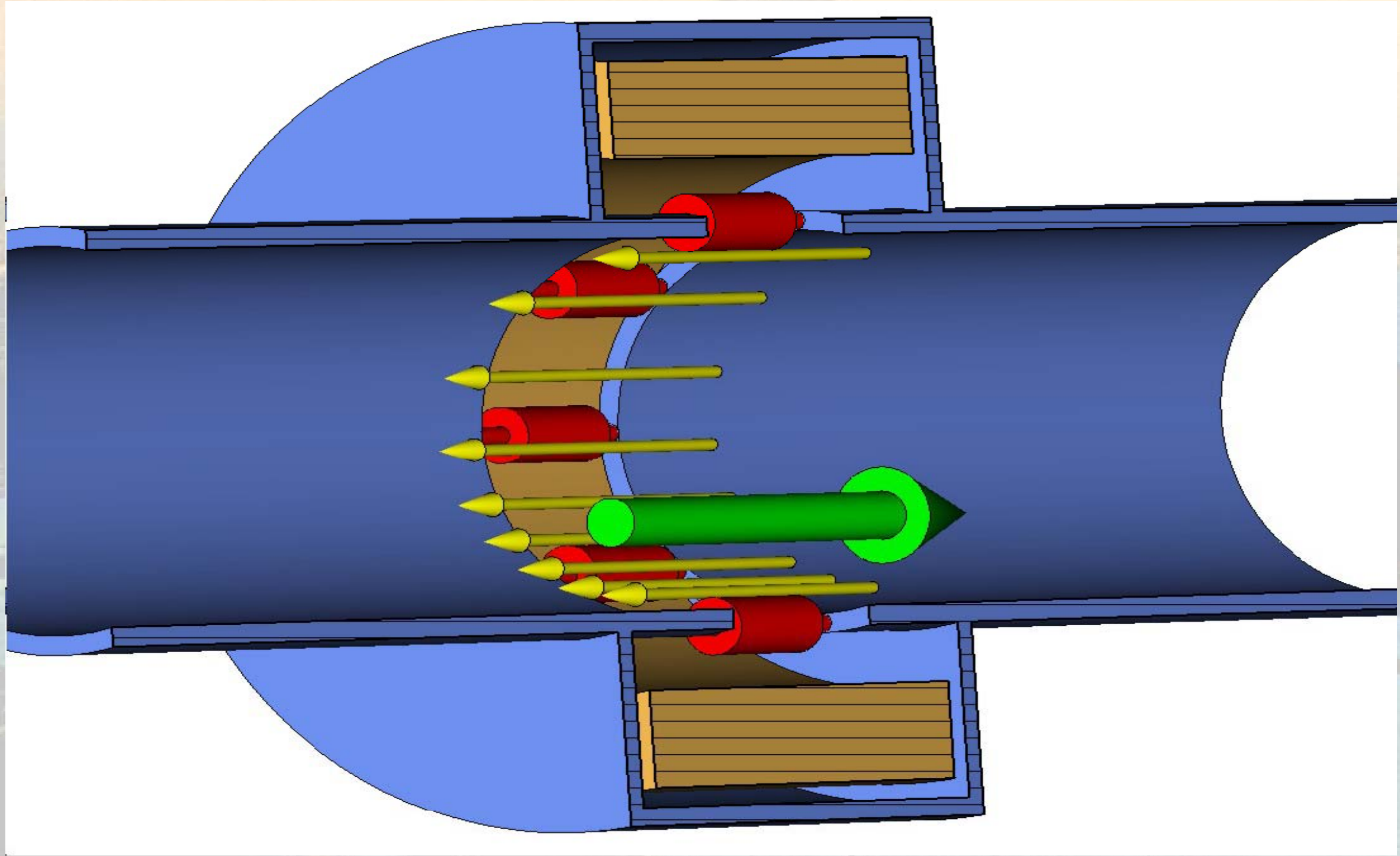
EuroTeV High Bandwidth Wall Current Monitor

Alessandro D'Elia
AB-BI-PI

Wall Current Monitors

Wall Current Monitors (WCM) are commonly used to observe the time profile and spectra of a particle beam by detecting its image current.



The “initial” aim

The 3rd generation of CLIC Test Facility (CTF3) foresees a beam formed by bunches separated of

Δ_b = 67 ps → WCM h. f. cut-off = 20 GHz

for a total pulse duration of

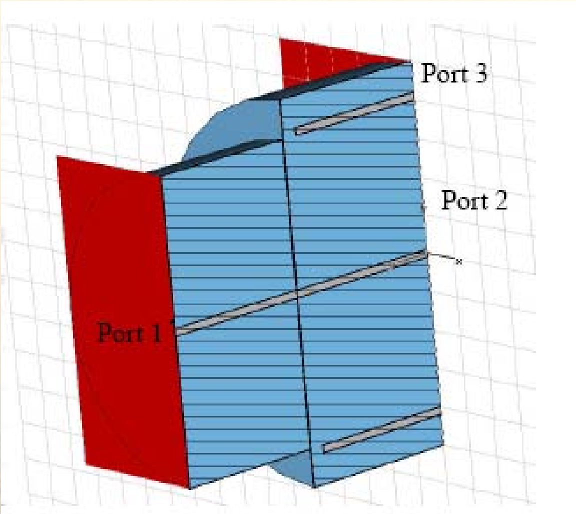
τ_r = 1.54 μs → WCM l. f. cut-off = 100 kHz

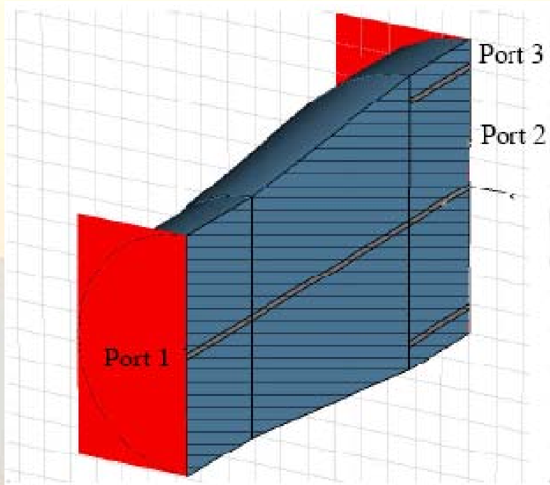
Furthermore

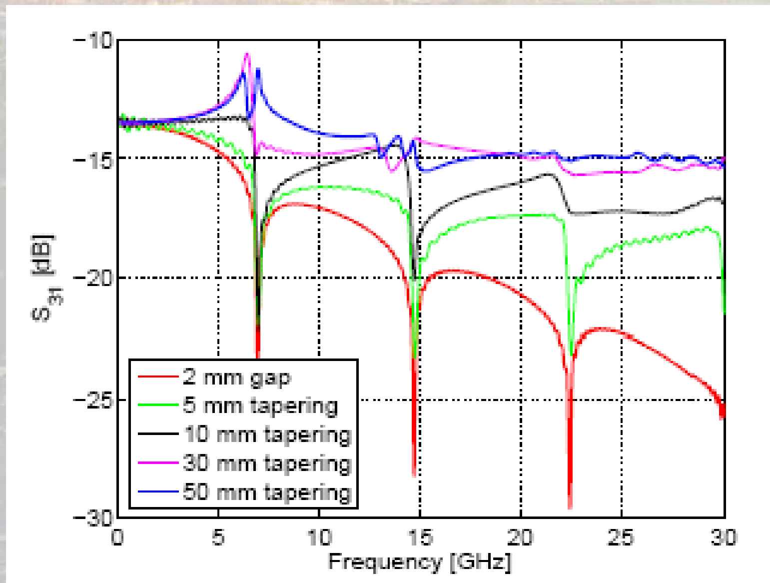
Bake out temperature:	150 C
Operating temperature:	20 C
Vacuum:	10^{-9} Torr

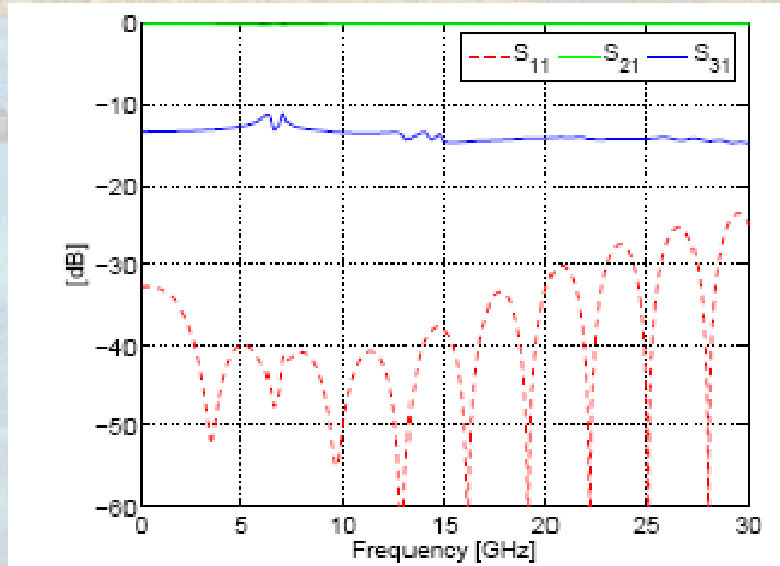
100kHz-20GHz WB signal transmission over 10-20m.

