Radomes at Submillimeter wavelengths: An open question

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Why we need a radome?

- Is not for bad weather conditions, since during rain or snow the antennas do not operate and (in ALMA) the antenna aperture is going to be closed with a metallic shutter.
- To seal the cabins to control temperature
- To give some protection (and keep clean) the warm optic and calibration devices

Some approaches

- Nothing: Expose the instruments to the environment. *-SMA(690GHz), CSO(665GHz)-*
- Closed cells foams (Zotefoam): *-SMT(500GHz)-*
- *Polymeric Films (FEP) – CARMA(345GHz)*
- Goretex: *-Apex(887GHz)-*
- Goretex?: *- ALMA-*

Requirements of a radome?

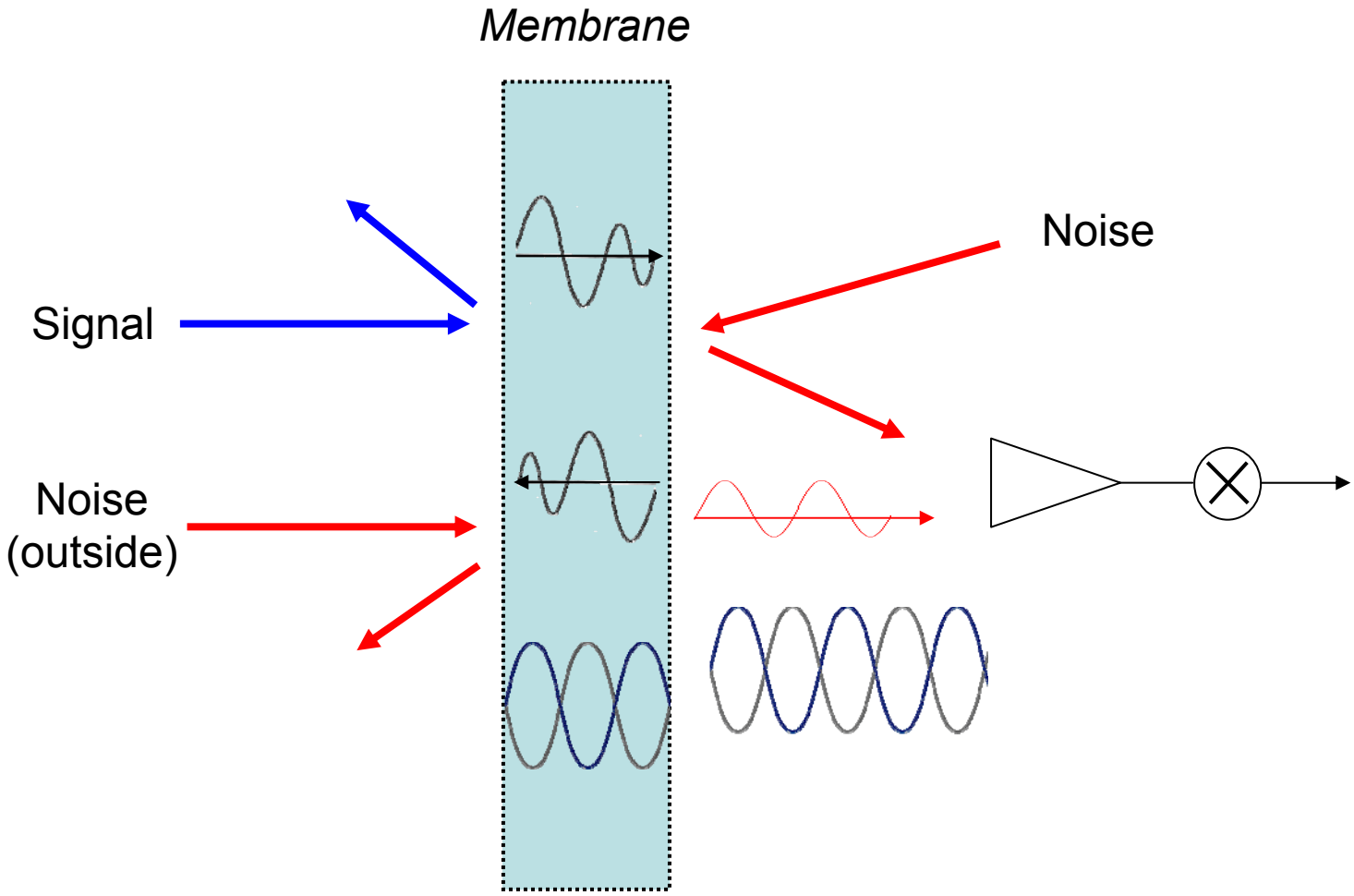
- Very low reflectivity (reflection is mostly to warm surfaces in space above the receivers)
  - Thickness below 5% wavelength, or
  - Thicker material but with very low dielectric constant and losses
- Small phase perturbation of the wavefront: a low thickness_variation*dielectric_constant
- Low thermal emission: Low loss
- Low cross polarization: very isotropic material.
- Very wide band performance (in ALMA 0-1THz)

