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Design and Simulation of a Waveguide Load for ALMA-band 9

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1 Introduction

An important element of any waveguide-based dispositive is the termination or load. At relatively large wavelengths the idea is to make them as compact as possible and usually contained inside of the waveguide. However, as the working frequency increases, the involved dimensions make more difficult such approach. In this memo, we describe a relatively simple waveguide load which is appropriate when the waveguide dimensions are prohibitory small. The load described here is rather large compared with the waveguide making it relatively easy to realize at small dimensions. Moreover, from the results of a simulation it is shown that besides its simplicity it can have a reflectivity as low as -40 dB if the appropriate material is used.

2 Load Design

The proposed load consists of a cavity at the end of the waveguide and which is partially filled with an absorbing material. This design is depicted in Fig. 1 where the space filled with the absorbing material is represented by gray lines. This geometry should be relatively easy to make as the the largest dimensions are designed to be parallel to the splitting plane of the block. Moreover, the dimensions of the load itself are suitable to be machined by conventional means.

3 Load Material

Unfortunately, there are few known materials that can be used as absorbers in the frequency range corresponding to ALMA-band 9. One candidate is the commercially sold epoxy MF112 [1, 2]. Although, to our knowledge, it has not been completely characterized in this frequency range, there are several studies

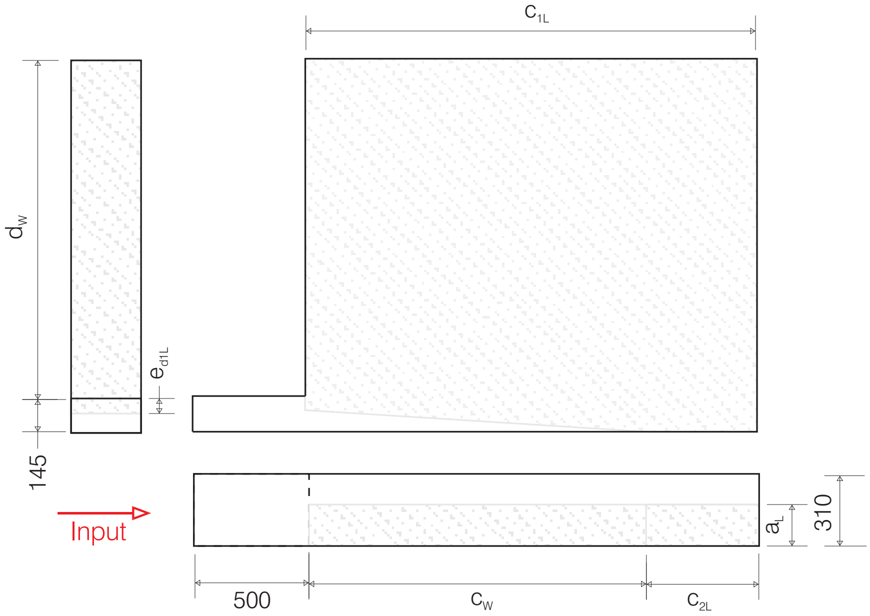

Figure 1: Proposed design for a waveguide load (all dimensions are in μm). At the end of the waveguide, a large cavity is built which is partially filled with an absorbing material (gray lines). The dimensions of the waveguide are intended to be used in the frequency range corresponding to ALMA-band 9. The figure also shows the parameters that have been changed during the simulations.

of its transmittance [1]. For the present study, we have attempted to obtain the dielectric function, $\epsilon = \epsilon' + i\epsilon''$, from such measurements. The procedure has been to fit the measured transmittance with a Lorentz oscillator through the well known Fresnel equations (for details in the procedure see, e.g., Ref. [3]). The results are summarized in Fig. 2 and Table 1. We have to mention that with this procedure, ϵ'' can be determined rather accurately but ϵ' can have rather large error bars. A complete characterization of the material is, therefore, needed.

Table 1: Parameters of the Lorentz oscillator used to simulate the transmission data of Ref. [1] as shown in Fig 1

ϵ_{inf} -	ω_o GHz	ω_p GHz	γ GHz
4.2	15300	14220	207900

4 Simulation Results

The one-port system depicted in Fig. 1 was simulated in CST Microwave Studio [4] with the load material simulated using the parameters given in Table 1. Figure 3 shows the results of the simulation when the length of the load cavity, c_W, is changed. In the simulation we have kept the cavity width, d_W, equal to its length and the dimensions c_{2L} and e_{d1L} equal to zero. Moreover, the height of the load, a_L, is set to 310 μm. The results indicate that S_{11} can be minimized if $c_W = d_W = 1500$ μm. This is not an artifact coming from the the particularly chosen length of the waveguide (500 μm) since simulations with different lengths gave the same result.