The gap resonances





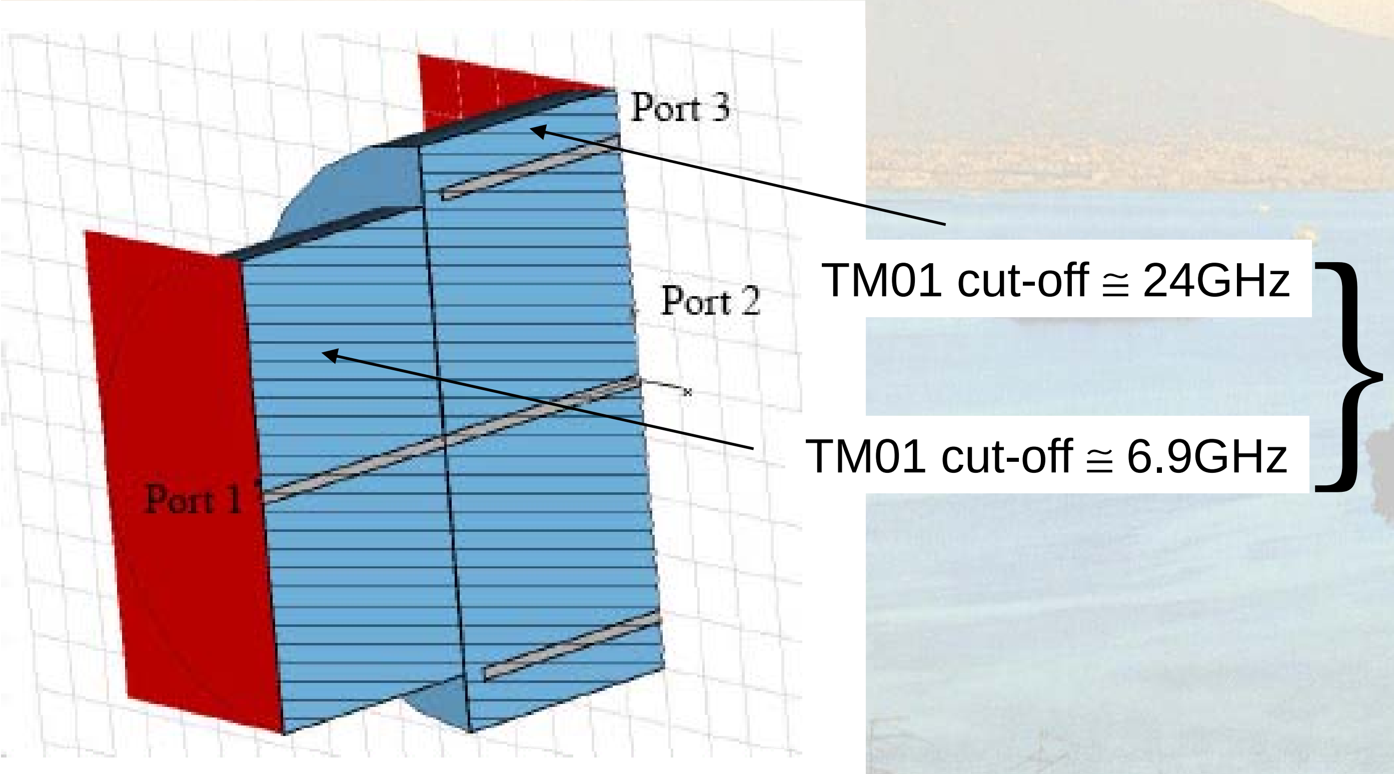




With the courtesy of Tom Kroyer ("*A Structure for a Wide Band Wall Current Monitor*", AB-Note-2006-040 RF)

A more accurate study of the gap resonances

The resonances due to the cross section changing are "structural"!!!! You cannot delete them, you can only to try to reduce them!



The TM01, with the frequency of about 6.9GHz will be trapped between the two coaxial

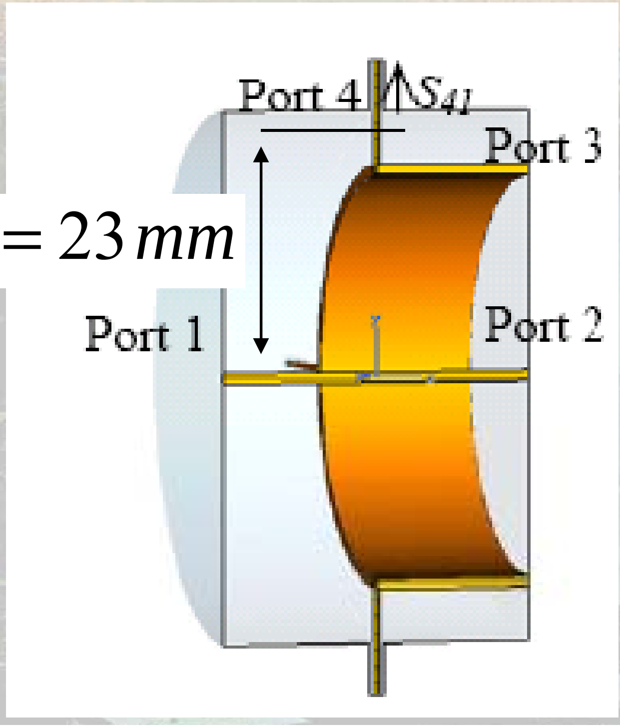
Feedthrough resonances

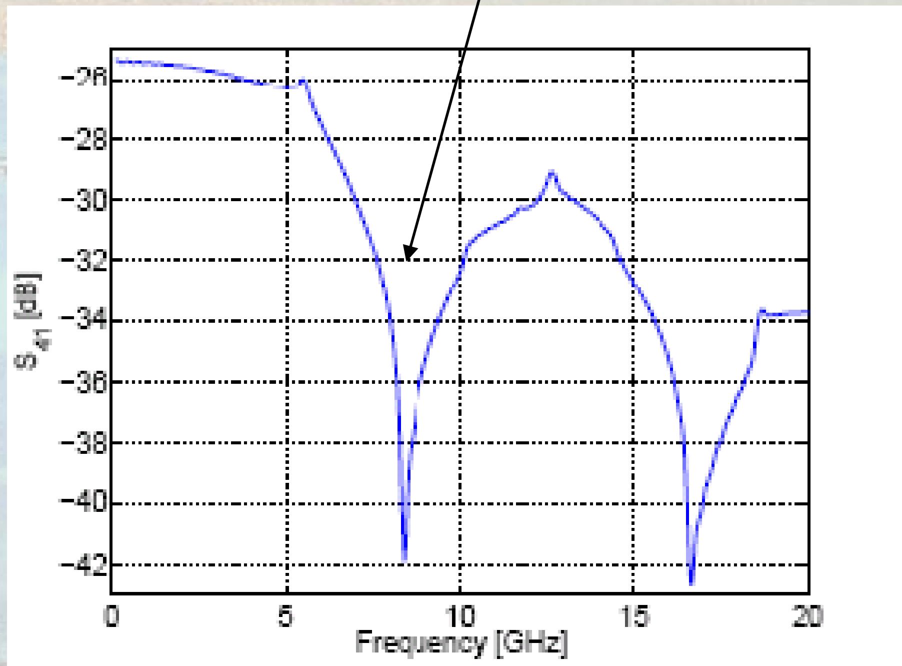
When the distance between two feedthroughs becomes equal to the free space wavelength, the first azimuthal resonance appears in the structure

