PBAR NOTE NO. 594
ANALYSIS OF MICROWAVE PROPERTIES FOR VARIOUS ABSORBING MATERIALS

Dave McGinnis

June 30, 1998

INTRODUCTION

The values of the complex permeability and permittivity as a function of frequency need to be known in order to design the isolating absorbers for the 4-8 GHz Debuncher Upgrade.

MEASUREMENT OF THE RELATIVE COMPLEX PERMEABILITY AND PERMITTIVTY

A variety of samples from different manufactures were measured (by Ding Sun on June 19, 1998) using the waveguide transmission technique[1,2]. The list of samples is shown in Table 1.

Sample	Thickness (inches)	Title
1	0.038	Ferrite 50
2	0.038	Repeat of Ferrite 50
3	0.038	TT2-111R
4	0.038	Repeat of TT2-111R
5	0.048	AlN-SiC40%
6	0.048	Repeat of AlN-SiC40%
7	0.095	SiC #1
8	0.095	SiC #2
9	0.06	MF190
10	0.06	Repeat of MF190
11	0.115	Plastic Glass
12	0.115	Repeat of Plastic Glass
13		Empty waveguide

Table 1. Sample description. The waveguide length is 0.752" and the spacing between the backside of the sample and the waveguide was 0.250"

Figure 1 shows the magnitude of the relative permeability (μ_r) as a function of frequency. Figure 2 shows the loss tangent ($Im(\mu_r)/Re(\mu_r)$) of the relative permeability as a function of frequency. Figure 3 shows the magnitude of the relative permittivity (ε_r) as a function of frequency. Figure 4 shows the loss tangent ($Im(\varepsilon_r)/Re(\varepsilon_r)$) of the relative permittivity as a function of frequency. For each parameter, a straight line fit of the form:

$$y = m(f - f_c) + b \quad (1)$$

was made. The value **m** is the slope of the line and **b** is the intercept at frequency f_c. These fit parameters are shown in Tables 2 and 3.

---

[1] PBAR Note 576 "Measurement of Complex Permittivity and Permeability of Microwave Absorber ECCOSORB MF190", Ding Sun, August 1997

[2] PBAR Note 585 "Measurement of Relative Permittivity and Permeability Using Two Port S-Parameter Technique", Dave McGinnis, April 13,1998

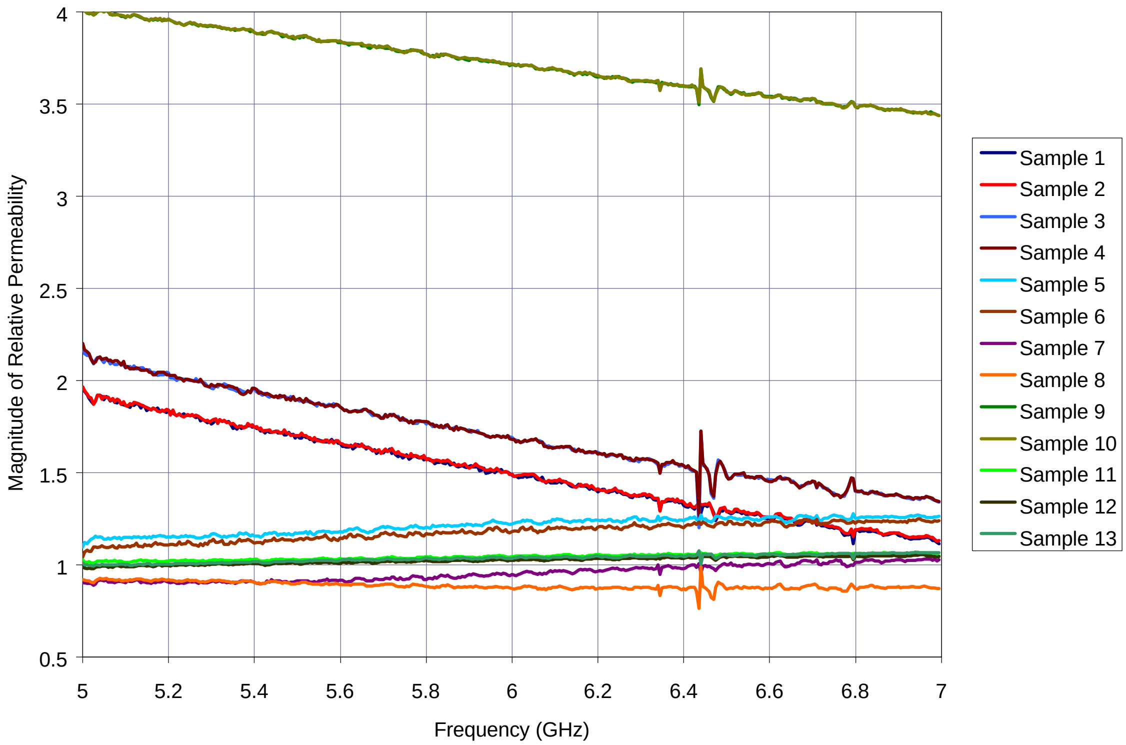

Figure 1. Magnitude of the relative permeability (m_r) vs. frequency

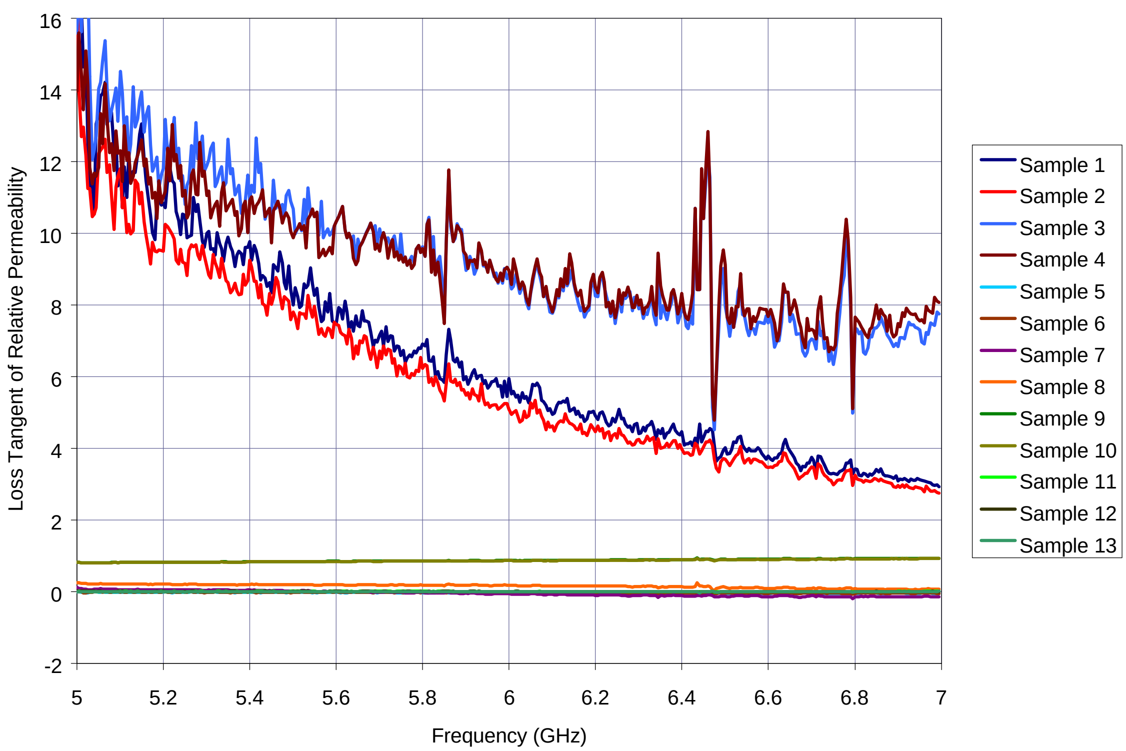

Figure 2. Loss tangent of the relative permeability ($Im(m_r)/Re(m_r)$) vs. frequency.

