Cross-polarization characterization of GORE–TEX© at ALMA band 9 frequencies

M. Candotti*, A. M. Baryshev†, N. A. Trappe*, R. Hesper †, J. A. Murphy*, J. Barkhof†.

*Experimental Physics Departement
National University of Ireland
Maynooth, Co. Kildare, (Ireland)
email: Massimo.Candotti@nuim.ie

†Netherlands Institute for Space Research
and Kapteyn Astronomical Institute
9700-AV Groningen, (The Netherlands)
email: A.M.Baryshev@sron.rug.nl

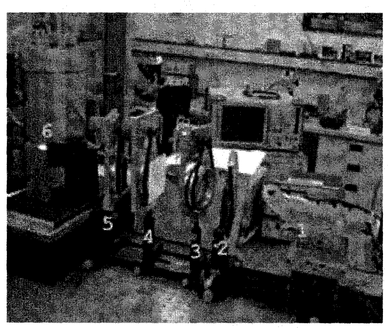
***Abstract*— GORE–TEX© material, commonly used in radomes, is known to be transparent at microwave bands. In ALMA a thin GORE–TEX membrane will cover the aperture through which the RF beam enters the cabin at the primary vertex hole. Slabs of GORE–TEX© are also generally employed in windows for intermediate temperature shields inside the cryostat. The purpose of these windows ideally is to allow the beam to pass through them without introducing any alteration to the beam properties. The main concern is RF loss, but also cross-polarization efficiency degradation. This paper will concentrate on the results we have obtained for ALMA band 9 (602-720 GHz), in relation of loss of cross-polarization efficiency of a linearly polarized beam passing through a GORE–TEX© slab, depending on its orientation relative to the direction of polarization of the beam. In order to spot anisotropic behavior of the material under test, an ad hoc measurements set-up has been used. Systematic measurements of cross-polarization properties for different thicknesses of GORE–TEX© slabs were undertaken. Cross-polarization information is given in relation of the relative angle between the incident beam polarization and the material under test.**

I. Introduction

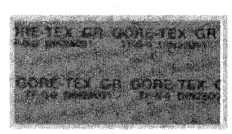
For the band 9 cryogenic receiver GORE–TEX[1] slabs are used at the windows of 12 and $90K$ intermediate shield temperature cryostat stages. During a cross-polarization measurement campaign of the two beam polarizations of the band 9 receiver, we noticed poor cross-polar efficiency performance of the system. After some trouble identifying the cause it remained to verify the transparency of the GORE–TEX windows. It became apparent that the slab of GORE–TEX was inducing extra cross-polarization levels accordingly to its relative orientation with the signal polarization passing through it. Further systematic analysis confirmed this indicating an anisotropic behavior of the GORE–TEX material. The aim of this paper is to report the cross-polar measurements we have taken on various samples of GORE–TEX slabs. In section II we give a brief description of the measurement set-up and the kind of measurement techniques we adopted in order to show the initial hypothesis. Section III shows the results obtained followed by conclusions.

II. Measurement set-up

In order to characterise various thicknesses of GORE–TEX samples we assembled an ad hoc measurement bench set-up. The system is depicted in figure 1 (a) including the numbering of the items that compose it. The system can allow total power measurement of a submillimeter signal using a computer controlled broadband source ($600 - 700\ GHz$) (item #1) and a cryogenic high sensitivity bolometer (item #6). The submillimeter signal is obtained from a Gunn diode at 100 GHz and further multiplied times 6 by a $x2$ and $x3$ multiplier. The output of the source is propagated to the free space by



(a) Measurement Set-up.



(b) GORE–TEX sample.

Fig. 1. Measurement set-up for the characterization of GORE–TEX slabs and GORE–TEX sample.

[1]GORE–TEX GR© sheet gasketing, according DIN 28091, TF-0-0.

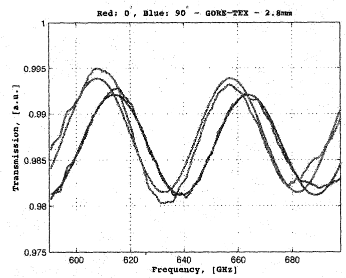


Fig. 2. Transmission for a 2.8 mm GORE–TEX slab rotated at 0° and 90° at band 9 frequencies.