With $c_W = d_W = 1500$ μm, we have also investigated if adding some extra material (parameterized by the length c_{2L}) can further improve the situation described above. The results (Fig. 4) show that although S_{11} does not further decrease, some standing waves are eliminated and the ripples in S_{11} are washed out with a relatively small extra quantity of material.

One advantage of the present design is its rather small sensitivity to air gaps. This has been simulated changing the height of the load, a_L. The results are presented in Fig. 5 where the space occupied by the absorbing material has been varied from half empty to completely filled.

Finally, a critical parameter in our design is the geometrical matching between the waveguide and the load material which is parameterized by e_{d1L}. The results summarized in Fig. 6 show the strong dependence of S_{11} with e_{d1L}. Even a small mismatch increases the reflectivity considerably. However, we believe that this type of error can be minimized with a careful mounting of the load material.

5 Conclusions

The present memo has described a relatively simple waveguide load which is appropriate when the dimensions of the waveguide become inconveniently small. A reflectivity of about -40 dB can be obtained with a suitable material which can be the commercially available MF112. Moreover, the present design is rather insensitive to air gaps that could appear when mounted in a split block. The present configuration is rather sensitive to a geometrical mismatch between the waveguide and the load, however this problem can be solved by a careful mounting of the load material.

References

[1] G. A. Ediss, A. R. Kerr, H. Moseley, and K. P. Stewart, "FTS Measurements of Eccosorb MF112 at Room Temperature and 5 K from 300 GHz to 2.4 THz", ALMA Memo 273, 2 September 1999.

[2] http://www.eccosorb.com/.

[3] F. P. Mena, PhD Thesis, University of Groningen (2004).

[4] http://www.sonnetusa.com/.

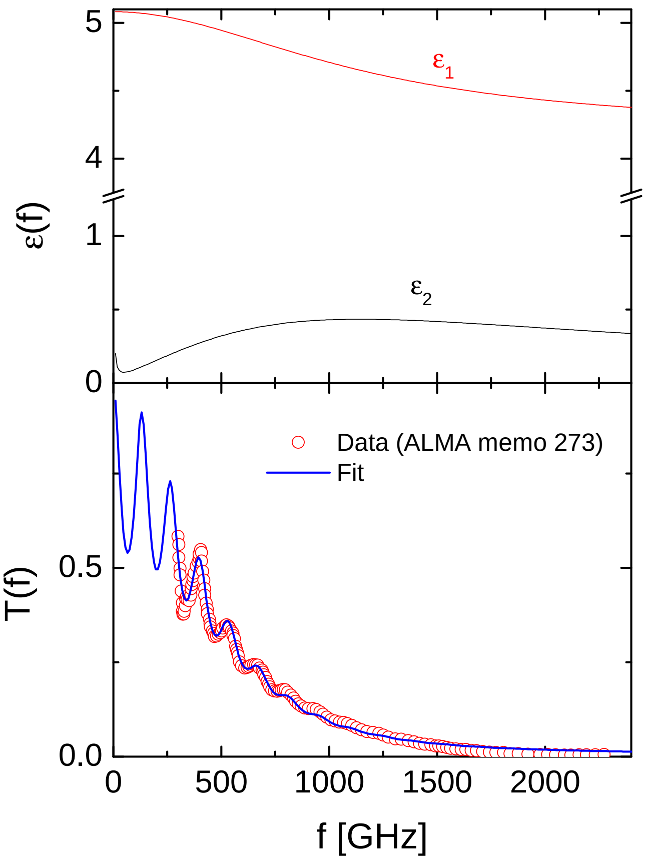

Figure 2: *Bottom panel:* Measured transmittance of MF112, together with the results of the fit. *Top panel:* Dielectric function of MF112, obtained via fitting, in the same frequency range.