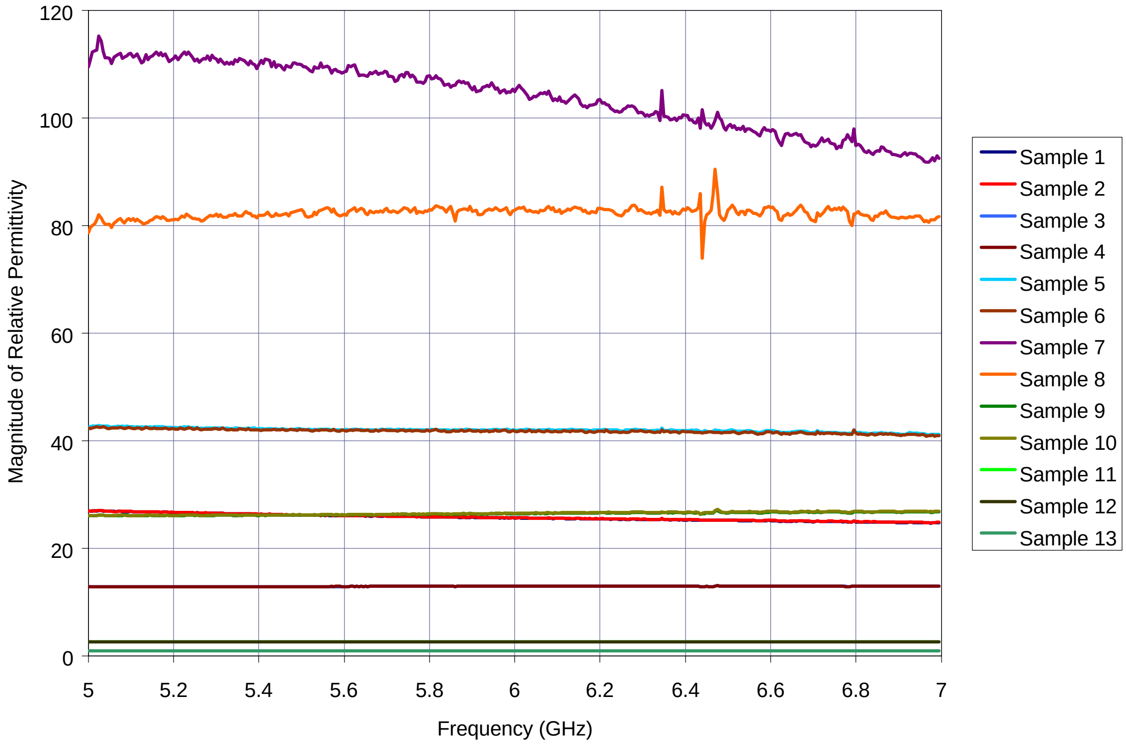

Figure 3. Magnitude of the relative permittivity (e_r) vs. frequency

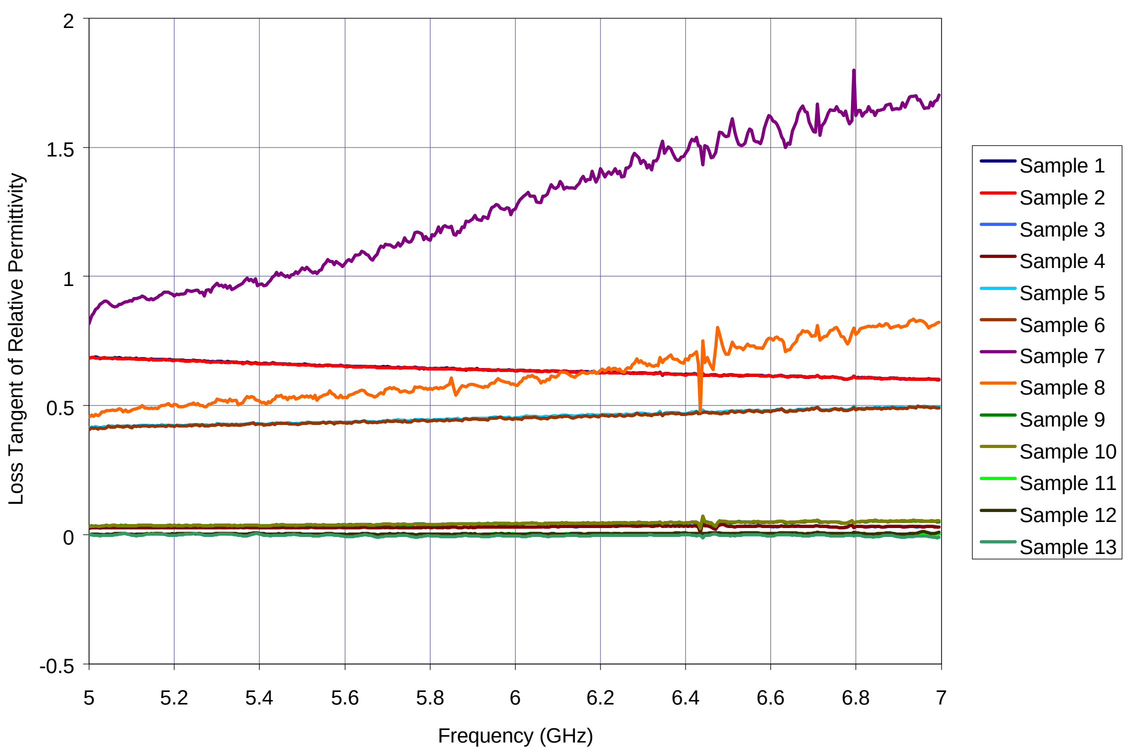

Figure 4. Loss tangent of the relative permittivity ($Im(e_r)/Re(e_r)$) vs. frequency

Sample	Title	$\lvert \mu_r \rvert$ Slope	$\lvert \mu_r \rvert$ Intercept (at 6 GHz)	$Im(\mu_r)/Re(\mu_r)$ Slope	$Im(\mu_r)/Re(\mu_r)$ Intercept (at 6 GHz)
1	Ferrite 50	-0.402	1.498	-4.873	6.517
2	Repeat of Ferrite 50	-0.399	1.504	-4.350	5.958
3	TT2-111R	-0.395	1.699	-3.340	9.447
4	Repeat of TT2-111R	-0.396	1.701	-2.494	9.317
5	AlN-SiC40%	0.069	1.213	-0.018	-0.026
6	Repeat of AlN-SiC40%	0.079	1.178	-0.019	-0.022
7	SiC #1	0.072	0.955	-0.125	-0.046
8	SiC #2	-0.024	0.887	-0.079	0.162
9	MF190	-0.288	3.717	0.062	0.873
10	Repeat of MF190	-0.289	3.719	0.056	0.868
11	Plastic Glass	0.026	1.043	-0.004	0.009
12	Repeat of Plastic Glass	0.032	1.023	-0.004	0.007
13	Empty waveguide	0.034	1.035	0.002	0.004

Table 2. Straight line fit parameters for the relative permeability (m_r)

Sample	Title	$\lvert \varepsilon_r \rvert$ Slope	$\lvert \varepsilon_r \rvert$ Intercept (at 6 GHz)	$Im(\varepsilon_r)/Re(\varepsilon_r)$ Slope	$Im(\varepsilon_r)/Re(\varepsilon_r)$ Intercept (at 6 GHz)
1	Ferrite 50	-1.073	25.745	-0.042	0.639
2	Repeat of Ferrite 50	-1.049	25.779	-0.042	0.638
3	TT2-111R	0.066	12.943	0.003	0.030
4	Repeat of TT2-111R	0.048	12.942	0.003	0.030
5	AlN-SiC40%	-0.569	42.016	0.042	0.455
6	Repeat of AlN-SiC40%	-0.587	41.791	0.041	0.452
7	SiC #1	-10.463	103.884	0.455	1.278
8	SiC #2	0.454	82.289	0.181	0.622
9	MF190	0.385	26.451	0.009	0.042
10	Repeat of MF190	0.460	26.527	0.010	0.043
11	Plastic Glass	0.023	2.623	0.001	0.003
12	Repeat of Plastic Glass	0.019	2.617	0.002	0.004
13	Empty waveguide	0.014	1.010	-0.002	-0.004

Table 3. Straight line fit parameters for the relative permittivity (e_r)

Absorber Design

Using the measure values of μ_r and ε_r, this section will develop design values for isolating absorbers placed on the walls of the waveguides.[3] The analysis is limited to treating absorber on the top walls and the side walls of the waveguide individually.