$$F = \frac{c}{2\pi(\bar{r}/n)} \qquad n = \text{number of feedthrough}$$

With *n* =4, one has *F* =8.3 GHz

$$\bar{r} = 23\,mm$$

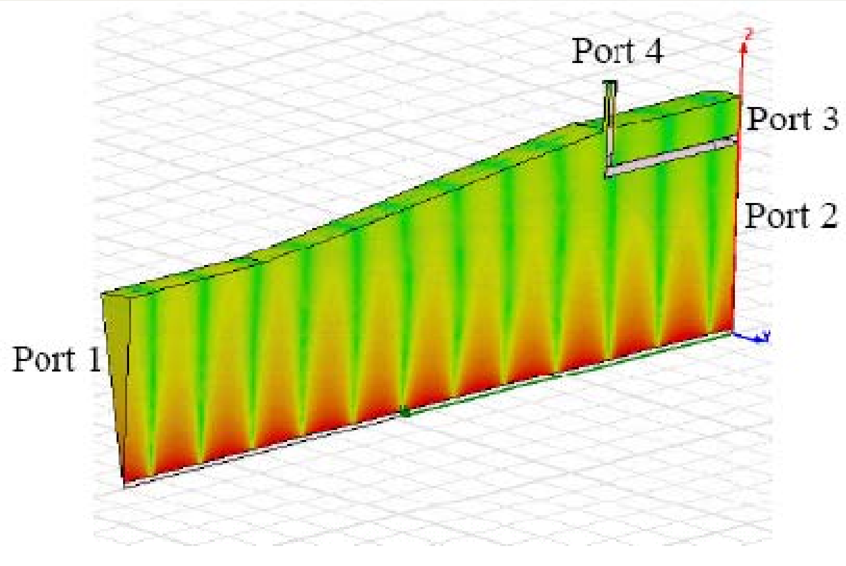


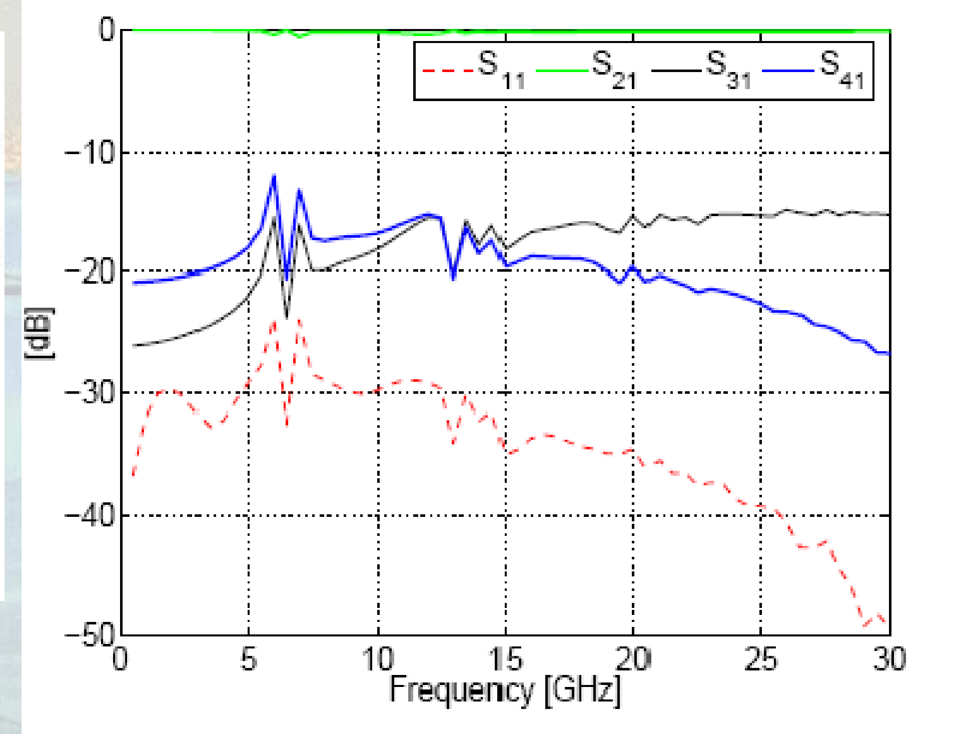


With the courtesy of Tom Kroyer ("*A Structure for a Wide Band Wall Current Monitor*", AB-Note-2006-040 RF)

The whole structure

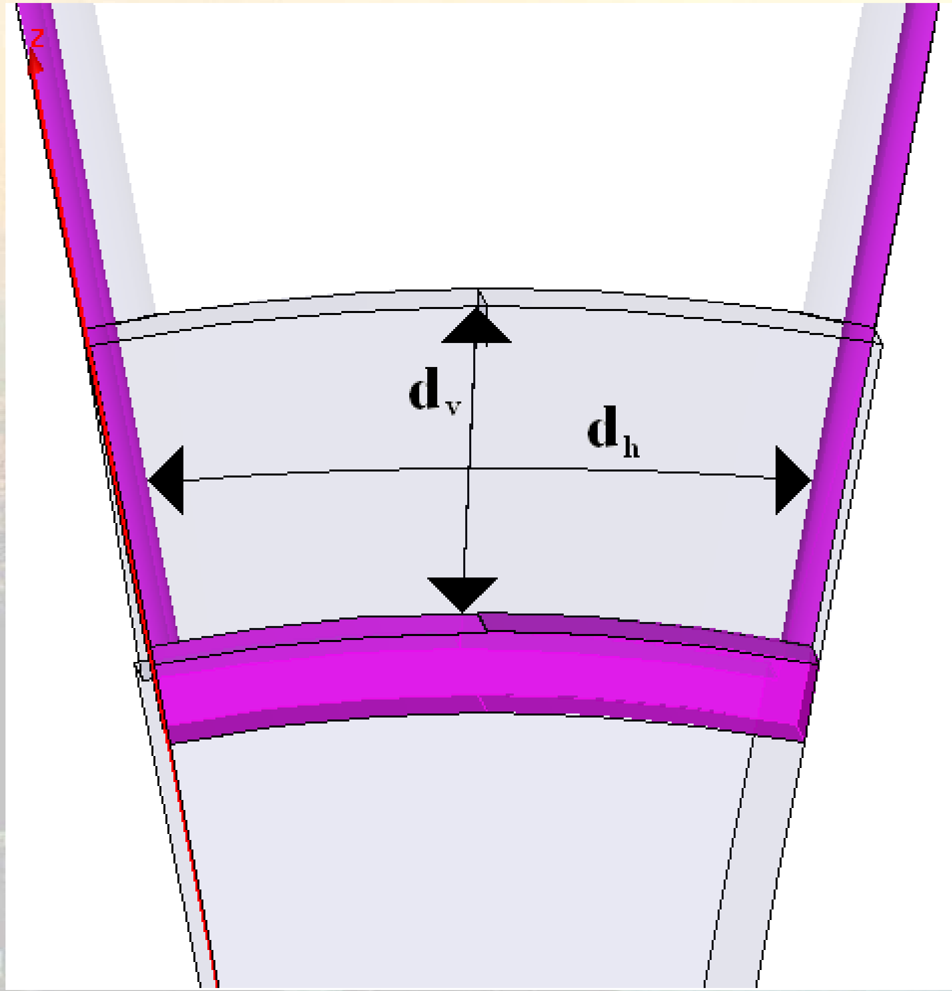
Therefore to have 16 feedthroughs means to push the previous resonance to ≅ 33 GHz





With the courtesy of Tom Kroyer ("*A Structure for a Wide Band Wall Current Monitor*", AB-Note-2006-040 RF)

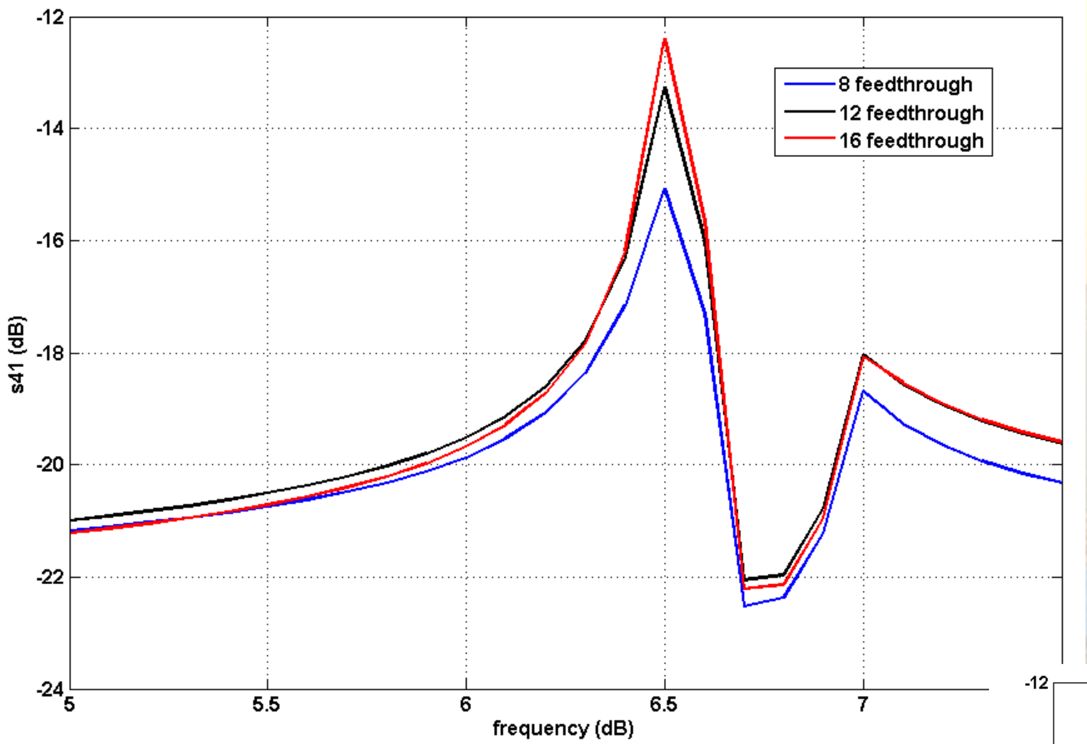
The effect of feedthrough's on the TM01 resonance



In the transversal plane you have either for vertical or horizontal directions that

$$\lambda_{TM01} >> \begin{cases} d_h \\ d_v \end{cases}$$

The effect of feedthrough's



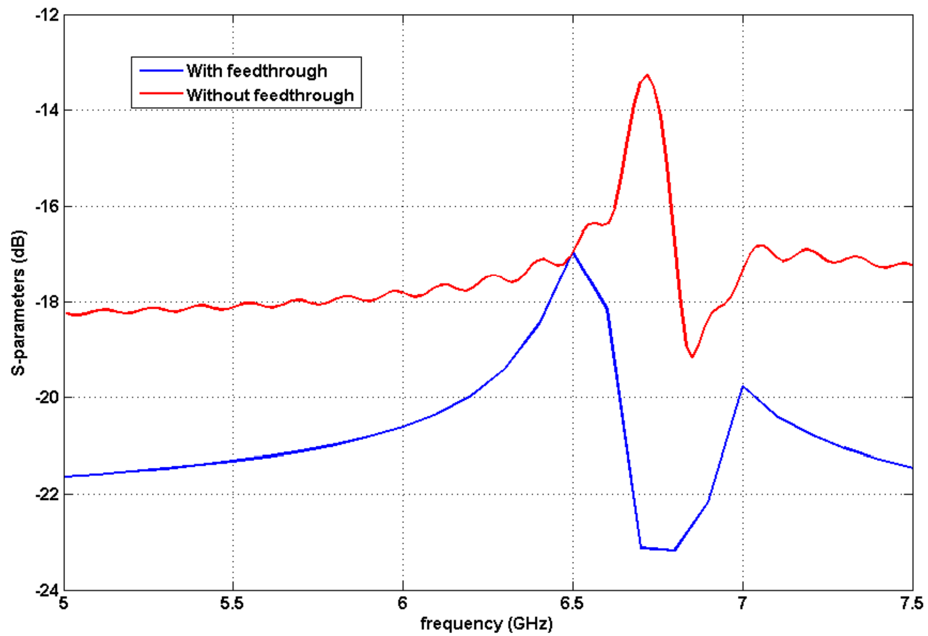
In order to reduce this enhancement, would have to happen that the distance between two feedthrough's should be at least equal to one half of the resonant mode wavelength

$$d_h = \frac{2\pi}{n}\bar{r} = \frac{\lambda_{TM01}}{2}$$

Indeed for a structure having $\bar{r} = 22\text{mm}$

$\lambda_{TM01} = c/6.9\text{GHz} = 43\text{mm}$

The optimum is for n=6



Some consideration

The two requirements concerning the feedthrough resonances and the effect of the feedthrough enhancement on the gap resonances are in conflict:

