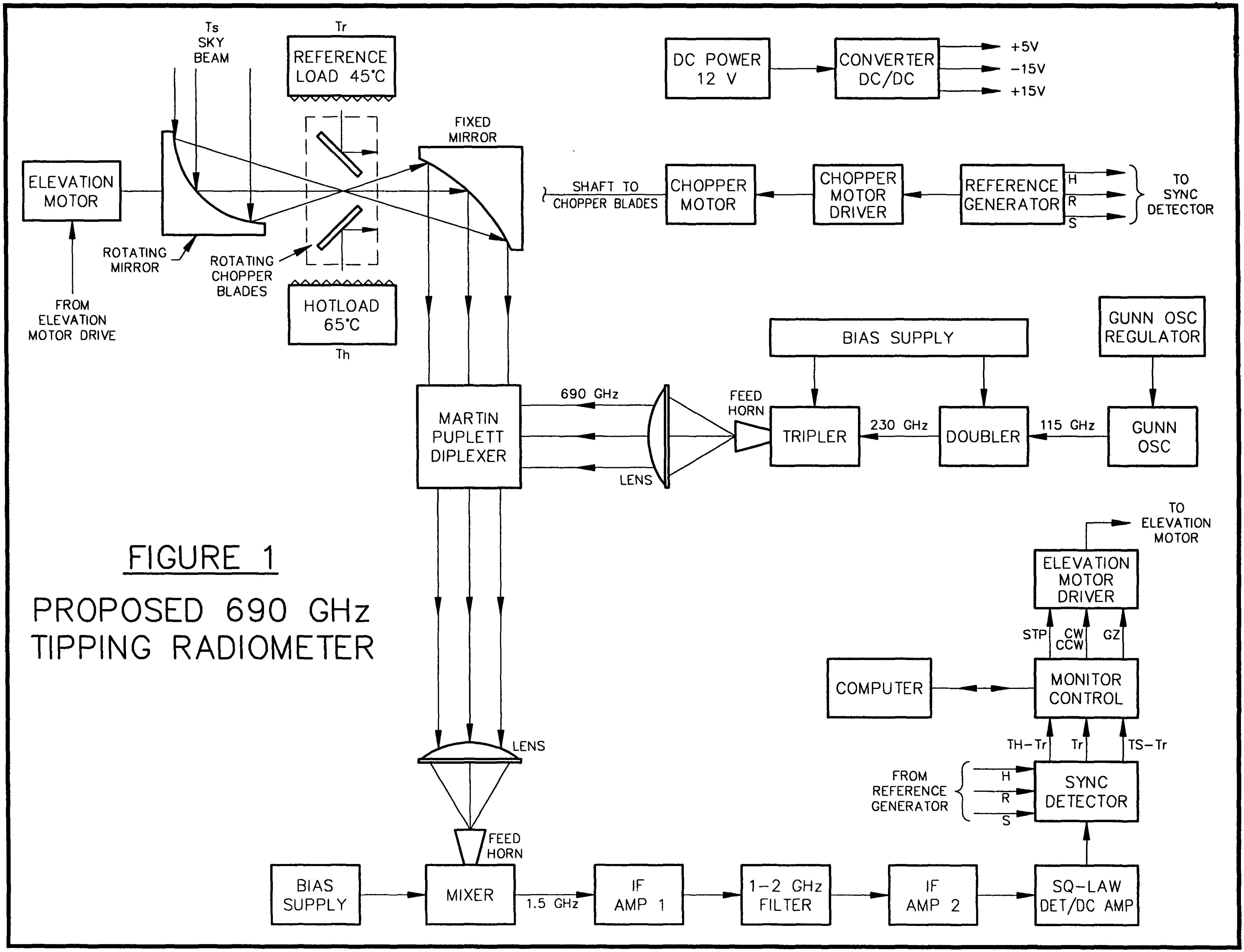

FIGURE 1

PROPOSED 690 GHz TIPPING RADIOMETER

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