1. The Debuncher Upgrade Band 1 is centered at 4.35 GHz and has beam pipe dimensions of width = 50.419 mm and height = 59.944 mm. The design plots for Band 1 are shown in Figures 5-8.

[3] PBAR Note 583 "Attenuation of Waveguide Modes with Absorbing Walls", Dave McGinnis, April 10, 1998

2. Band 2 is centered at 5.25 GHz and has beam pipe dimensions of width = 42.291 mm and height = 48.895 mm. The design plots for Band 2 are shown in Figures 9-12.
3. Band 3 is centered at 6.3 GHz and has “average” beam pipe dimensions of width = 44 mm and height = 45 mm. The design plots for Band 3 are shown in Figures 13-16.
4. Band 4 is centered at 7.5 GHz and has “average” beam pipe dimensions of width = 43 mm and height = 33 mm. The design plots for Band 4 are shown in Figures 17-20. (The slopes of the magnetic properties for Ferrite 50 and TT2-111R were set to zero for calculations in this band. The large slopes fitted from the data between 5-7 GHz would extrapolate to negative values in the Band 4 frequencies, which is not physical.)

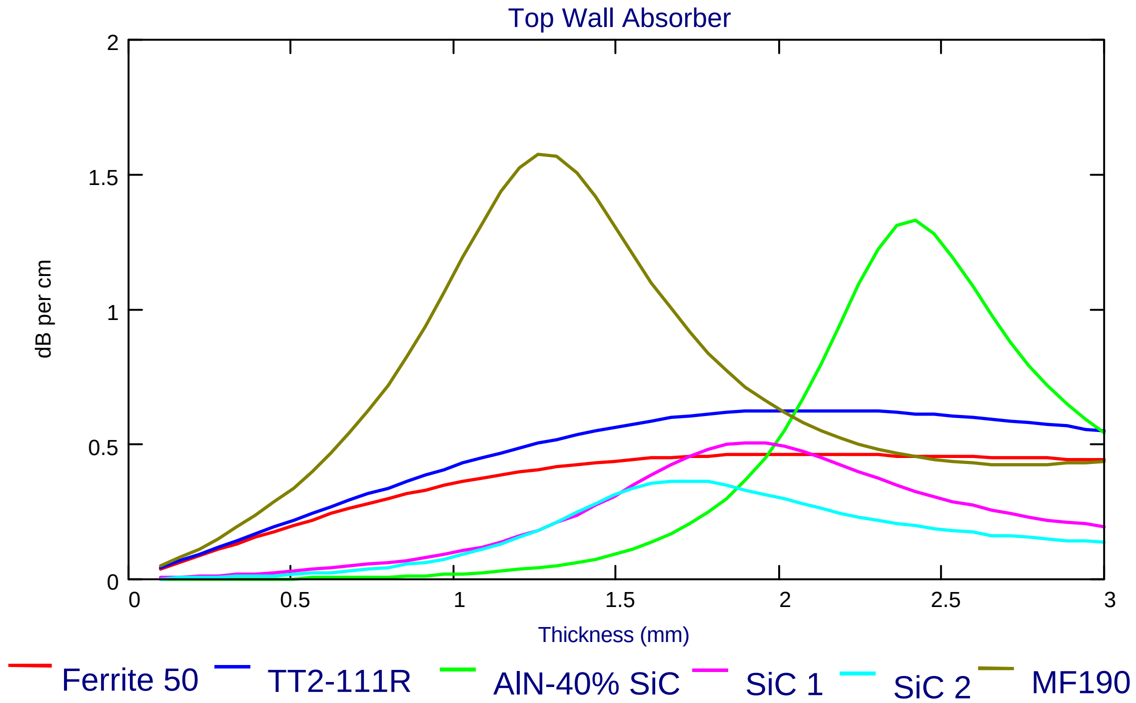

Figure 5. Attenuation vs. absorber thickness for Band 1 isolating absorber at 4.35 GHz.

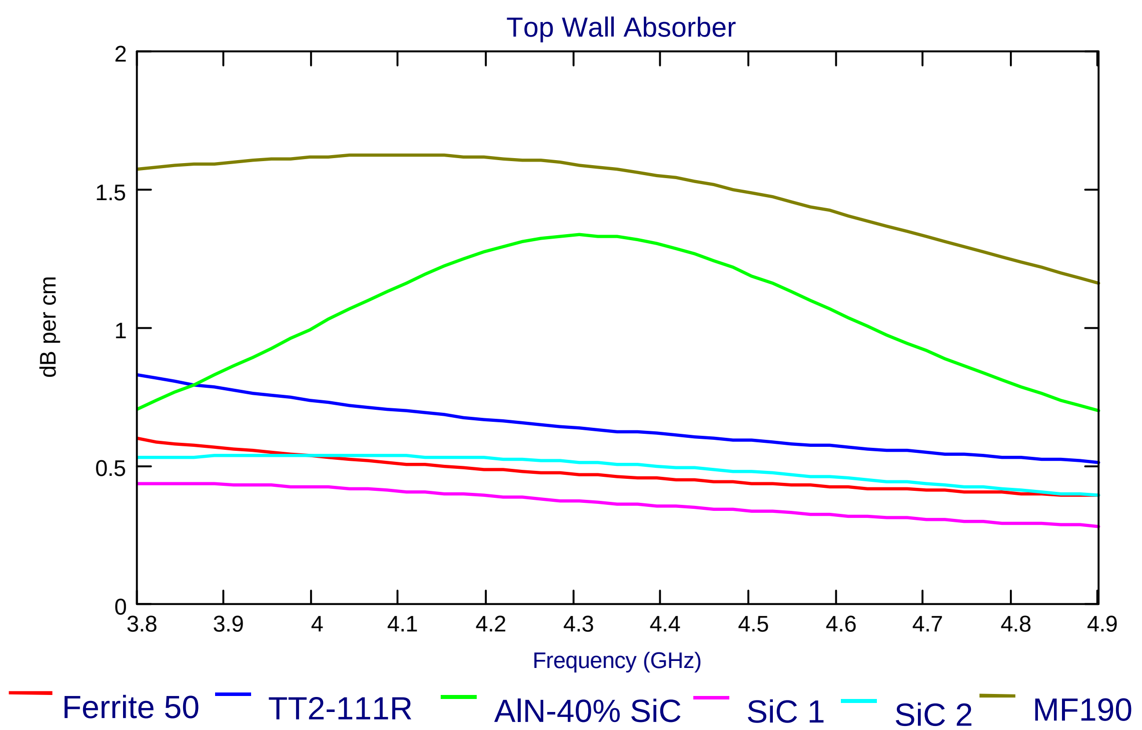

Figure 6. Attenuation vs. frequency for Band 1 isolating absorber. The absorber thickness was chosen from maximum value of corresponding trace in Figure 5.