Feedthrough resonances

$$F = \frac{c}{\mathrm{d_h}}$$

Gap resonance enhancement

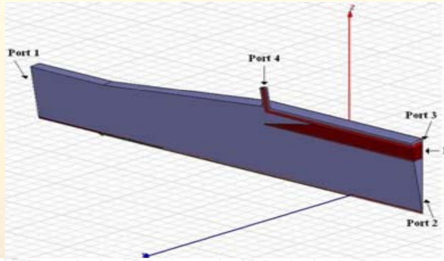
$$\mathrm{d_h} = \frac{2\pi}{\mathrm{n}}\bar{r} = \frac{\lambda_{\mathrm{TM01}}}{2}$$

$\mathbf{d_h}$ has to be, on the one hand, as small as possible, on the other hand, at least equal to one half of the TM01 wavelength

Three possible solutions found

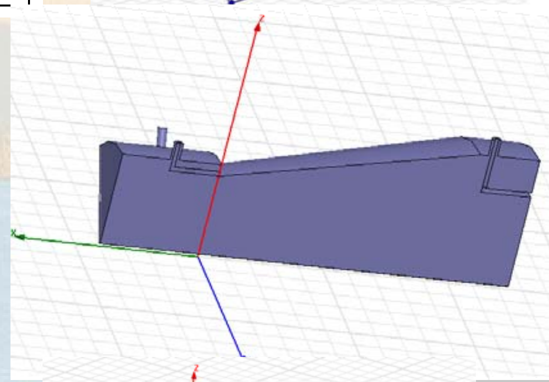
1.

Number of feedtrhoughs	16
Whole foreseen length	50-60cm
Frequency range of the 3dB signal	2Ghz-20GHz



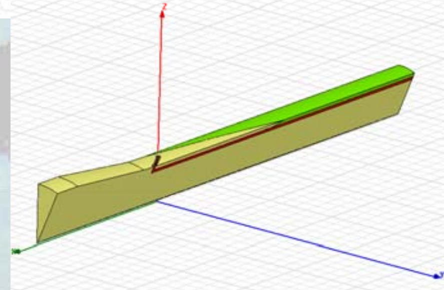
2.

	Low freq	High freq
Number of feedtrhoughs	4	12
Whole foreseen length	≅ 70cm	
Frequency range staying in the 3dB	100kHz-20GHz (except ≅ 5.7GHz-6.2GHz)	



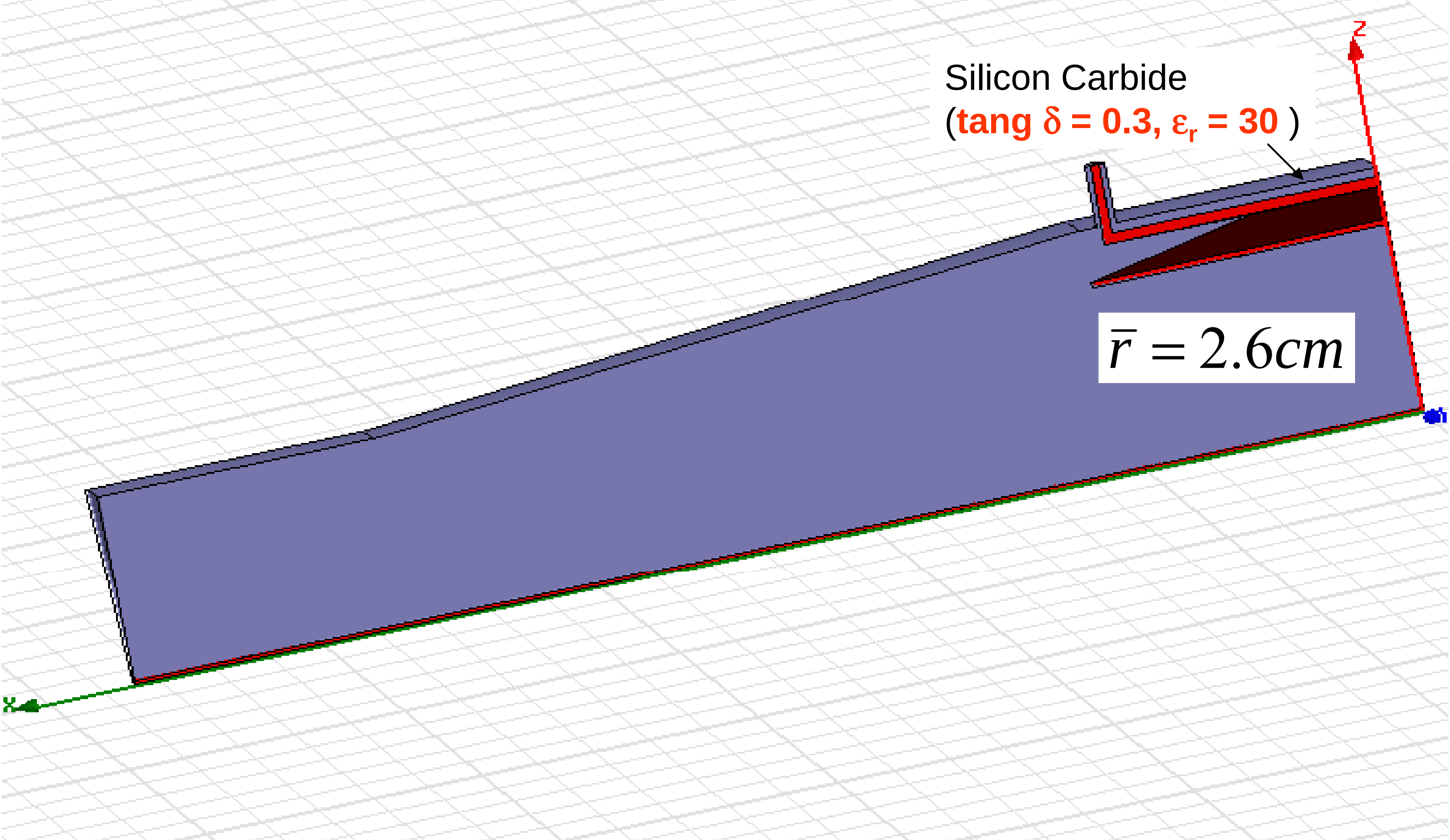
3.

Number of feedtrhoughs	8
Whole foreseen length	≅ 50cm
Frequency range staying in the 3dB	6.2GHz-20GHz

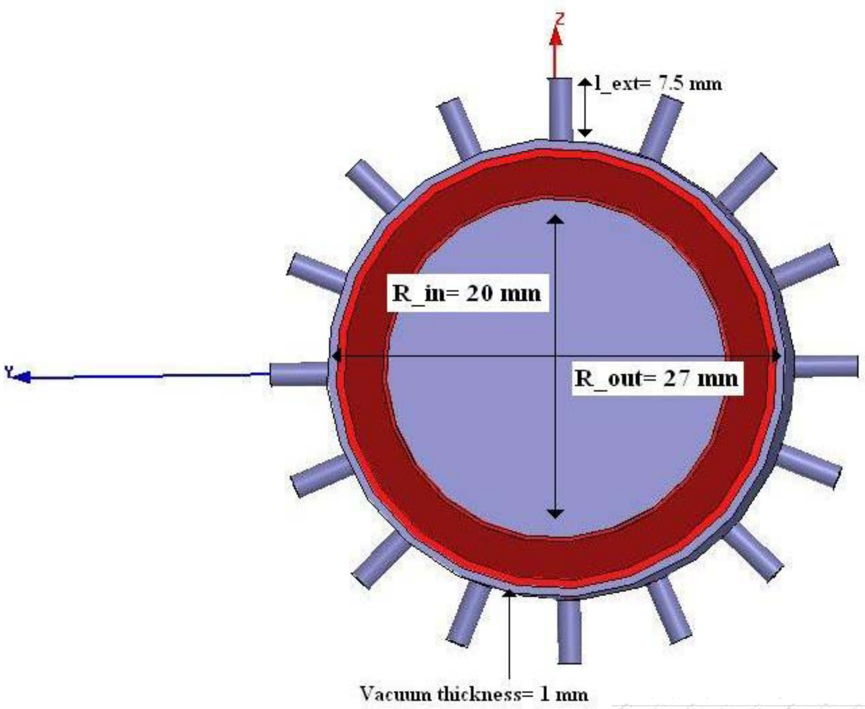


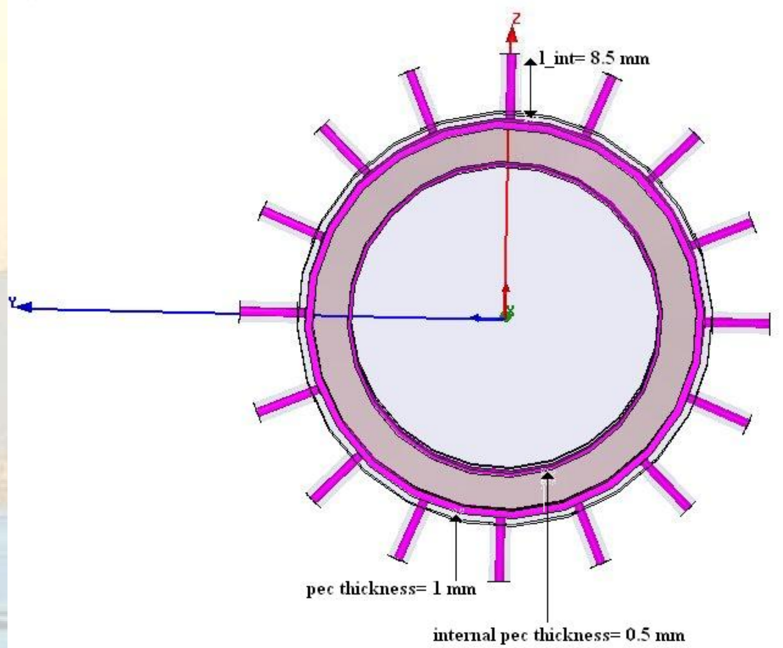
The last two structures present an aperture reduction of 15% and 30%, respectively. For that reason the first one has been chosen.