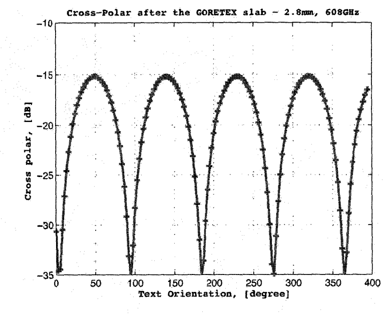
mean of a diagonal horn. A plano-convex Teflon lens (item #2) is used to refocus the beam power along the other system components and finally at the bolometer aperture. In order to obtain a pure linearly polirised signal at the Sample Under Test (SUT) (item #4) a rotatable wire grid is located between the SUT and the lens. A second wired grid between the SUT and the bolometer is used to allow power detection of the co- or cross-polar polarization of the SUT transmitted signal. The standing wave phenomena occurring along the chain set-up was minimised by using Ecosorb sheets and rotating items $2, 3, 4, 5$ in such a way the standing waves couldn't form. The SUT is mounted on a computer controlled rotational support. Grids #5 and #3 were manually rotated in order to ensure the measurement of only co- or cross- polar signal at the bolometer. The system as it is can be used for SUT power transmission measurements sweeping the source frequency and co- and cross-polarization power signal measurements of the transmitted signal at different rotation angles of the SUT. The aim of the first kind of measurement is to show at which frequencies the SUT is transparent. If this measurement procedure is taken for the two principal axis directions of the SUT than we can highlight the possible anisotropic properties. The second measurement procedure is performed at a fixed frequency but with the SUT rotating around the axis normal to the SUT surface. By measuring co- and cross-polar power versus the rotation angle of the SUT it is possible to show the level of cross-polarization introduced by the SUT at different relative orientation angles in relation with the source linear polarization direction.

III. Results

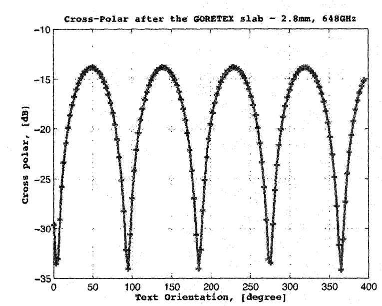
It has been noticed that by rotating the sample of GORE–TEX around the normal at the surface of the sample, different levels of power were recorded when the system of figure 1 (a) was tuned to a fixed polarization direction. This suggests that there is a material anisotropic behavior. It has also been noticed that there is a direction of preference of the sample rotation. When the text on the sample (figure 1 (b)) is aligned or at 90° with the polarization of the incident beam we have a peak in the transmitted signal. Thus in the following pictures the 0 in the abscissa axis will refer to co-alignment of the text with the polarization of the incident signal.

A. Transmission

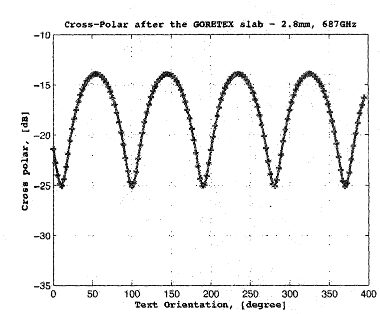
The aim of this measurement is to show possible differences in the refractive index along the two main axis directions of the sample (along and at 90° of the text direction). As an example a slab of 2.8 mm was tested sweeping the frequency source from 590 GHz to 700 GHz. Figure 2 shows the transmission varying with frequency and also with the sample text rotation, indicating a different refraction index along these directions. For the purpose of finding the peaks of transmission a sine curve was fitted to the data. At these peaks (607.7 and 657.4 GHz for 0° – 614.0 and 663.8 GHz for 90°)



(a) 608 GHz.

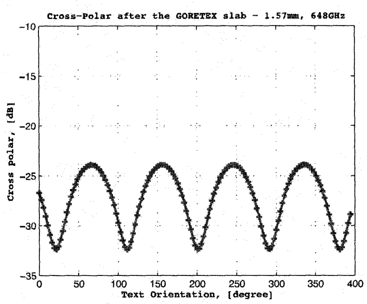


(b) 648 GHz.