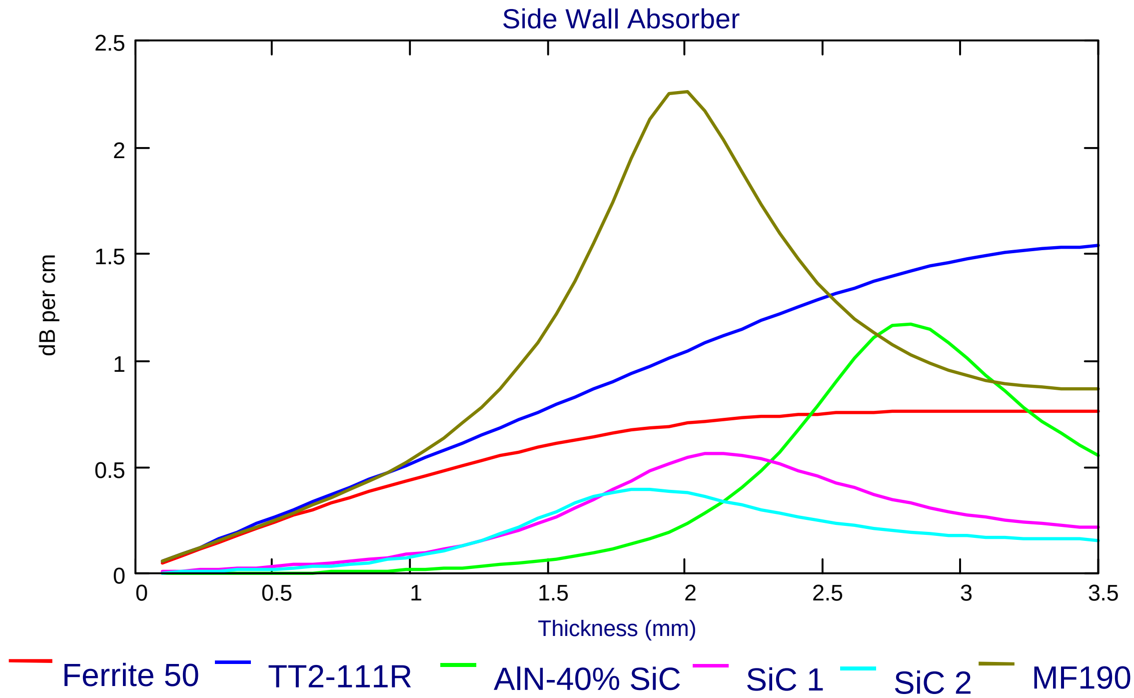

Figure 7. Attenuation vs. absorber thickness for Band 1 isolating absorber at 4.35 GHz.

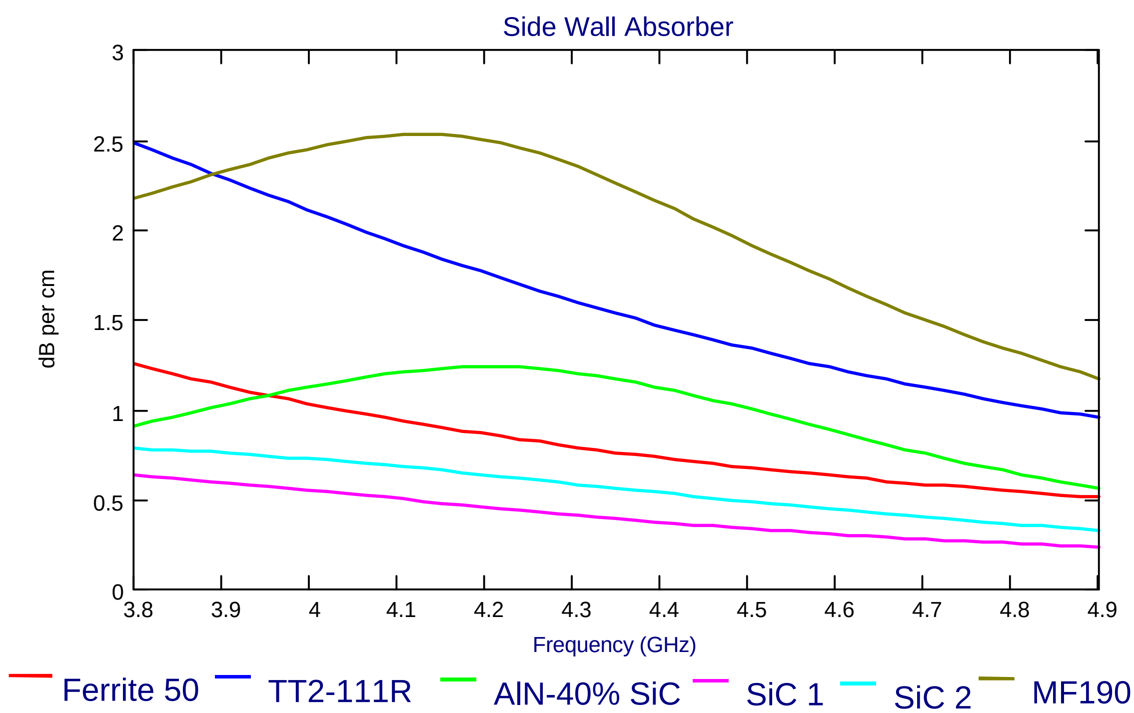

Figure 8. Attenuation vs. frequency for Band 1 isolating absorber. The absorber thickness was chosen from maximum value of corresponding trace in Figure 7.

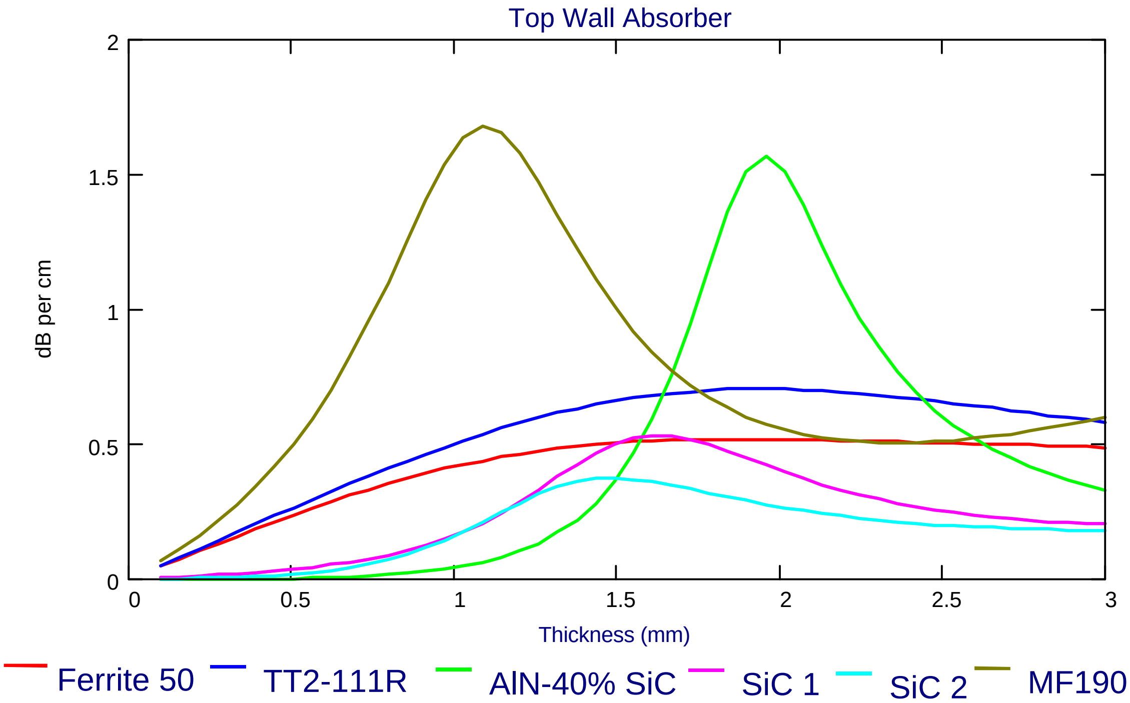

Figure 9. Attenuation vs. absorber thickness for Band 2 isolating absorber at 5.25 GHz.