ALMA Specs

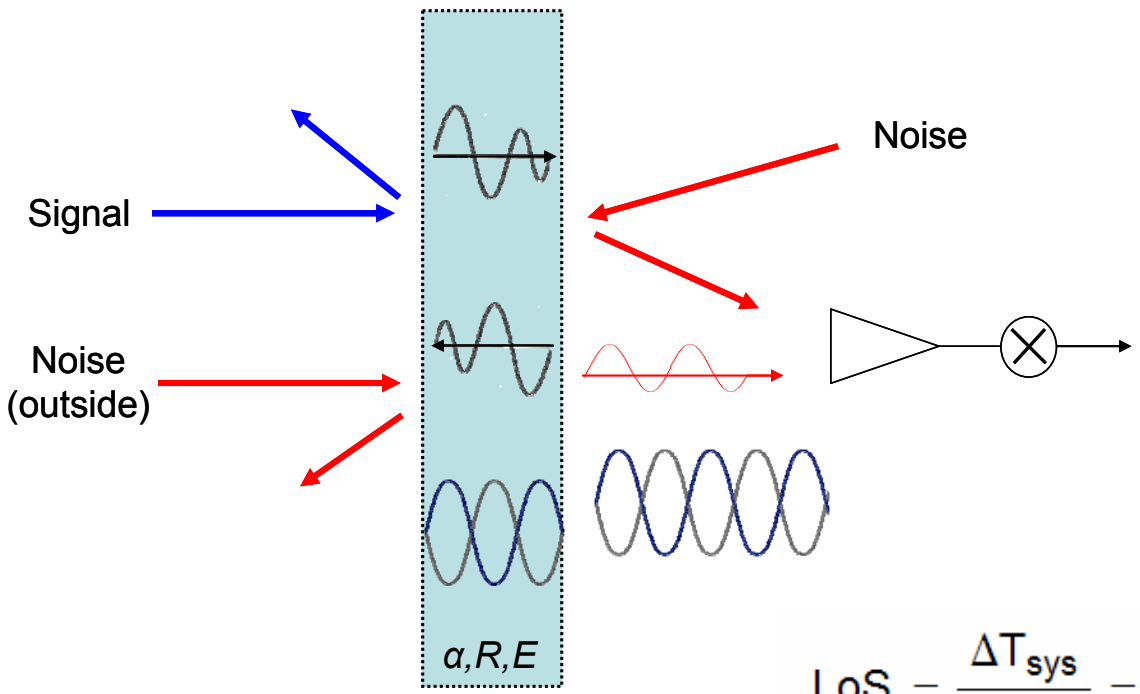
Table 1. Science Requirements for the ALMA RF Membrane

Requirement category	*Specification*
Overall Loss of Sensitivity	Must be no greater than 3% in any ALMA receiver band
Cross- Polarization introduced by membrane	Must be less than 0.1% in band 7, and no more than 0.3% in any other band.
Phase Loss	The rms perturbation to the wavefront passing through the membrane from any receiver feed should not exceed a differential path of 5 microns. As an example, if the refractive index of the material is 1.25, this implies a physical uniformity of thickness of the membrane of no worse than 40 microns.

What happens when you insert a membrane?



Overall Loss of Sensitivity



α,R,E : Transmission, Reflection and Emission power coefficients of the membrane (f)

T: Temperatures

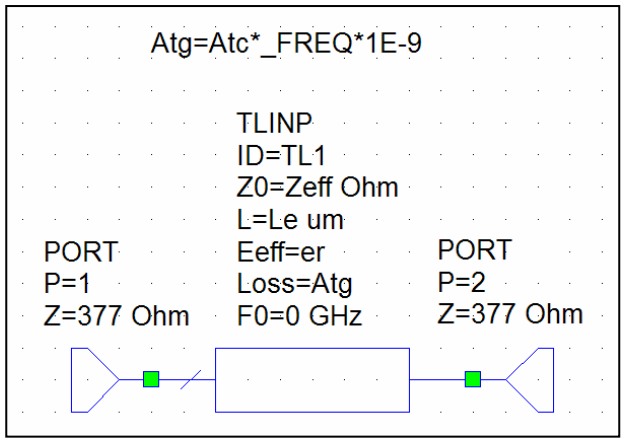
T_{sys_0} = T_{sys} without membrane

$$LoS = \frac{\Delta T_{sys}}{T_{sys\_0}} = \left[\frac{1-\alpha}{\alpha}\right]\frac{T_{rx}}{T_{sys\_0}} + \frac{1}{\alpha}\frac{T_{added}}{T_{sys\_0}}$$