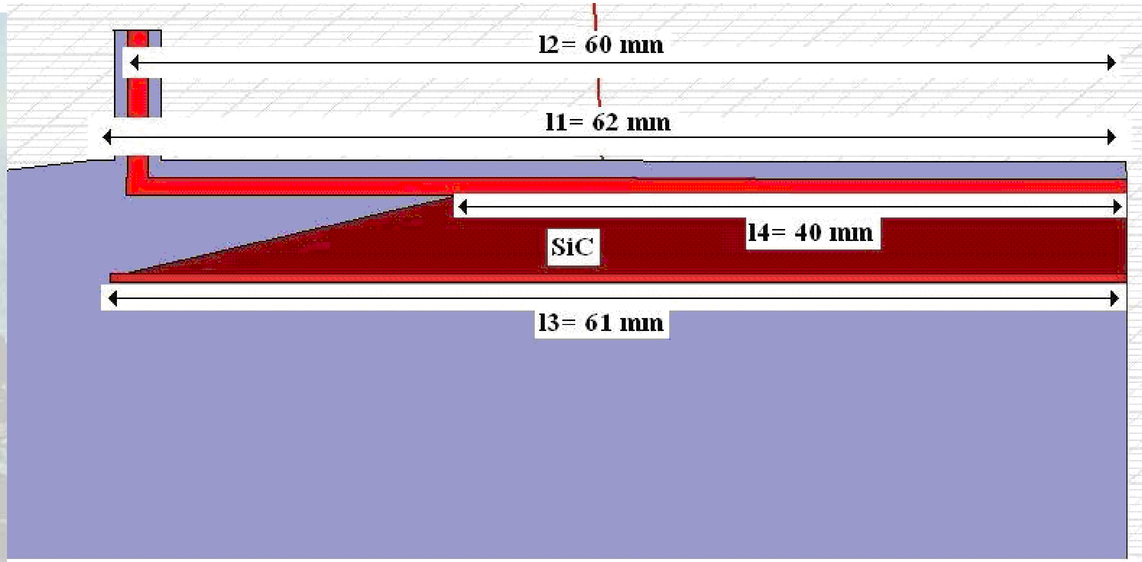
The chosen structure



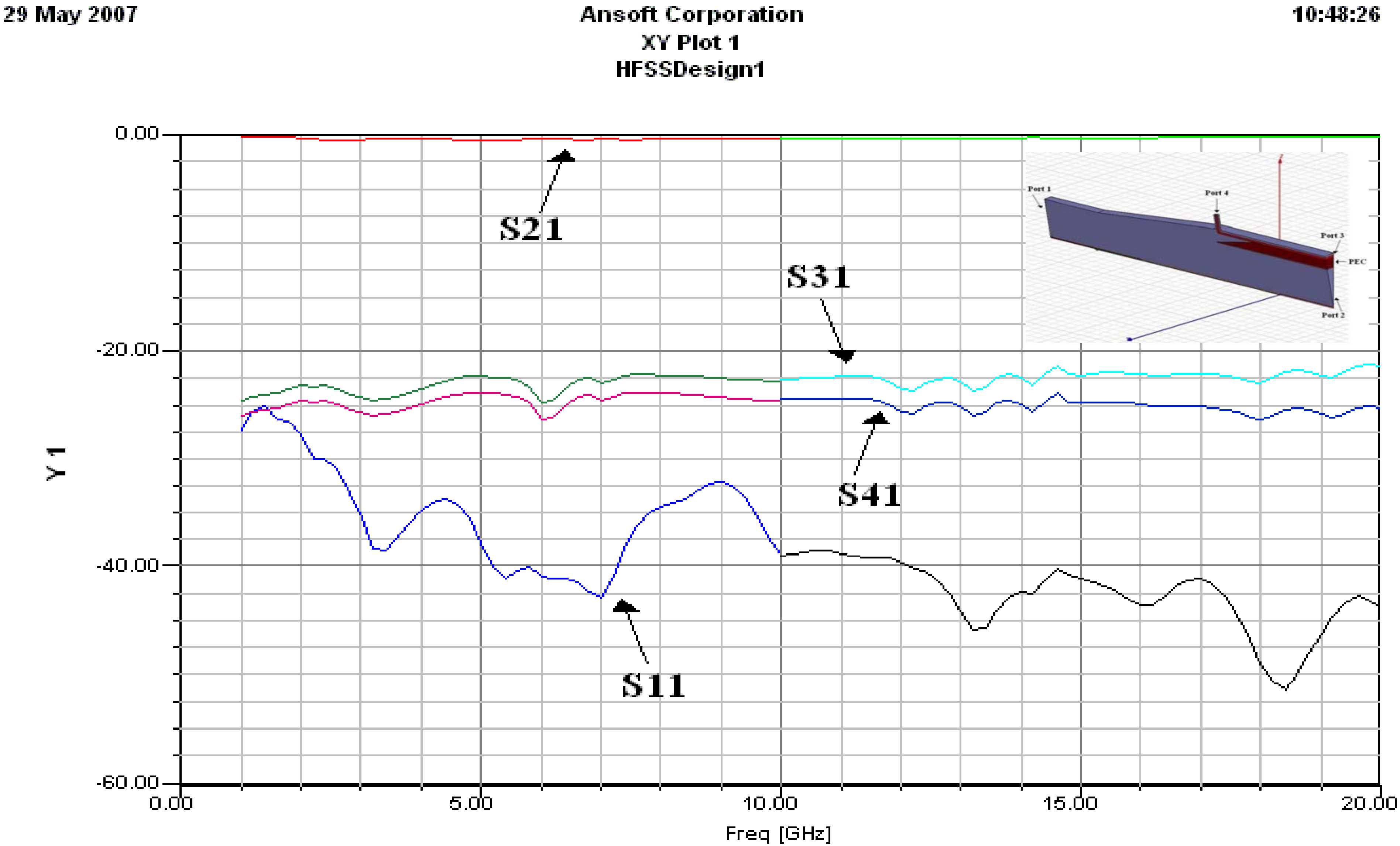
Some geometrical details





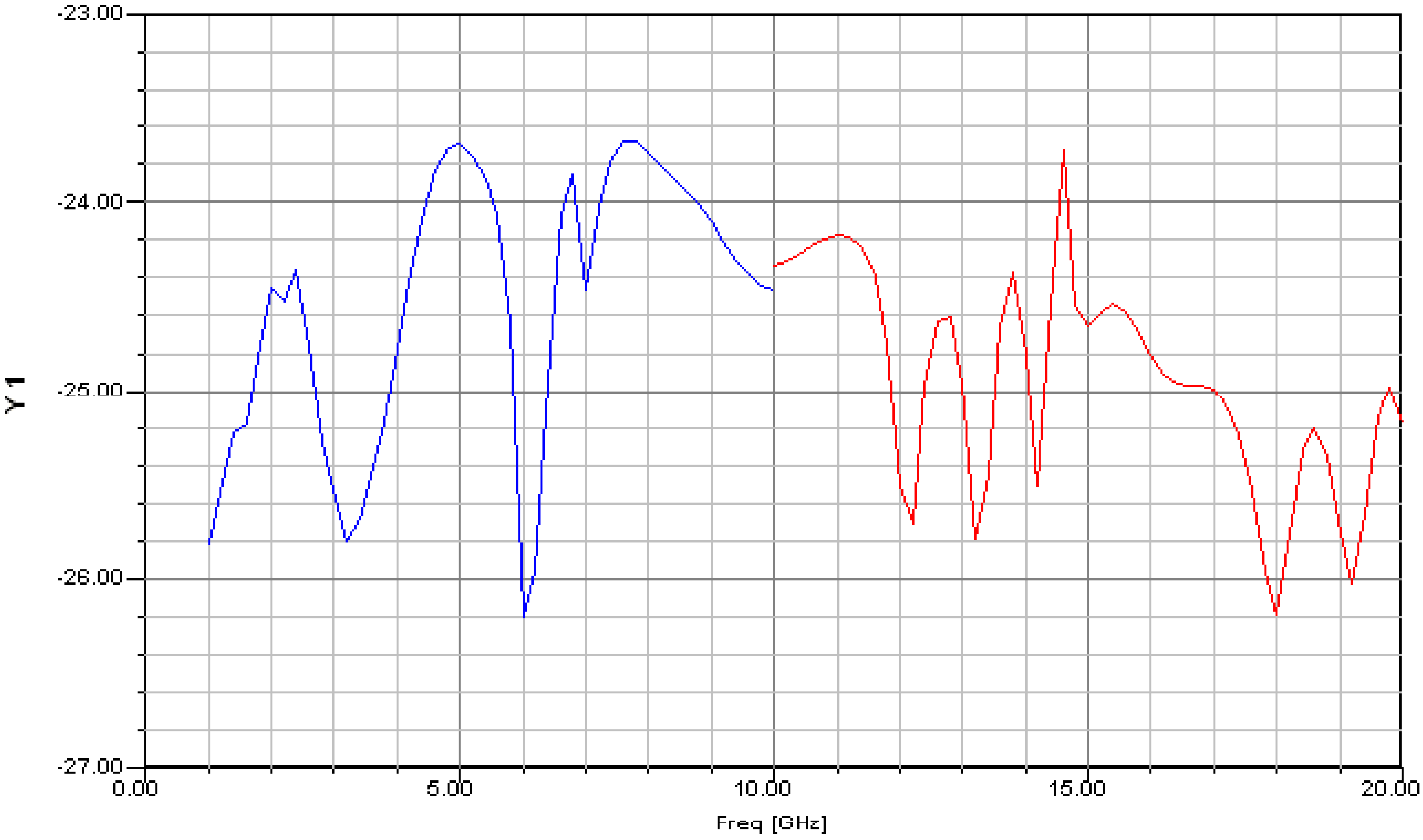


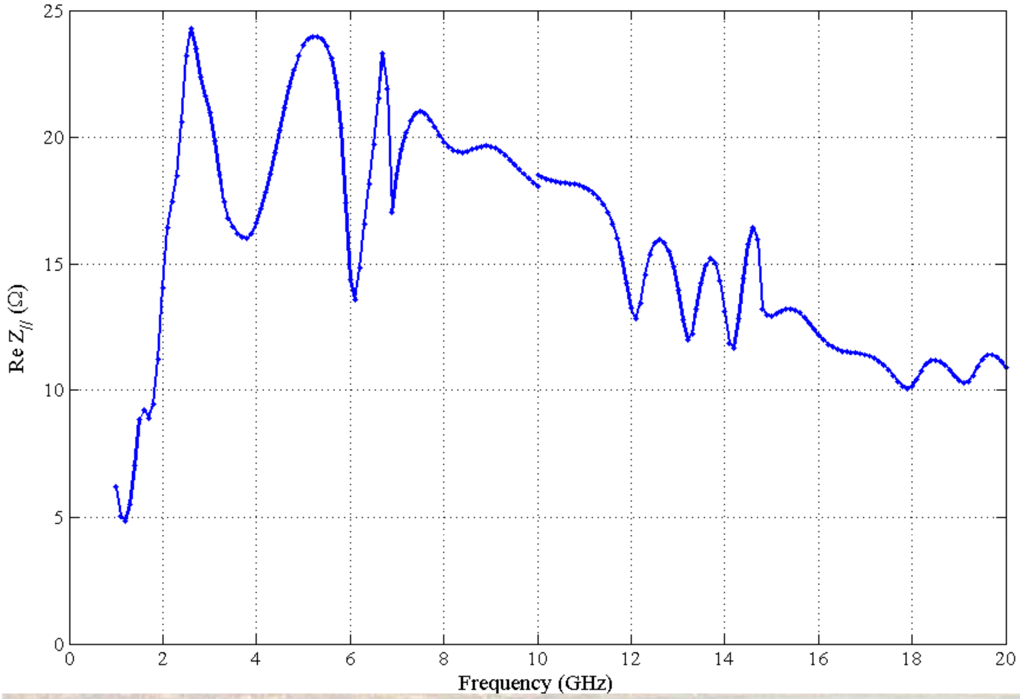