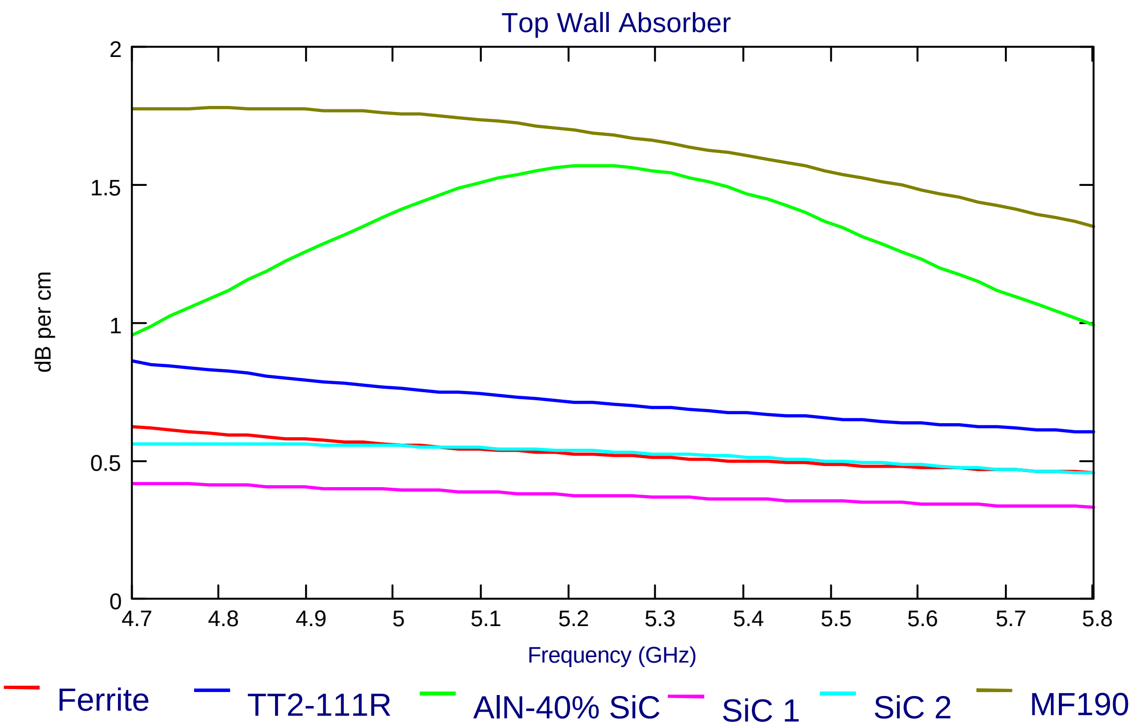

Figure 10. Attenuation vs. frequency for Band 2 isolating absorber. The absorber thickness was chosen from maximum value of corresponding trace in Figure 9.

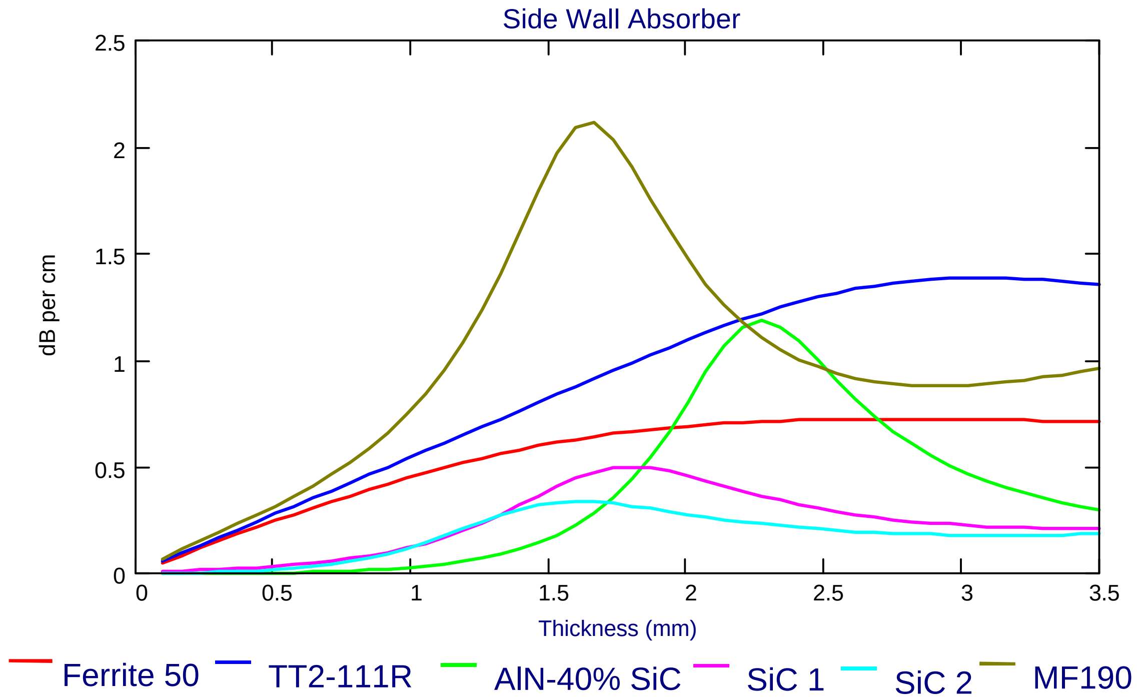

Figure 11. Attenuation vs. absorber thickness for Band 2 isolating absorber at 5.25 GHz.

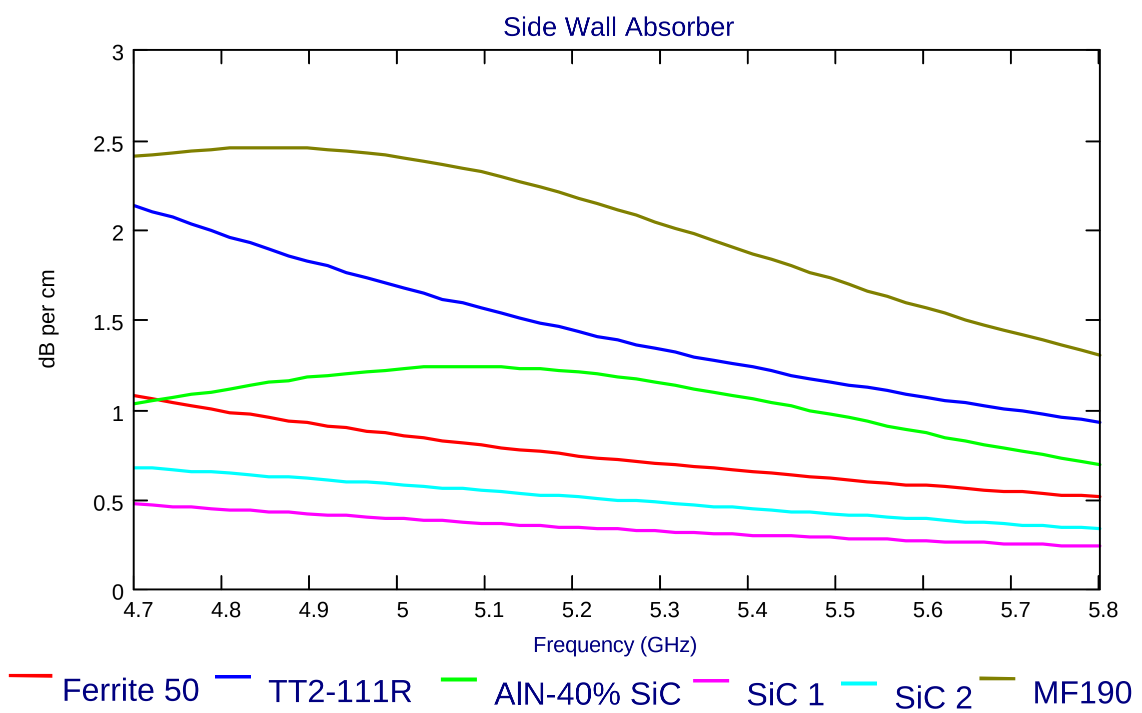

Figure 12. Attenuation vs. frequency for Band 2 isolating absorber. The absorber thickness was chosen from maximum value of corresponding trace in Figure 11.