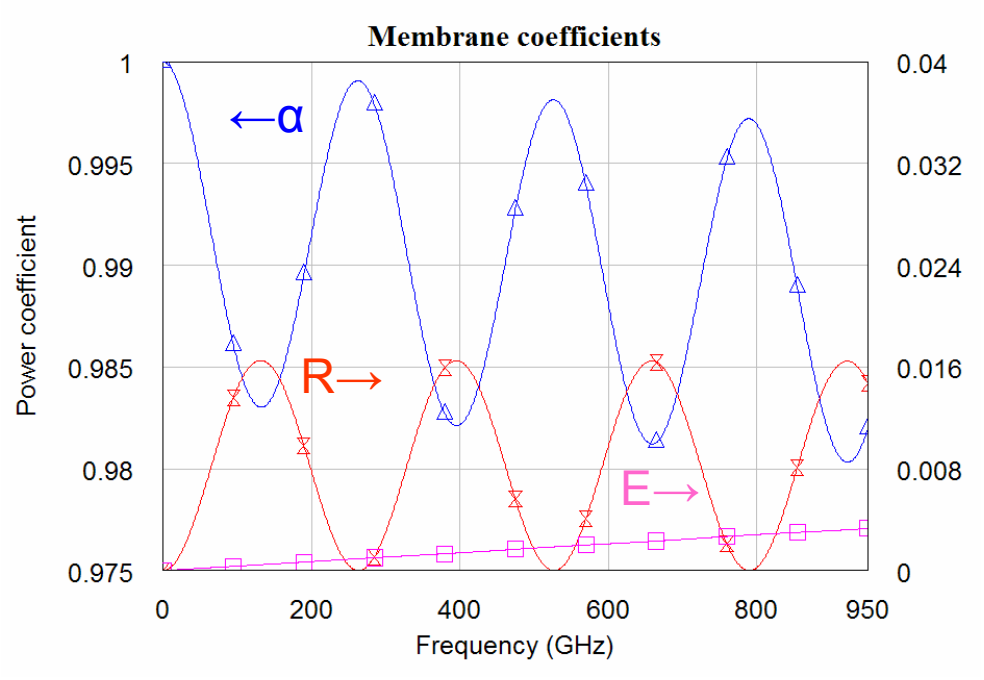
$$T_{added} = E\,T_{membrane} + R\left(\frac{3}{4}\,T_{cabin} + \frac{1}{4}\,\alpha\,T_{outside}\right)$$

(The ¾ and ¼ are guesses)

Membrane coefficients



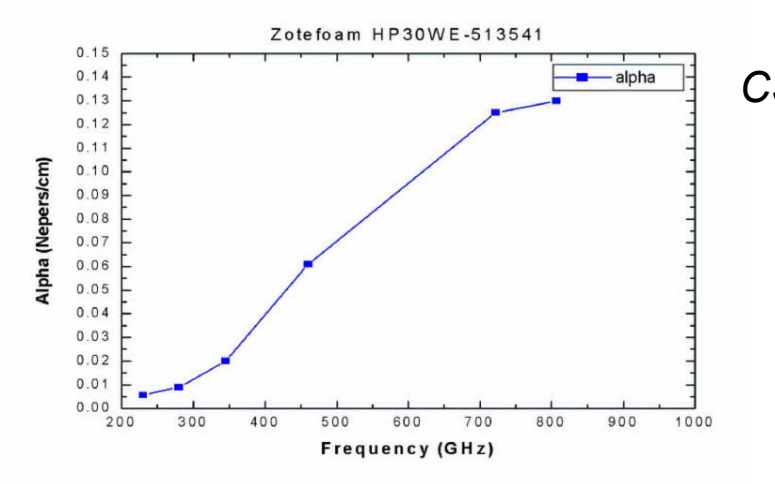
Transmission - Reflection - Emission



- Lossy line model with an attenuation constant linear with frequency
- The ports are at free space impedance and the line is at Zeff=377/sqrt(Er)