S-parameters



XY Plot 2

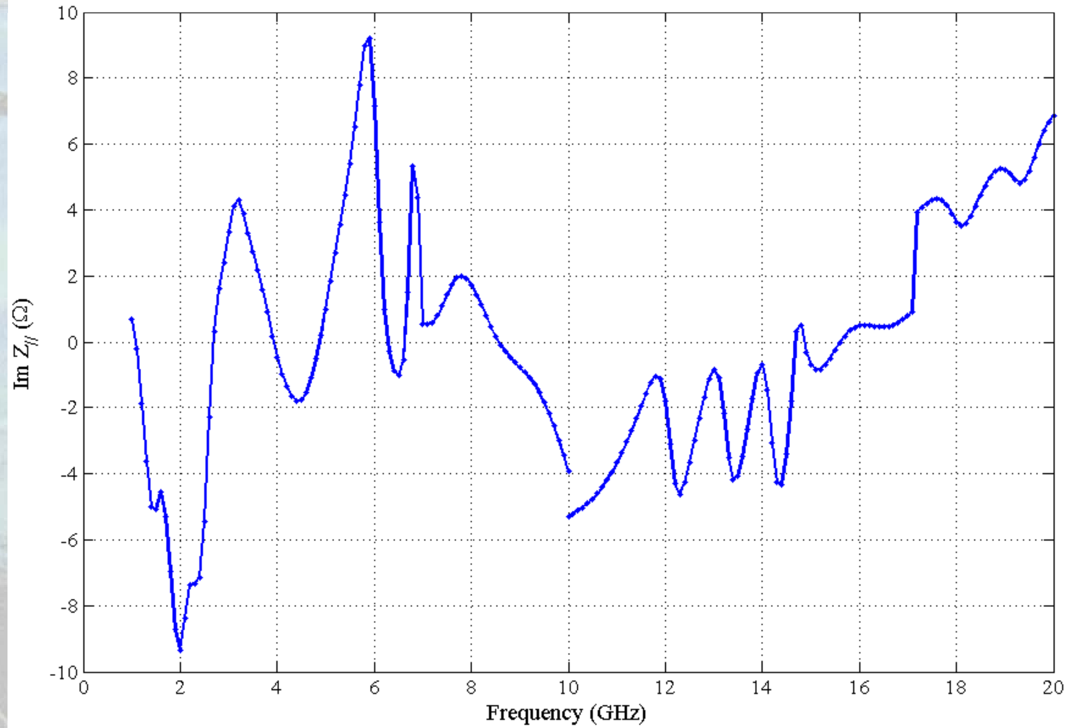
HFSSDesign1



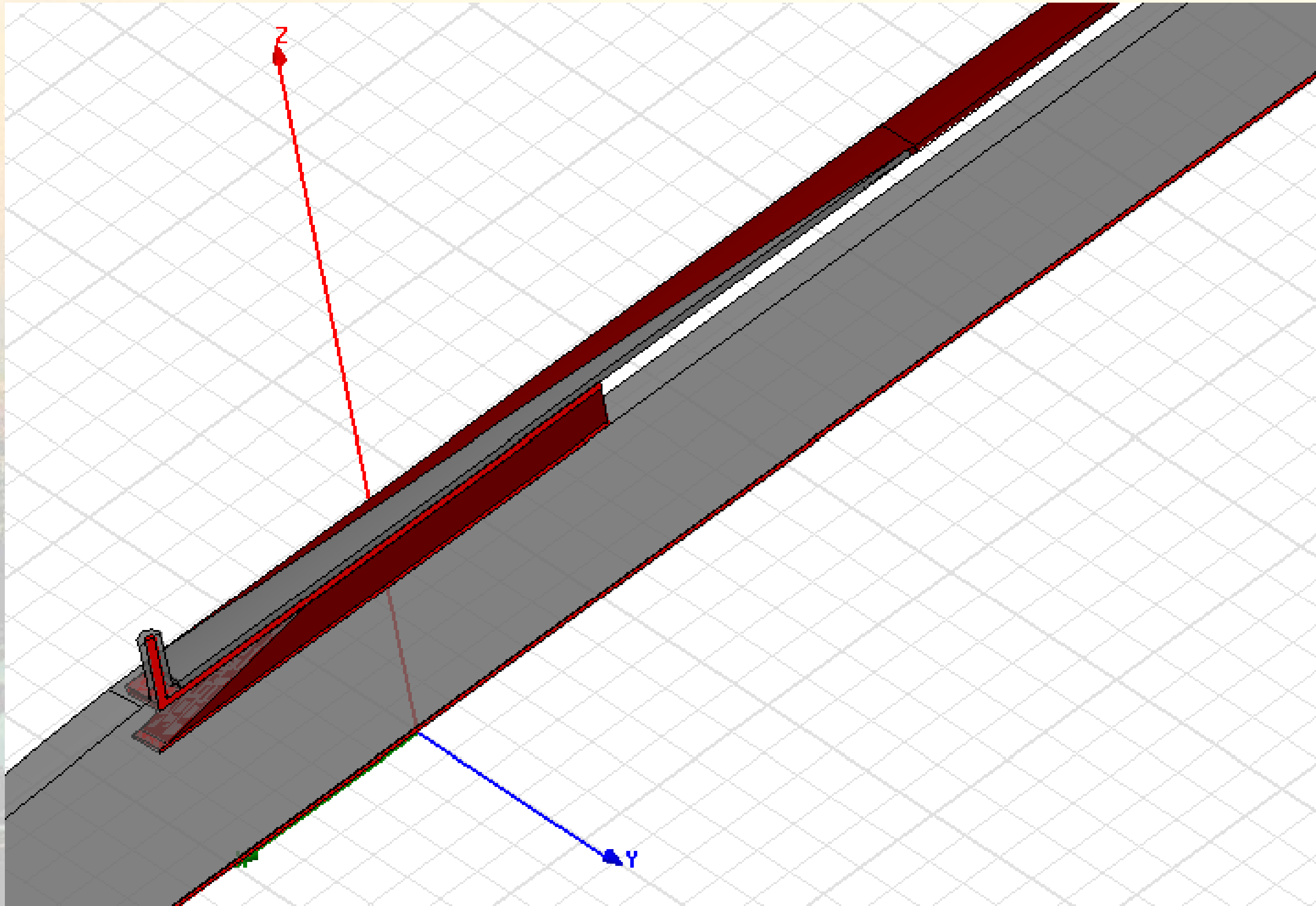


Longitudinal coupling impedance: Real part

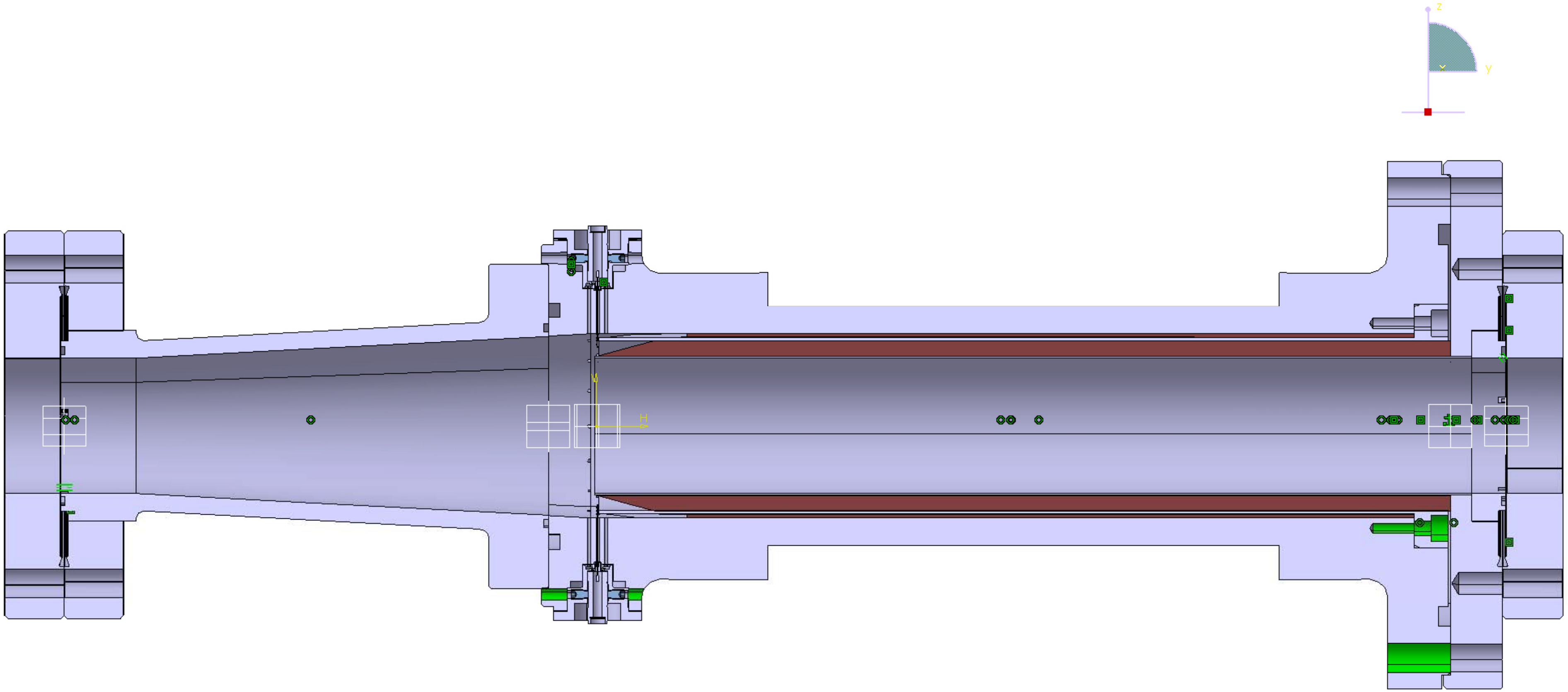