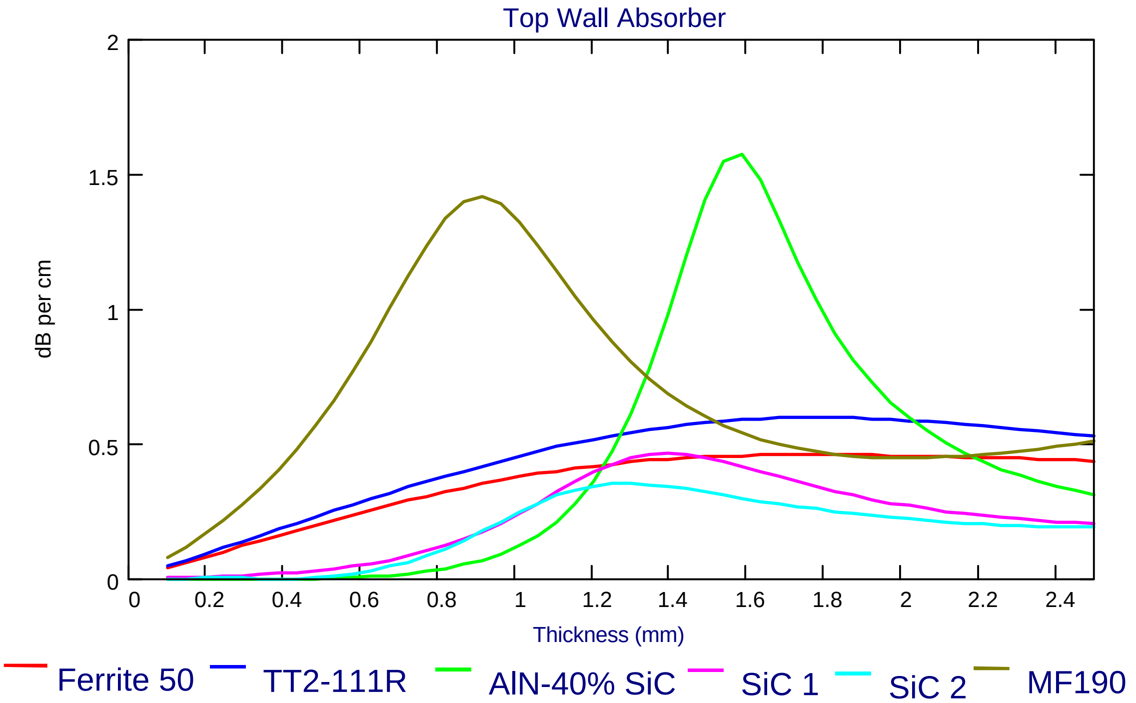

Figure 13. Attenuation vs. absorber thickness for Band 3 isolating absorber at 6.3 GHz.

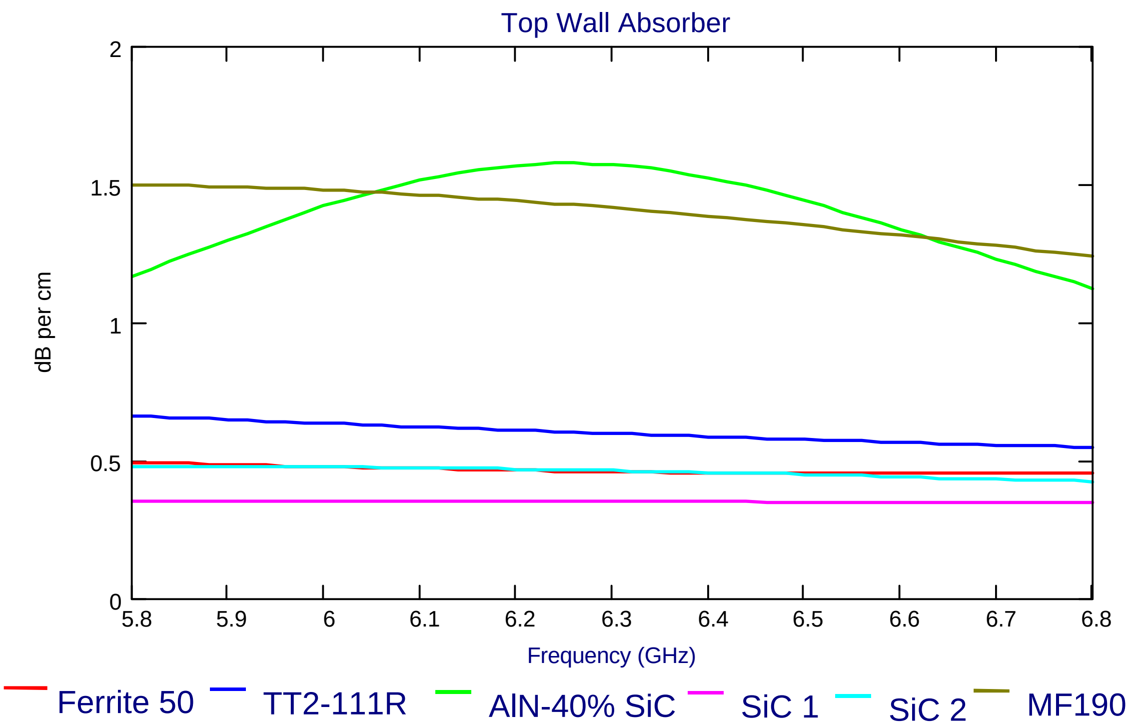

Figure 14. Attenuation vs. frequency for Band 3 isolating absorber. The absorber thickness was chosen from maximum value of corresponding trace in Figure 13.