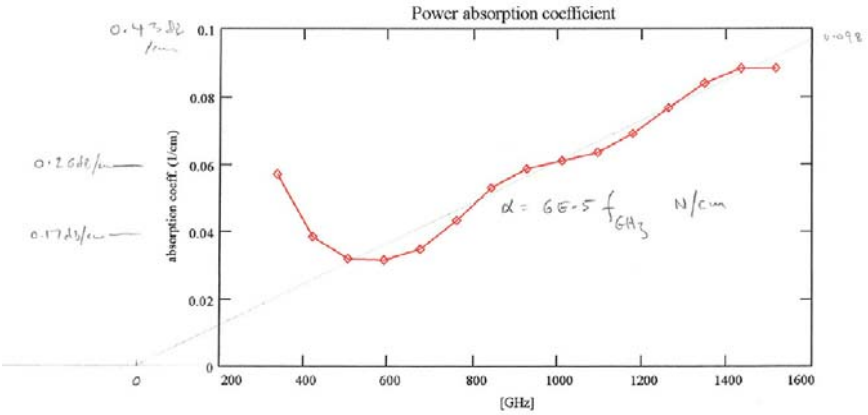
Material properties

Zotefoam

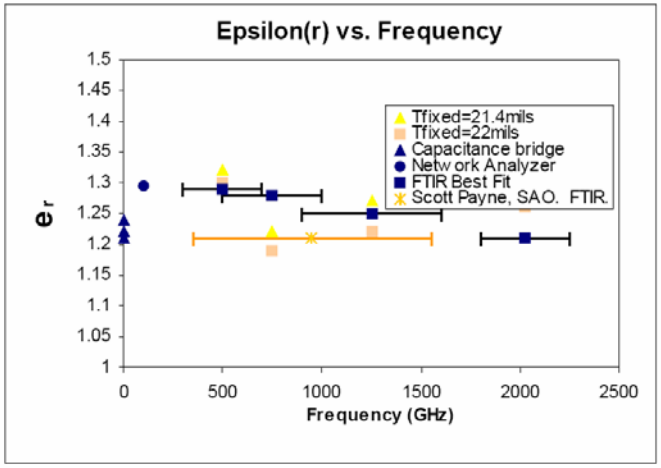


CSO: Jacob Kooi

Goretex



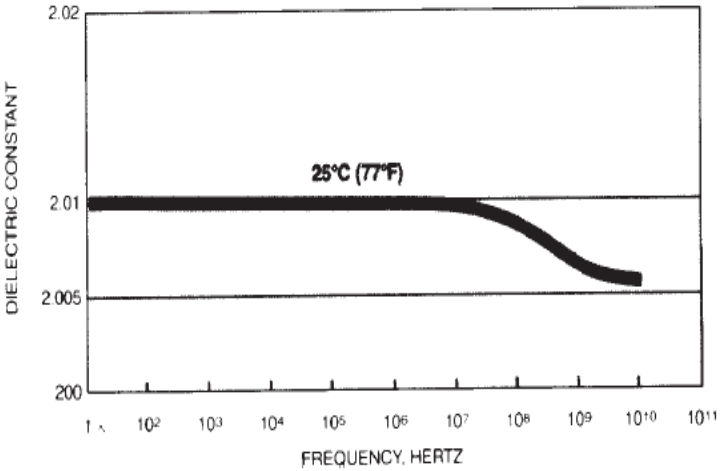
Smithsonian Astrophysical Observatory: Scott Paine

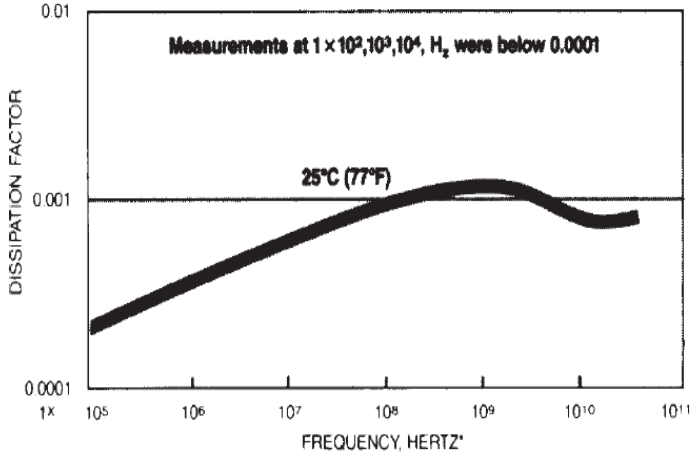


ALMA Memo 309: D.Kooller, G.A.Ediss, A.R.Kerr

Material properties

FEP





Dupont Films

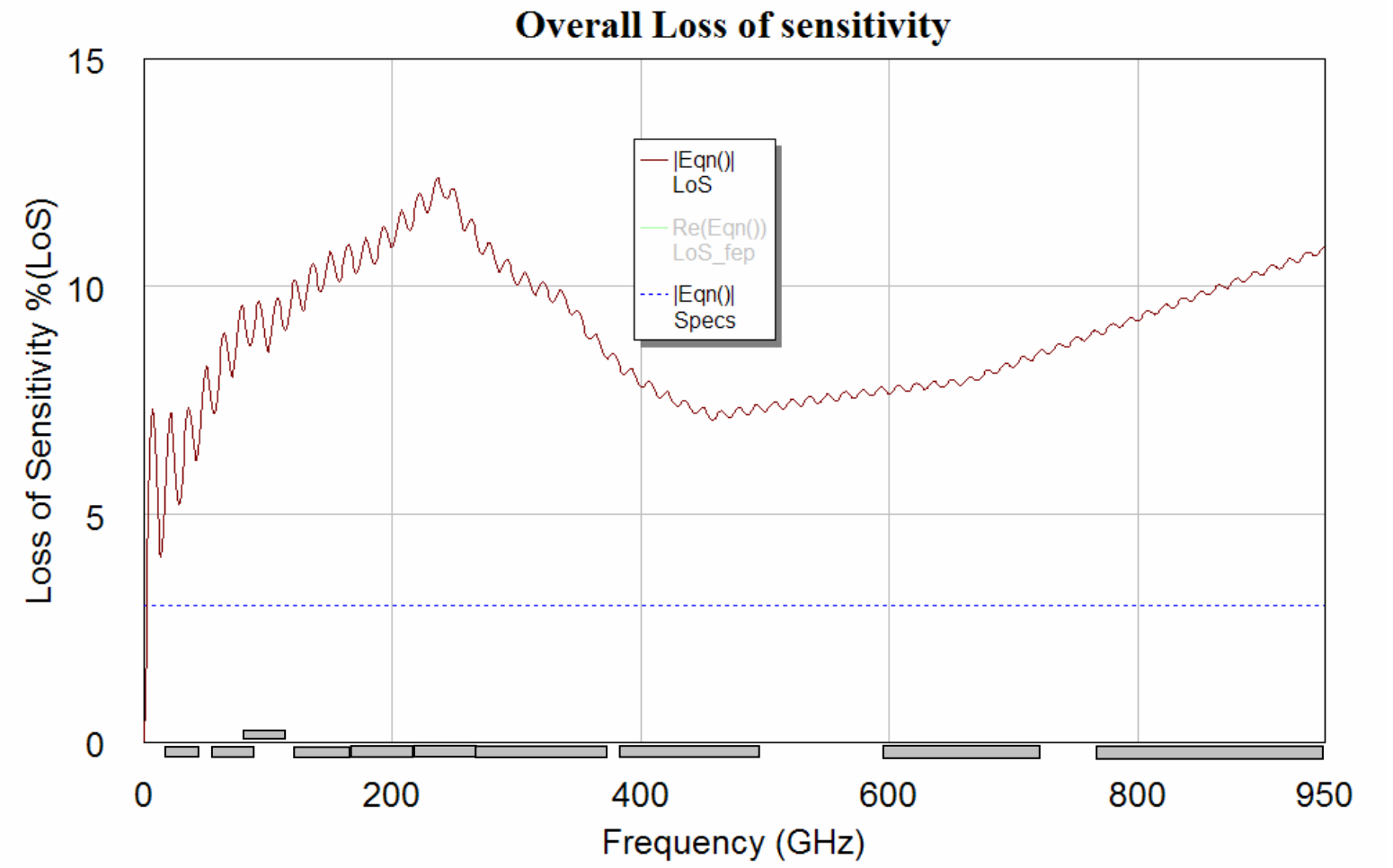
Why FEP?. What about Mylar?