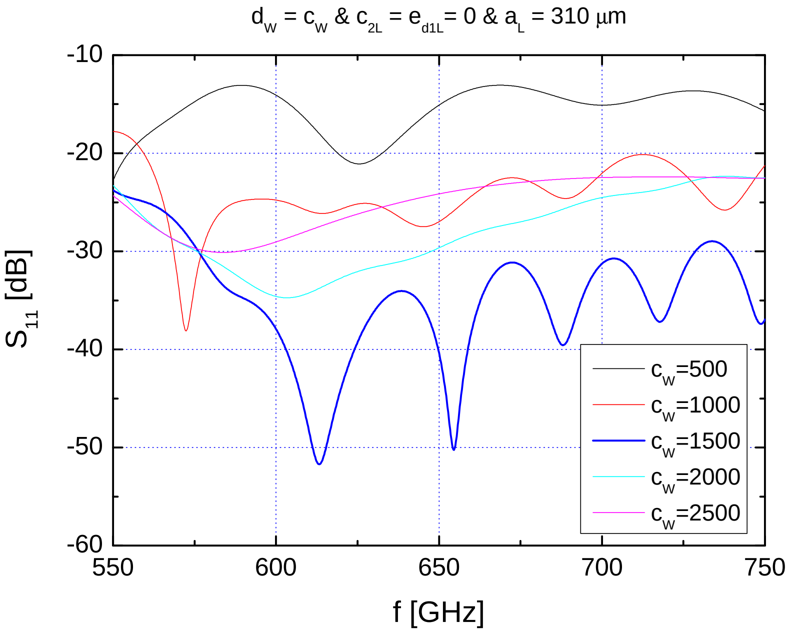

Figure 3: Resulting S_{11} coefficient when the dimension c_W is varied. In this simulation, we have set $c_{2L} = e_{d1L} = 0$ and $a_L = 310\mu$m.

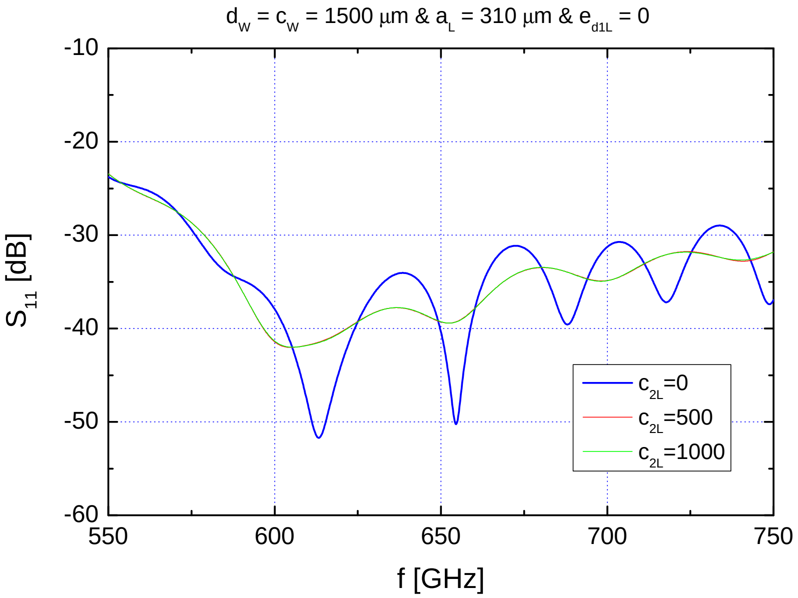

Figure 4: Resulting S_{11} parameter when the dimension c_{2L} is varied. The other parameters are set to $c_W = d_W = 1500$ μm, $e_{d1L} = 0$ and $a_L = 310\mu$m.