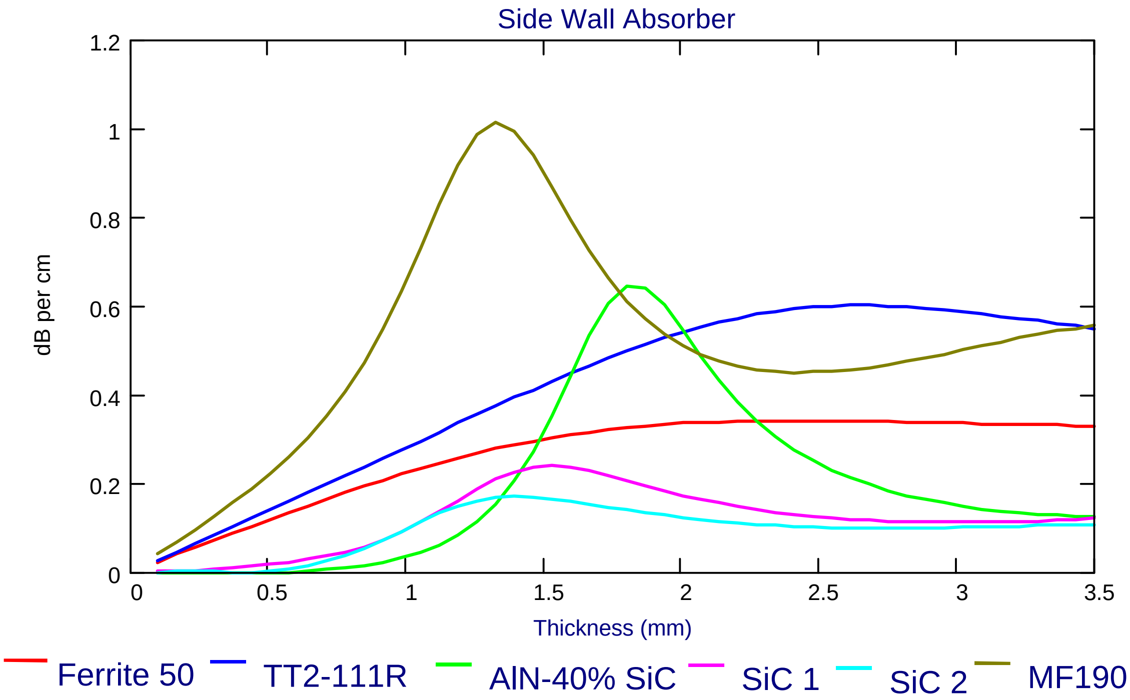

Figure 15. Attenuation vs. absorber thickness for Band 3 isolating absorber at 6.3 GHz.

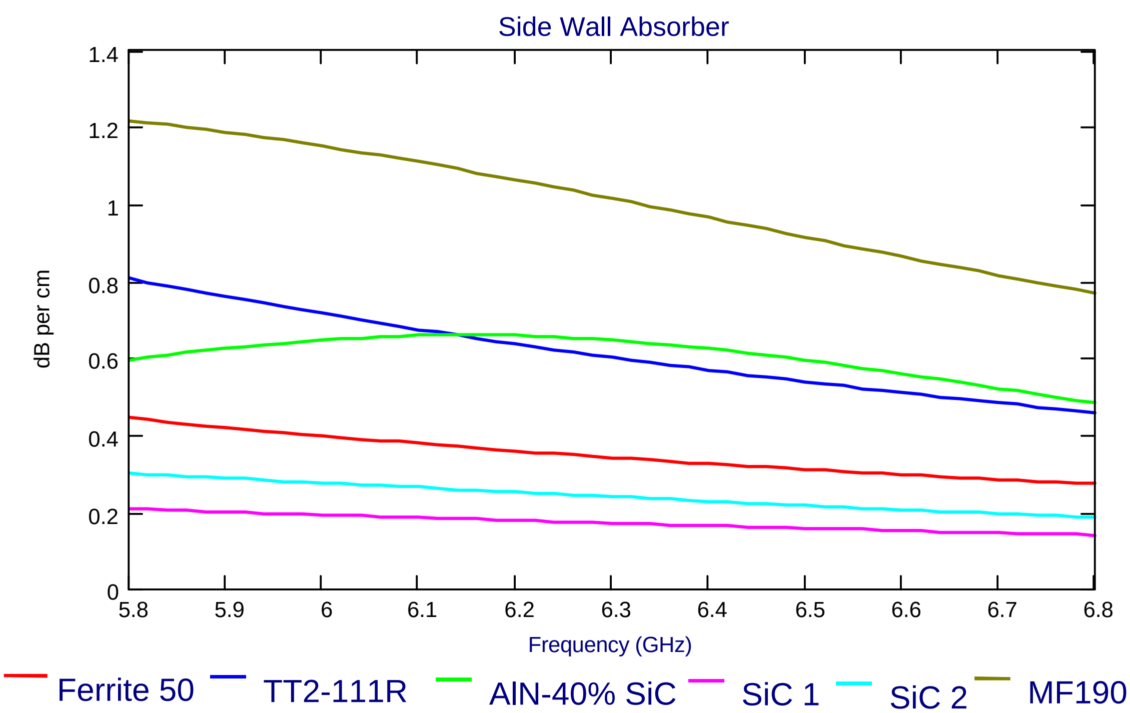

Figure 16. Attenuation vs. frequency for Band 3 isolating absorber. The absorber thickness was chosen from maximum value of corresponding trace in Figure 15.

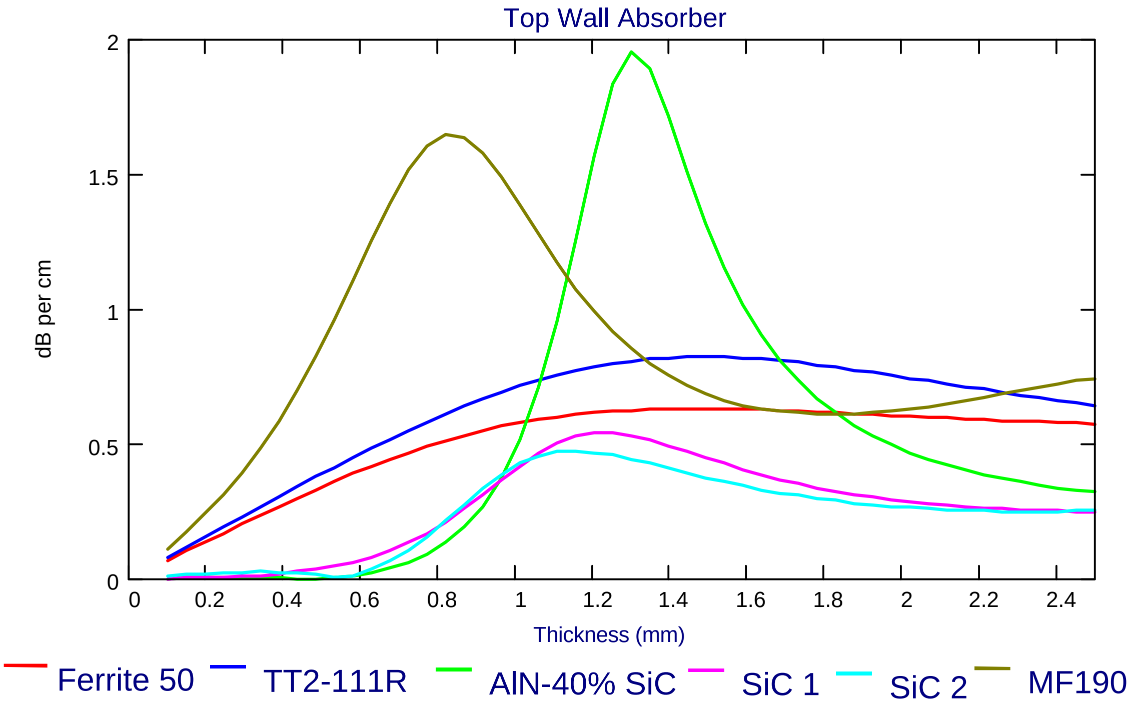

Figure 17. Attenuation vs. absorber thickness for Band 4 isolating absorber at 7.5 GHz.

