Development of Sources and Receivers to Cover 1.25-1.51 THz

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Abstract— **This article describes the development of test instrumentation and a source covering the 1.25-1.51 THz frequency range. The instrumentation being developed includes a WM-164 (1.1-1.7 THz) waveguide interface, a 30 uW source, a heterodyne receiver, and a diagonal horn.**

I. Introduction

The Atacama Large Millimeter/Submillimeter Array (ALMA) covers the atmospheric windows from 84 GHz to 950 GHz (see Fig. 1) in a series of discrete bands. For example, the highest frequency band is Band 10, which covers 787-950 GHz. In recent years there has been discussion of a possible extension of the ALMA telescopes to above 1 THz [1]. Fig. 1 shows the predicted atmospheric transmittance on a dry day at the ALMA site, and shows two windows between roughly 1.25 THz and 1.55 THz [2]. Although the transmittance is relatively low, these windows do offer the opportunity to observe above 1 THz at the Atacama site.

The article will describe the development of sources and test instrumentation to cover these THz atmospheric windows. First the development of a waveguide interface in the 1.1-1.7 THz band will be described. Next, initial work on a room temperature heterodyne receiver covering the 1.1-1.5 THz range will be described. Finally, the development of a room temperature source to cover 1.25-1.51 THz with 30 uW of output power will be described.

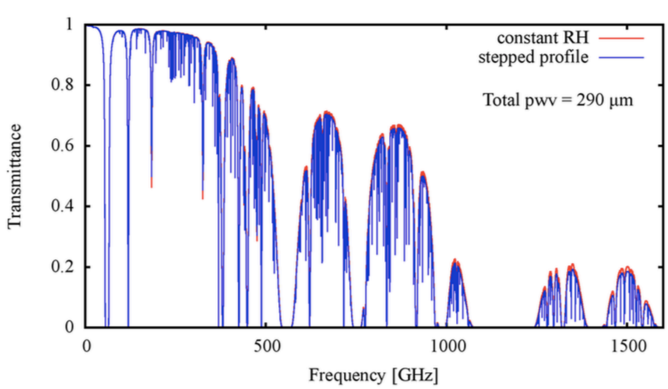

Fig. 1. Predicted atmospheric transmittance for the ALMA site under dry conditions [2].

II. WM-164 (WR-0.65) Waveguide Interface

The highest frequency waveguide interface currently in use at Virginia Diodes Inc. (VDI) is WM-250 (WR-1.0), covering 750-1100 GHz, and with a waveguide size of 250x125 um. Above this band VDI has used integrated diagonal horns at the output of components such as multipliers and mixers. However, for general laboratory measurements it is desirable to use a waveguide interface, which allows greater measurement flexibility. For example, waveguide-based directional couplers can be used, thus allowing for accurately calibrated measurements. Because of the success of the WM-250 waveguide interface it is believed that this basic interface technology can be extended above 1 THz.

The WM-164 (WR-0.65) waveguide band, covering 1.1-1.7 THz, has a waveguide size of 164x82 um. Given such a small waveguide size careful alignment is required to connect the waveguides while achieving low interface reflections. The IEEE P1785 workgroup [3] has been working on a new waveguide interface standard entitled "IEEE Standard for Rectangular Metallic Waveguides and Their Interfaces for Frequencies of 110 GHz and Above." Part 2 of the standard, titled "Waveguide Interfaces," focuses on an improved waveguide interface.

Fig. 2 shows a diagonal feedhorn at WM-164 with a waveguide interface, and Fig. 3 shows a detailed drawing of the waveguide interface. This VDI WM-164 interface is compatible with the IEEE standard, although it differs slightly in having a smaller diameter for the outer slip fit "S" holes. The waveguide interface has two alignment mechanisms being considered for use. The first alignment mechanism is the "Precision Dowel" method (IEEE 1785-2a) that uses the inner "K" holes and two differently sized dowels. The second is the "Ring-Centered" method (IEEE 1785-2b) that uses a ring to align the alignment mechanism on the central boss. The details of these alignment mechanisms are described in Part 2 of the IEEE standard that has been sent to the IEEE Standards Associations for final vote and is expected to be published during this coming year.