Material properties

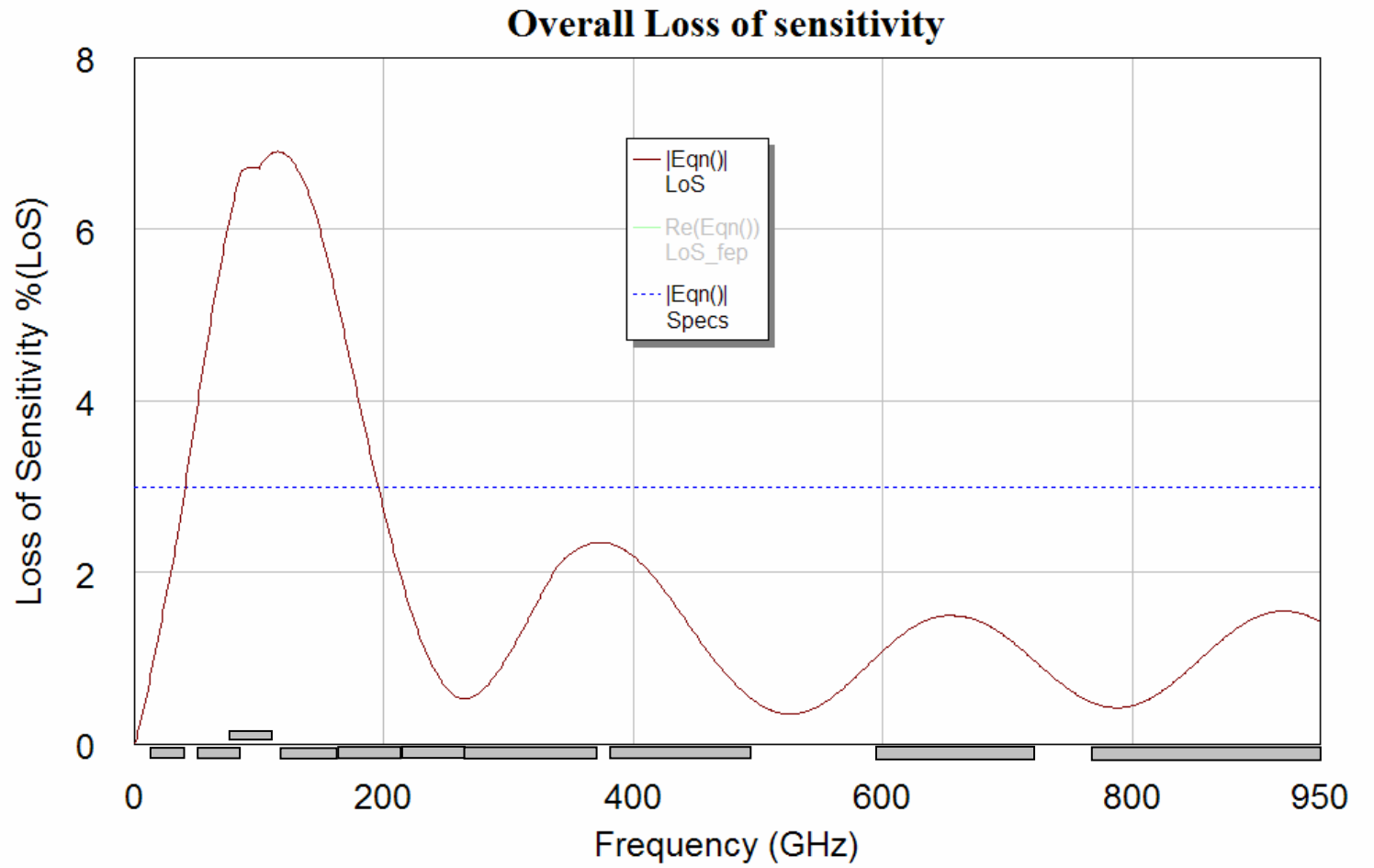
1	PHFPO	Poly(hexafluoropropylene oxide)	1.301
2		Alginic acid, sodium salt	1.3343
3		Hydroxypropyl cellulose	1.337
4		Poly(tetrafluoroethylene-co-hexafluoropropylene)	1.338
5	**FEP**	**Fluorinated Ethylene Propylene**	**1.338**
6		**Poly(pentadecafluorooctyl acrylate)**	**1.339**
7		**Poly(tetrafluoro-3-(heptafluoropropoxy)propyl acrylate)**	**1.346**
8		**Poly(tetrafluoro-3-(pentafluoroethoxy)propyl acrylate)**	**1.348**
9	PTFE	Poly(tetrafluoroethylene)	1.35
10	THV	Tetrafluoroethylene hexafluoropropylene vinylidene fluoride	1.35
11		Poly(undecafluorohexyl acrylate)	1.356
12	PFA	Perfluoroalkoxy	1.34
13	ETFE	Ethylene Tetrafluoroethylene	1.4
14		Poly(nonafluoropentyl acrylate)	1.36
15		Poly(tetrafluoro-3-(trifluoromethoxy)propyl acrylate)	1.36
16		Poly(pentafluorovinyl propionate)	1.364
17		Poly(heptafluorobutyl acrylate)	1.367
18		Poly(trifluorovinyl acetate)	1.375
19		Poly(octafluoropentyl acrylate)	1.38
20		Poly(methyl 3,3,3-trifluoropropyl siloxane)	1.383
21		Poly(pentafluoropropyl acrylate)	1.385
22		Poly(2-heptafluorobutoxy)ethyl acrylate)	1.39
23	PCTFE	Poly(chlorotrifluoroethylene)	1.39
24		Poly(2,2,3,4,4-hexafluorobutyl acrylate)	1.392
25		Poly(methyl hydro siloxane)	1.397
26		Poly(methacrylic acid), sodium salt	1.401
27		Poly(dimethyl siloxane)	1.4035
28		Poly(trifluoroethyl acrylate)	1.407
29		Poly (2-(1,1,2,2-tetrafluoroethoxy)ethyl acrylate)	1.412
30		Poly(trifluoroisopropyl methacrylate)	1.4177
31		Poly(2,2,2-trifluoro-1-methylethyl methacrylate)	1.4185
32		Poly(2-trifluoroethoxyethyl acrylate)	1.419
33	PVDF	Poly(vinylidene fluoride)	1.42
34	ECTFE	Ethylene Chlorotrifluorotheylene	1.447
35		Poly(trifluoroethyl methacrylate)	1.437
36		Poly(methyl octadecyl siloxane)	1.443
37		Poly(methyl hexyl siloxane)	1.443