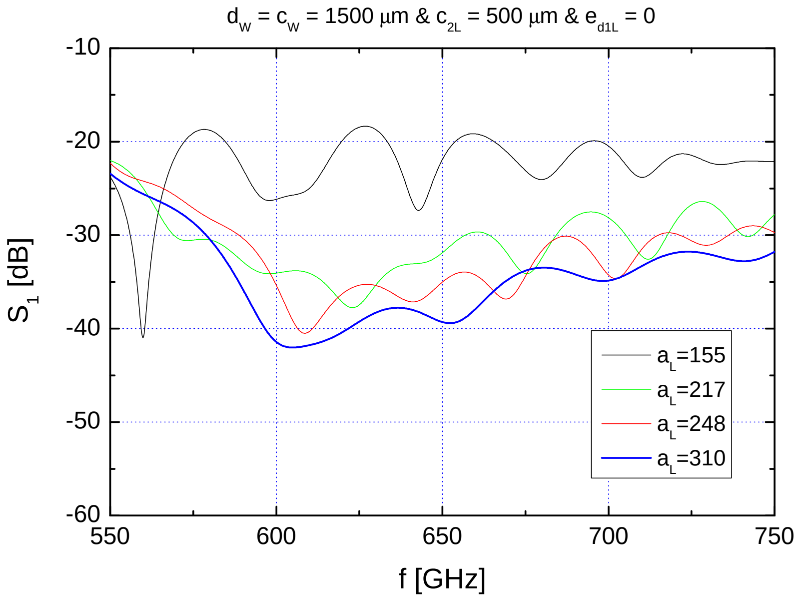

Figure 5: Resulting S_{11} coefficient when the dimension a_L is varied. The other parameters are set to $c_W = d_W = 1500$ μm, $c_{2L} = 500$, and $e_{d1L} = 0$. Similar results (not shown here) are obtained when $c_{2L} = 0$.

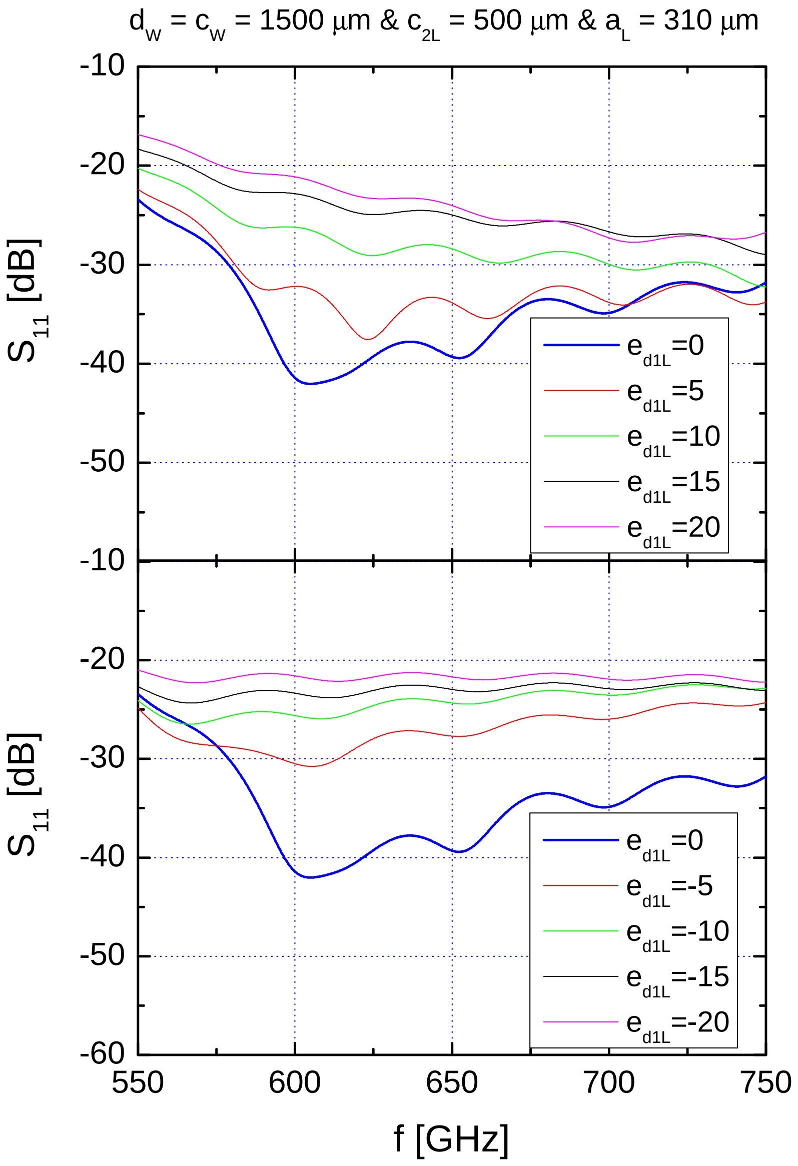

Figure 6: Resulting S_{11} coefficient when a geometrical mismatch is introduced (by varying e_{d1L}). The other parameters are set to $c_W = d_W = 1500$ μm, $c_{2L} = 500\mu$m, and $a_L = 310\mu$m.