Longitudinal coupling impedance: Imaginary part



The real structure (1)

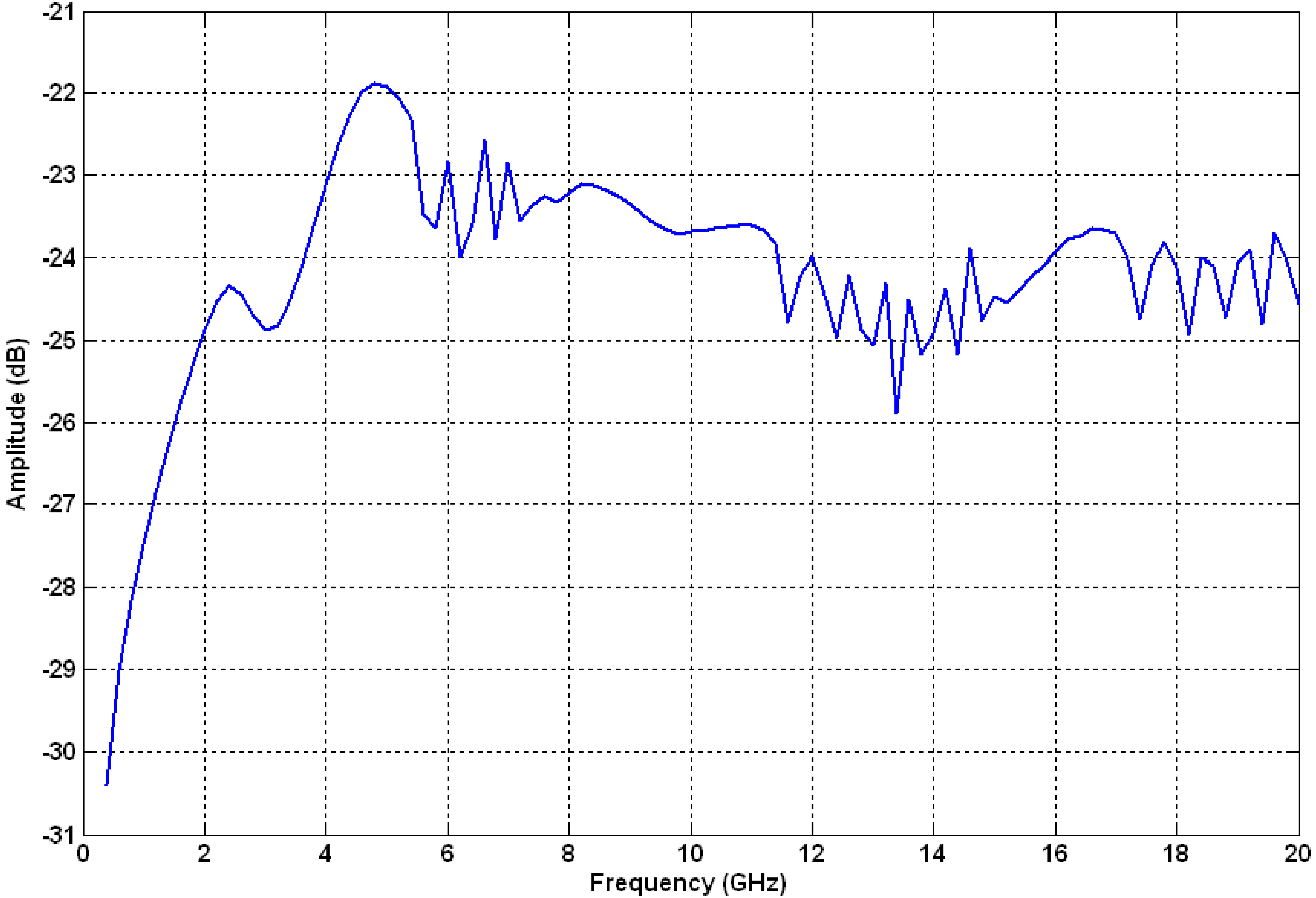


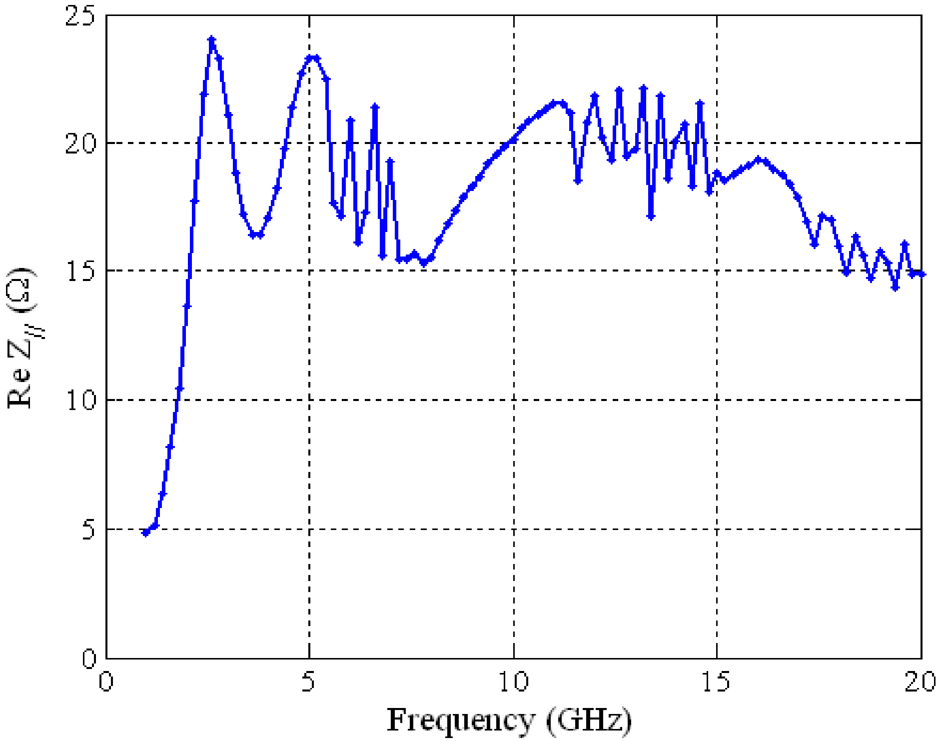
The real structure (2)