38		Poly(methyl octyl siloxane)	1.445
262		Poly(pentachlorophenyl methacrylate)	1.608
263		Poly(2-chlorostyrene)	1.6098
264	PaMes	Poly(alpha-methylstyrene)	1.61
265		Poly(phenyl alpha-bromoacrylate)	1.612
266		Poly{2,2-propane bis[4-(2,6-dibromophenyl)cabonate]}	1.6147
267		Poly(p-divinylbenzene)	1.615
268		Poly(N-vinyl phthalimide)	1.62
269		Poly(2,6-dichlorostyrene)	1.6248
270		Poly(chloro-p-xylene)	1.629
271		Poly(beta-naphthyl methacrylate)	1.6298
272		Poly(alpha-naphthyl carbinyl methacrylate)	1.63
273	PEI-ULTEM	Polyetherimide (880 nm wavelength)	1.63
274	PEI-ULTEM	Polyetherimide (643.8 nm wavelength)	1.651
275	PEI-ULTEM	Polyetherimide (587.6 nm wavelength)	1.66
276	PEI-ULTEM	Polyetherimide (546.1 nm wavelength)	1.668
277	PEI-ULTEM	Polyetherimide (480 nm wavelength)	1.687
278		Poly(phenyl methyl silane)	1.63
279		Poly(sulfone) {Poly[4,4'-isopropylidene diphenoxy di(4- phenylene)s	1.633
280	PSU	Polysulfone resin	1.633
281		Poly(2-vinylthiophene)	1.6376
282	**Mylar Film**	**Polyethylene terephthalate (boPET)**	**1.64-1.67**
283		**Poly(2,6-diphenyl-1,4-phenylene oxide)**	**1.64**
284		**Poly(alpha-naphthyl methacrylate)**	**1.641**
285		**Poly(p-phenylene ether-sulphone)**	**1.65**
286		**Poly{diphenylmethane bis(4-phenyl)carbonate}**	**1.6539**
287		**Poly(vinyl phenyl sulfide)**	**1.6568**
288		**Poly(styrene sulfide)**	**1.6568**
289		**Butylphenol formaldehyde resin**	**1.66**
290		**Poly(p-xylylene)**	**1.669**
291	PVN	Poly(2-vinylnapthalene)	1.6818
292	PVK	Poly(N-vinyl carbazole)	1.683
293		Naphthalene-formaldehyde rubber	1.696
294	PF	Phenol-formaldehyde resin	1.7
295		Poly(pentabromophenyl methacrylate)	1.71
296	MFA	Polytetrafluoroethylene-Perfluoromethylvinylether	unknown
297	PEEK1	(amorphous) Polyetheretherketone	1.65-1.71
298	PEEK2	(crystalline) Polyetheretherketone	1.68-1.77