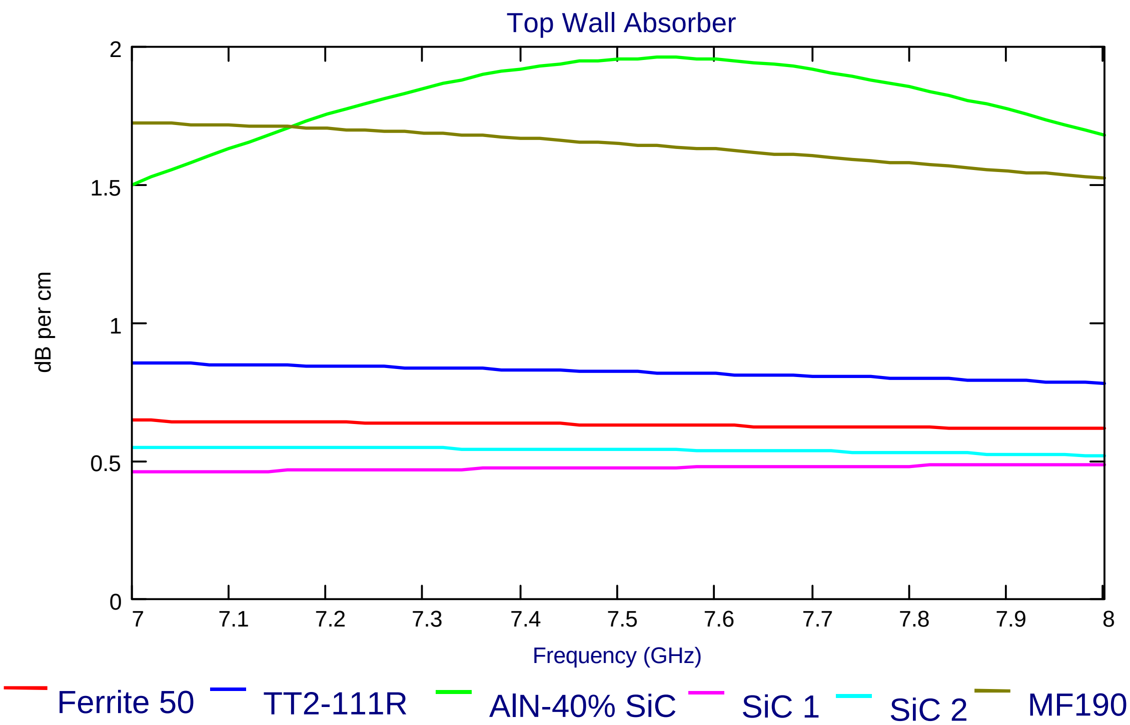

Figure 18. Attenuation vs. frequency for Band 4 isolating absorber. The absorber thickness was chosen from maximum value of corresponding trace in Figure 17.

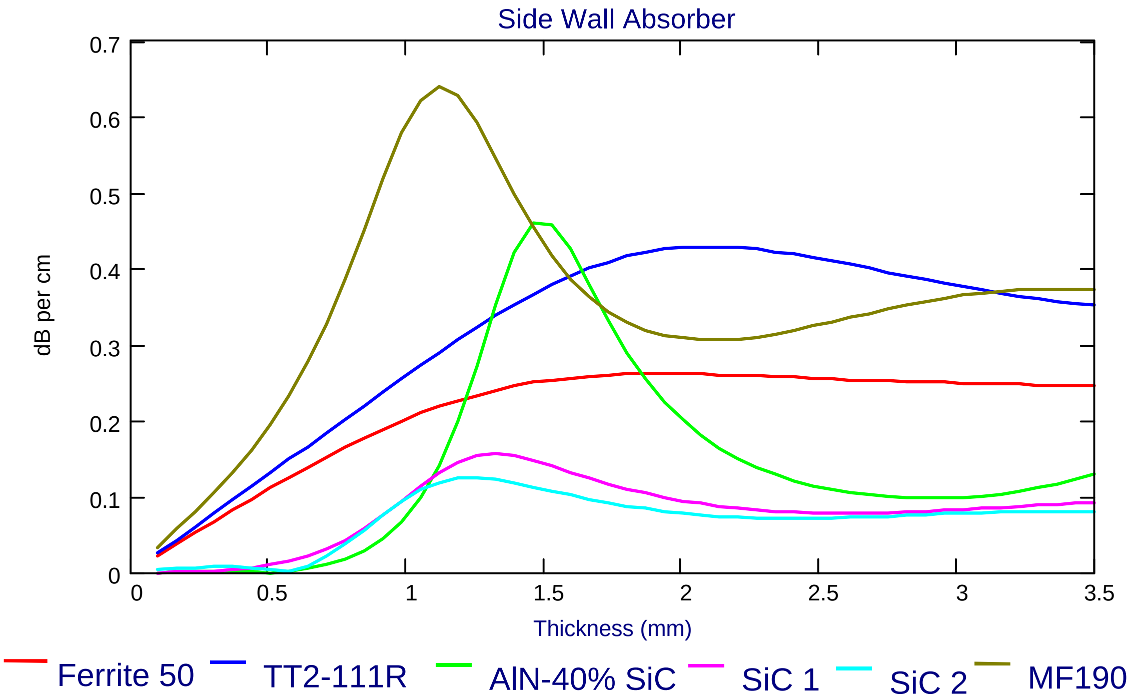

Figure 19. Attenuation vs. absorber thickness for Band 4 isolating absorber at 7.5 GHz.

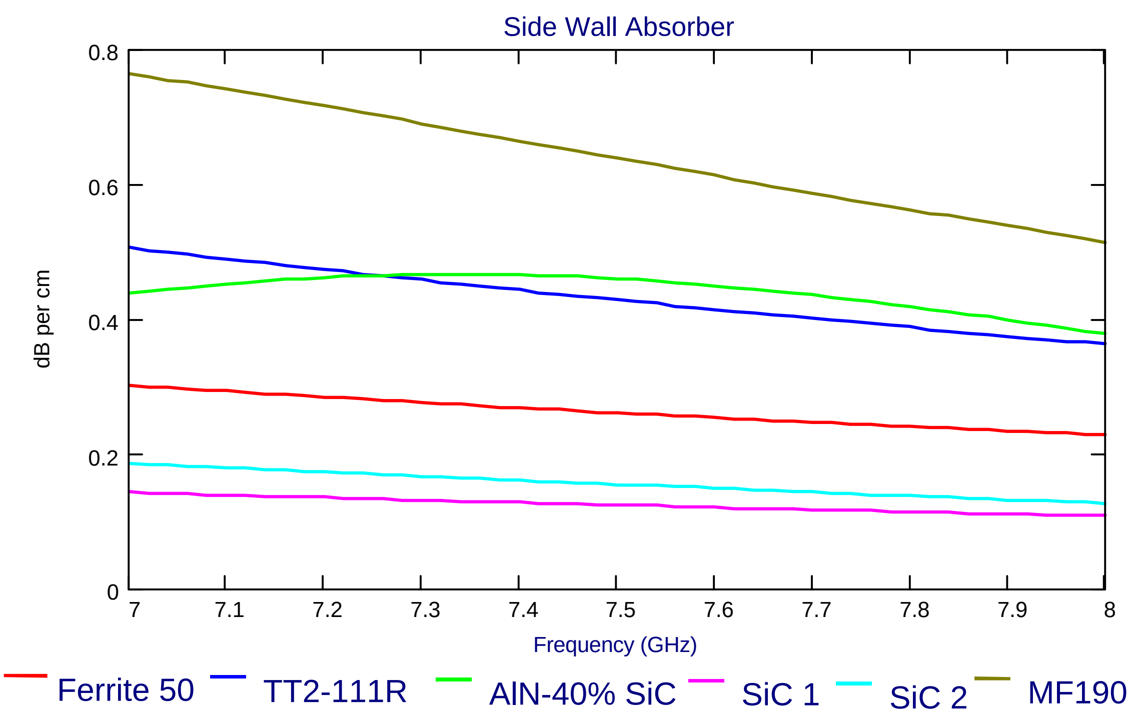

Figure 20. Attenuation vs. frequency for Band 4 isolating absorber. The absorber thickness was chosen from maximum value of corresponding trace in Figure 19.