The "Precison Dowel" method has a predicted worst case reflection coefficient of -12 dB over the WM-164 band, and the "Ring-Centered" method has a predicted worst case reflection coefficient of -16 dB. In either case the reflection coefficient is low enough that it will have minimal impact on the system performance. Experiments will be performed with both alignment methods in order to determine which gives the best performance over repeated connections.

The WM-164 horns are being manufactured now, and testing will begin once the WM-164 triplers (see Section IV) have also been completed.

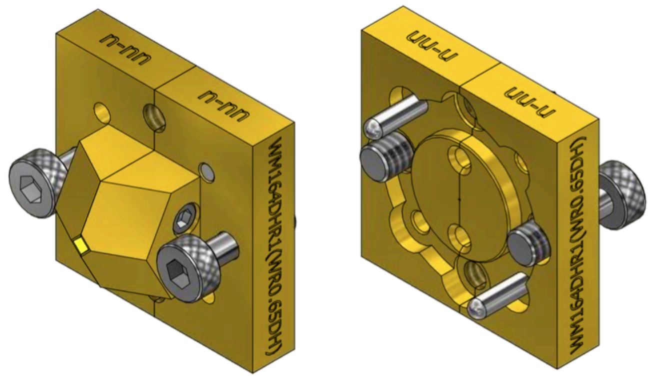

Fig. 2. Two views of the WM-164 diagonal horn with high precision waveguide interface. The left view shows the output aperture of the 25 dB gain diagonal horn, and the right view shows the high precision interface.

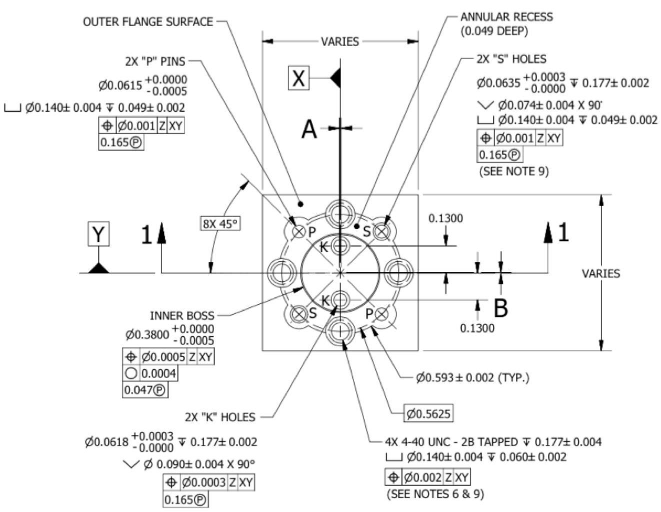

Fig. 3. Schematic of the VDI High Precision waveguide interface for use at WM-164.

III. WM-164 RECEIVER DEVELOPMENT

For astronomical observations on the ALMA telescopes the highest possible sensitivity receivers are required, and so liquid Helium-cooled mixers will be used for observing. However, for laboratory development of the receiver cartridges and quasi-optics the ability to use an ambient receiver can save a great amount of time and expense. In order to fulfil this need a Schottky-diode based receiver system that operates at ambient is being developed. The initial goal is for the receiver to cover the frequency range from 1.1-1.55 THz.

The heart of the receiver consists of the WM-164X3SHM tripler-mixer, a schematic of which is shown in Fig. 4. This component consists of a wideband tripler followed by a fullband subharmonic mixer. The WM-164X3SHM will require an input power of roughly 20 mW from 183-258 GHz to fully pump the mixer. In order to generate this power a standard VDI source (output power 1-2 mW) will be used to drive an amplifier covering the 183-258 GHz range with output power in the 30-50 mW range [4]. Initial testing of a prototype local oscillator chain yielded 0.3-0.9 mW from 500-700 GHz. Work is underway on the packaging of the MMIC chip to improve the high end performance and extend the upper frequency to 750 GHz.