http://www.texloc.com/closet/cl_refractiveindex.html

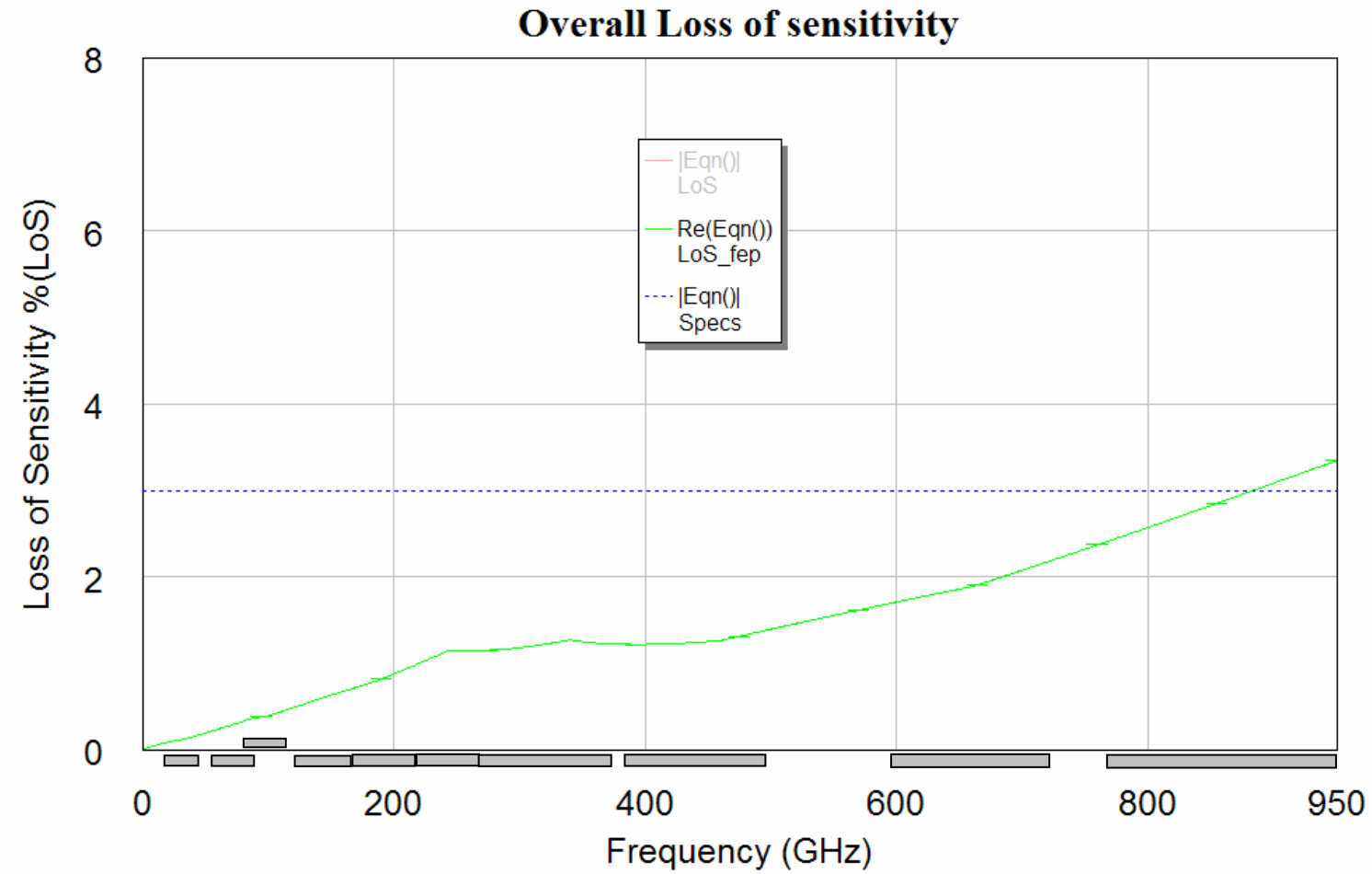
Results: Zotefoam 1cm



Results: Goretex 500um (Current Baseline)