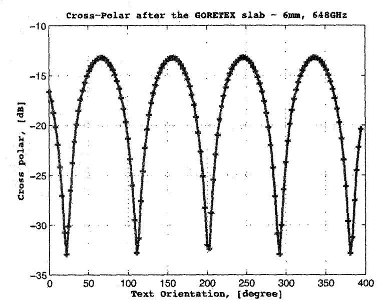


(c) 687 GHz.

Fig. 3. Cross-polarization introduced by a 2.8 mm slab of GORE–TEX at various frequencies.



(a) 1.57 mm.



(b) 6 mm.

Fig. 4. Cross-polarization introduced by 1.57 mm and 6 mm slabs of GORE–TEX at 648 GHz.

the refractive index n, can be evaluated from the expression that gives the phase delay inside the slab of thickness d: $\phi = 2\pi dn/\lambda_0$ [3]. At peak locations the phase delay is an integer multiple of π. Solving this expression for two frequencies of maximum transmission we found a refractive index of 1.0587 at 0° and 1.048 at 90°. This preliminary result shows the anisotropy of GORE–TEX and brought us to investigate the cross-polarization properties of this material.

B. Cross-Polarization

We than acquired more data for different thicknesses and at different frequencies in order to find out how the transmitted cross-polar level was affected by the SUT at different rotation angles with respect to the incident polarization signal. We first considered the sample of 2.8 mm at three frequencies (608, 648 and 687 GHz). In figure 3 we observe that indeed the GORE–TEX slab introduces cross-polarization. The lowest peaks (no cross-polar introduced) coincide with the direction of the text on the slab surface and its orthogonal direction. At 45° and at 90° spaced multiples we notice a level of cross-polar introduced by the SUT of $-14\ dB$ at highest frequencies. Other two different sample thicknesses were tested, 1.57 mm and 6 mm. As expected for a thinner slab the cross-polarization introduced is lower compared with the 2.8 mm previous case. For a slab of 6 mm the extra cross-polarization does not appear to increase much more because of twice the thickness, in fact at 45° the level is at $-13dB$ for the frequency of 648 GHz.

Another interesting experiment was to measure the cross-polarization of a pair of same thickness sheet samples (2.8 mm) facing each other at 90°. Since the predominant orientation of the polymer chains in the GORE-TEX slab develops anisotropy (i.e. birefringence), it has two different dielectric constants for two different orthogonal axes inducing elliptical polarization. It is known that elliptical polarization can be converted back to linear by the same slab of material rotated 90° [4]. Figure 5 shows the results of this experiment. Indeed we observe a cancellation of the cross-polarization effect, leading to a low level flattered cross-polarization response.

IV. Conclusions

In this paper we have shown the cross-polarization effect introduced by a slab of GORE–TEX of different thicknesses at the frequencies of ALMA band 9. We have pointed out that there is a dependence on the rotation of the sample in relation to the incident signal linear polarization. In particular it looks that due to fabrication procedures, there are two preferred directions of minimum cross-polarization effect: along and normal to the text on the GORE–TEX sheets. At 45° it has been shown that there is indeed a high cross-polarization effect scattering co-polar power to the cross-polar component of the transmitted signal up to $-13dB$ of cross-polarization efficiency for a thickness of 6 mm. A further experiment having two identical slab samples of 2.8 mm thickness orthogonally faced has demonstrated that the cross-polarization effect induced by the first slab can be cancelled by the second one.

Despite the qualitative work carried out in this paper we suggest that further tests must be carried out on more samples, as well as on different kind of materials, even at different ALMA bands where cross-polarization is a concern.

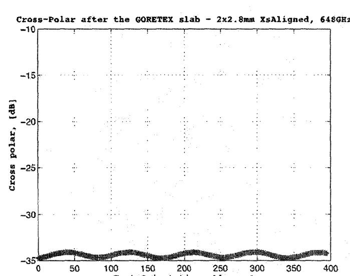


Fig. 5. Cross-polarization introduced by a pair of same thickness sheet samples (2.8 mm) facing each other at 90°. $f = 648\ GHz$.

References

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