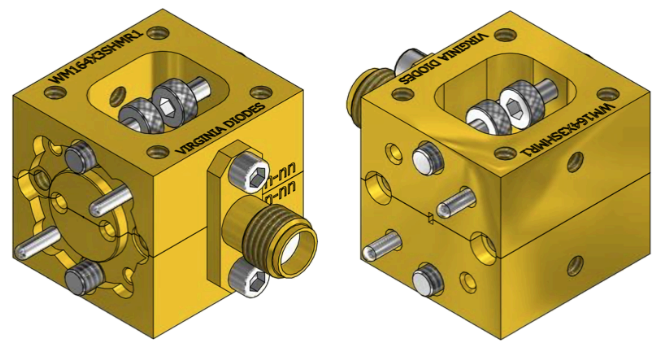

Fig. 4. Two views of the WM-164X3SHM, which consists of a broadband tripler followed by a full-band subharmonic mixer. The left view shows the WM-164 high precision waveguide interface, and the right view shows the input waveguide at WR-4.5.

IV. 1.25-1.51 THZ SOURCE DEVELOPMENT

A source covering 1.25-1.51 THz is being developed both for use as a local oscillator drive for the SIS receiver, and also as a test source for general laboratory development and testing. The goal is to obtain greater than 30 uW over the band 1.25-1.51 THz. An earlier version of the source is pictured in Fig. 5. Two varactor multiplier chains are used to drive the source, one covering 138.9-157.8 GHz and the other covering162.2-167.8 GHz. The gap between the two sources is placed so that it is coincident with the water absorption line centered at ~1.44 THz, as shown in Fig. 1. A waveguide diplexer is then used to combine the two signals into a signal waveguide that feeds a cascade of two broadband triplers with output from 1.25-1.51 THz. This earlier version of source covers the correct band, but with an output power of only 10-30 uW.

In order to increase the output power the varactor multipliers are being redesigned to improve thermal grounding and also two-way power combining has been added. The other bottleneck in the system is the final THz tripler, which was significantly compressed for the system pictured in Fig. 5. A power combined version of the THz tripler has been designed and is now being manufactured. With these improvements it is believed that greater than 30 uW of output power can be achieved over the full frequency range.

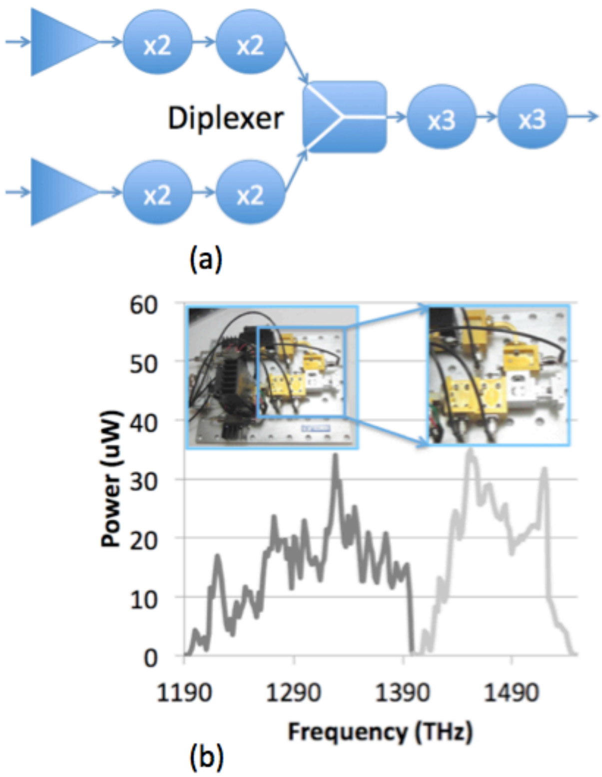

Fig. 5. (a) Basic architecture of 1.25-1.51 THz Source and (b) measured output power from a previous prototype of the source, showing the two varactor chains combined using the waveguide diplexer.

V. Conclusions

Initial developments of test instrumentation covering the 1.25-1.51 THz range have been presented. Measurements on the final systems will be presented at the conference.

Acknowledgment

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