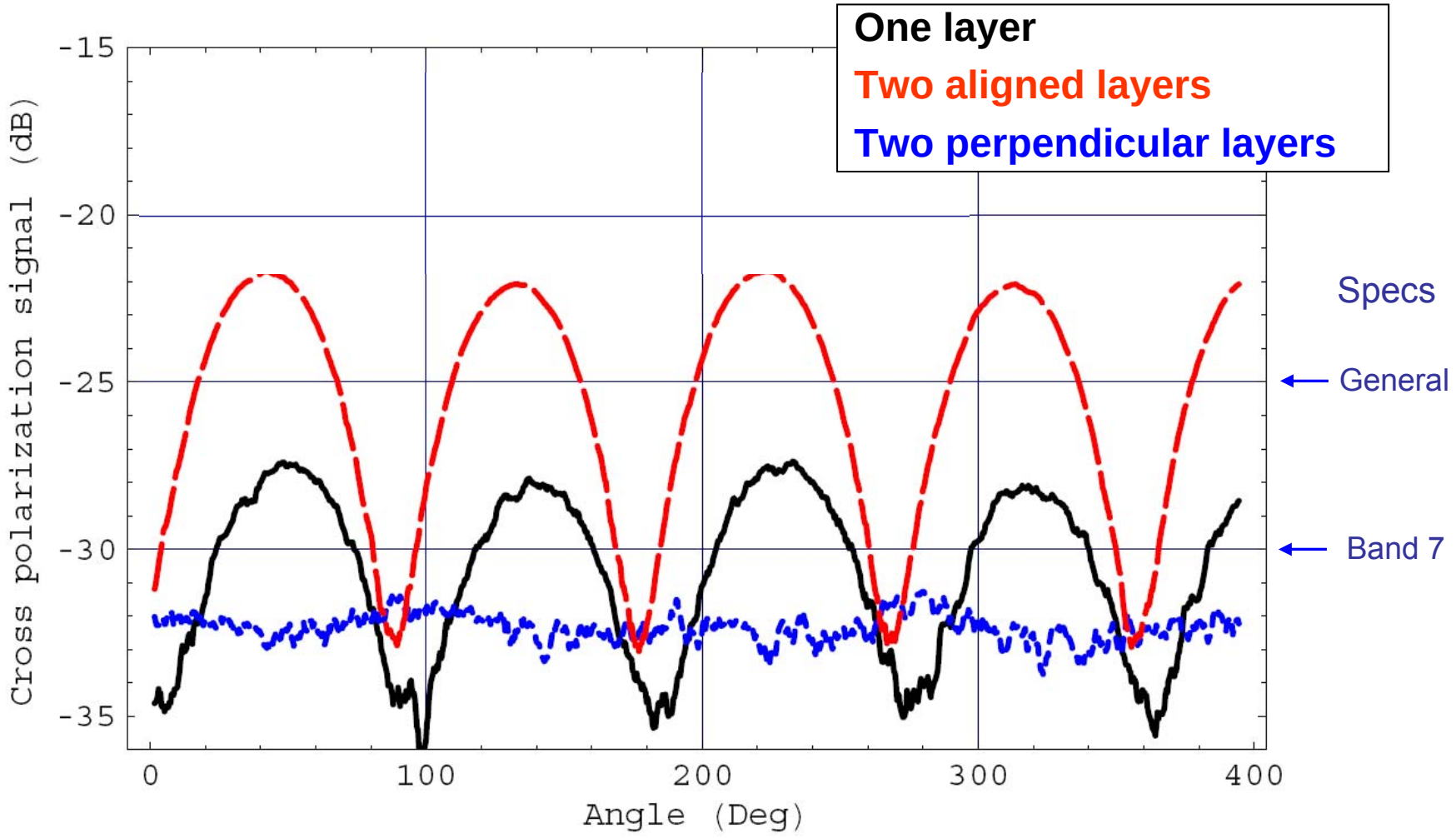


Results: FEP 25um

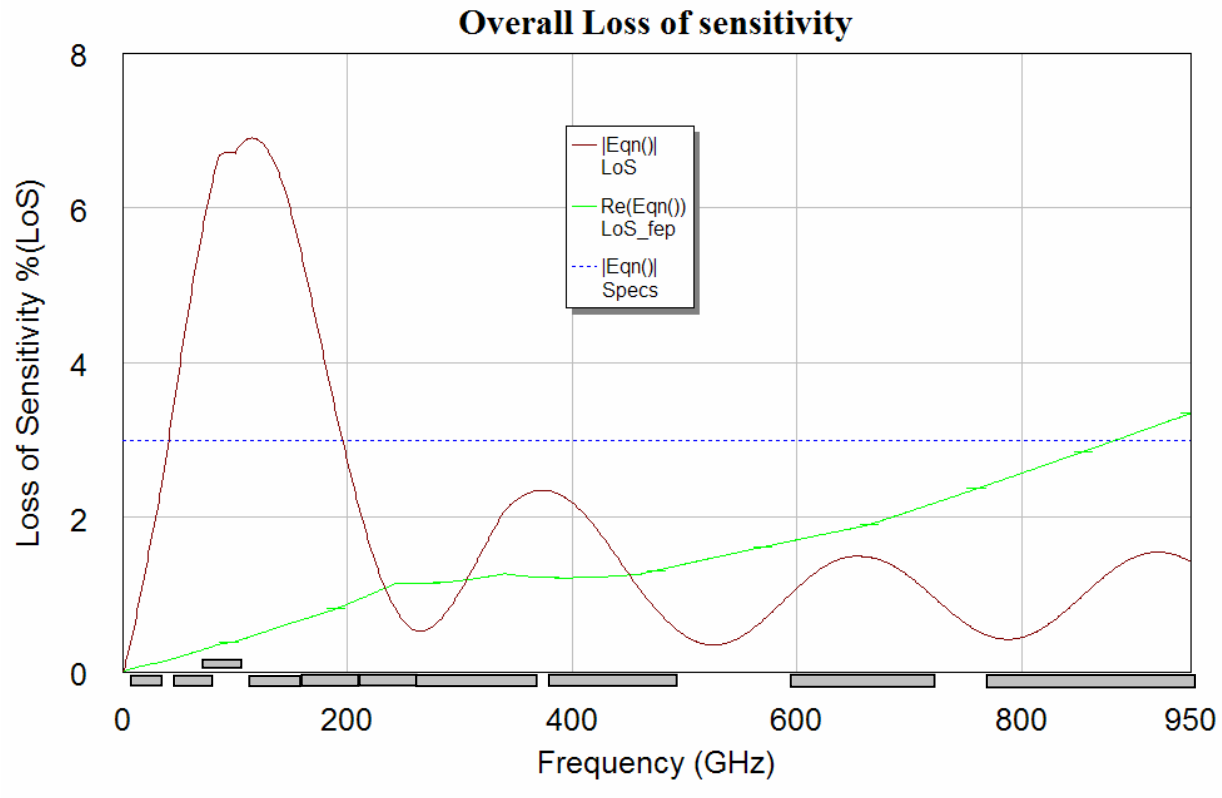


Polarization issues (Memo 551, Baryshev et Al)

Goretex 500um



Conclusions



- *We need to characterize FEP at Submillimitter wavelengths*
- *We need to test the mechanical integrity of a membrane of 75cm diameter*
- *We have to do it quickly*

Mounting

- *First try at mounting 25 micron FEP on a suitable ring.*

Thanks!