With the courtesy of Vincent Maire

Transmission at the feedthrough





Longitudinal coupling impedance: Real part

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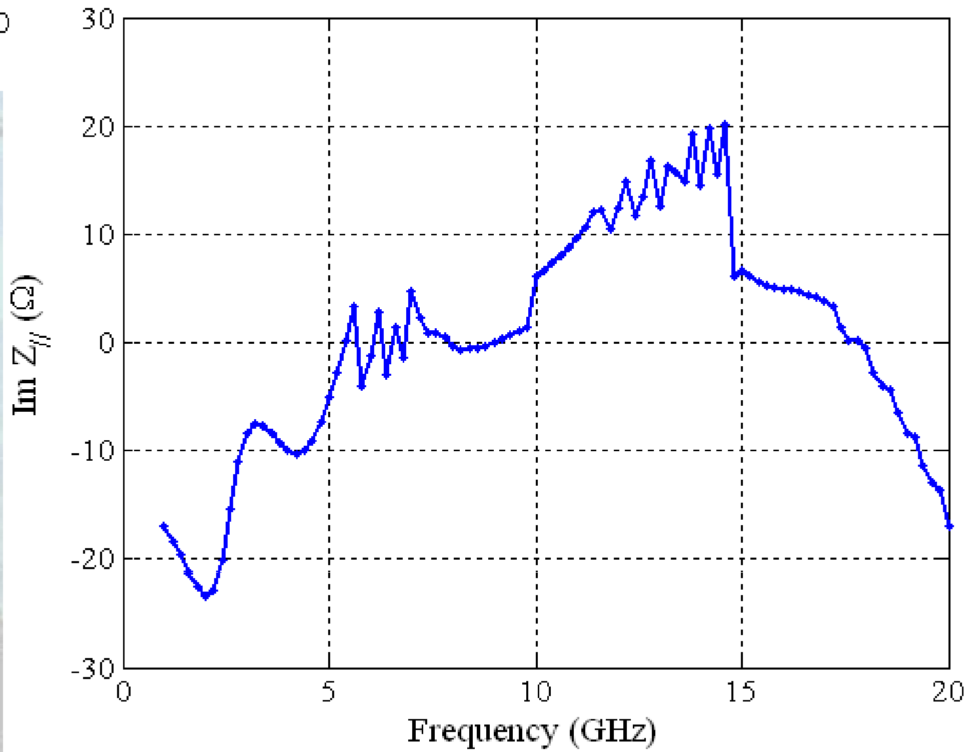
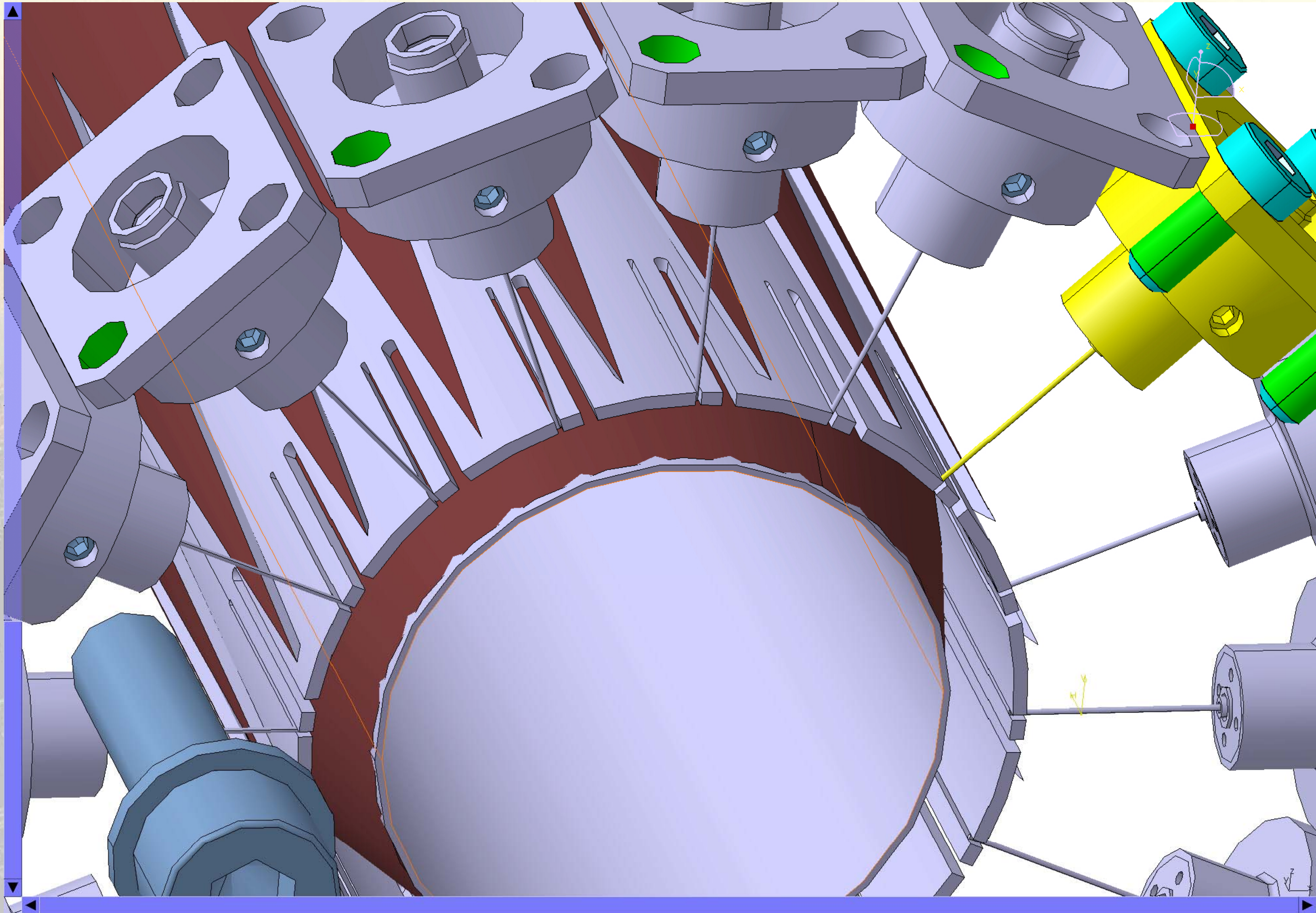
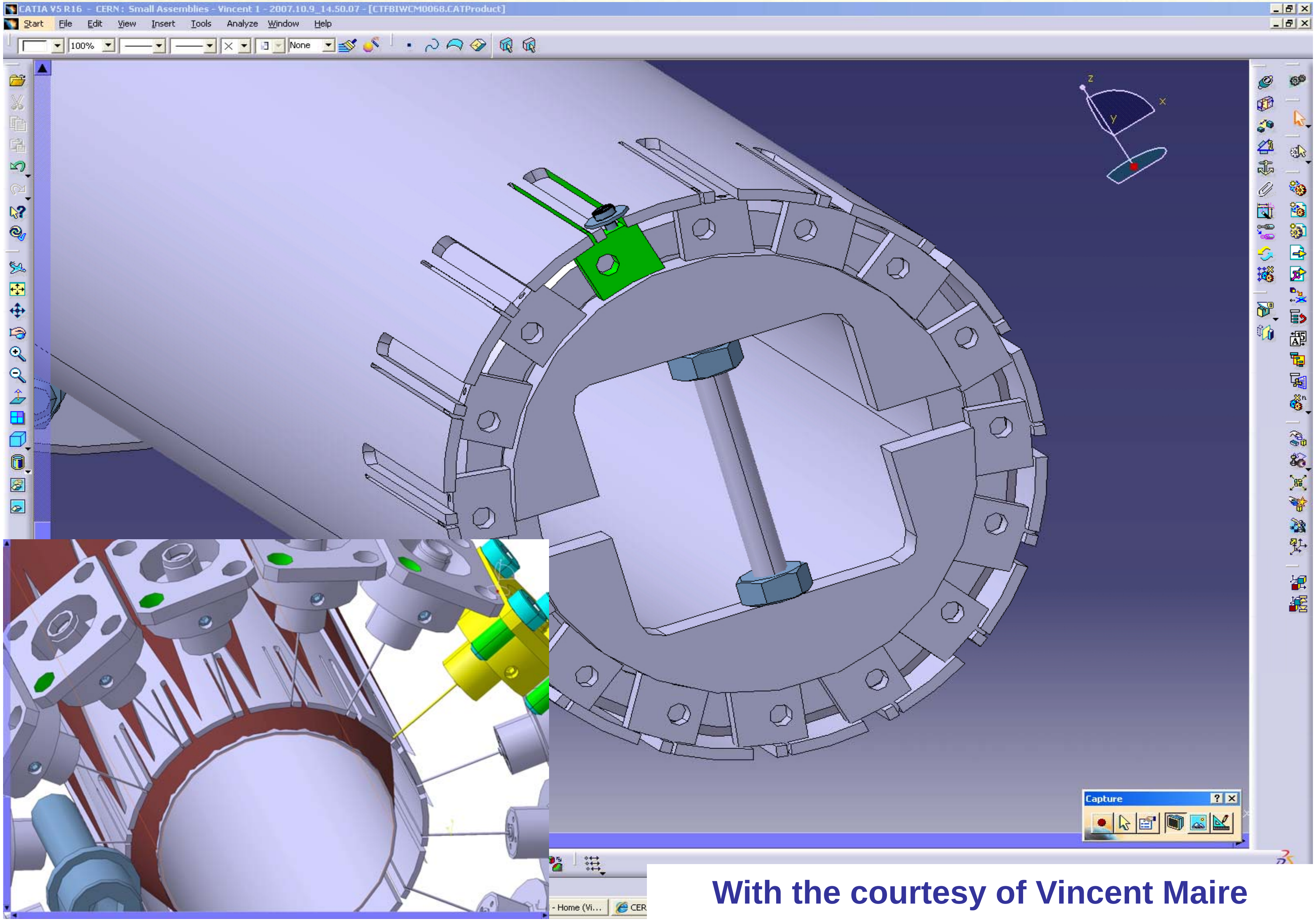


Feedthrough positioning (1)



With the courtesy of Vincent Maire

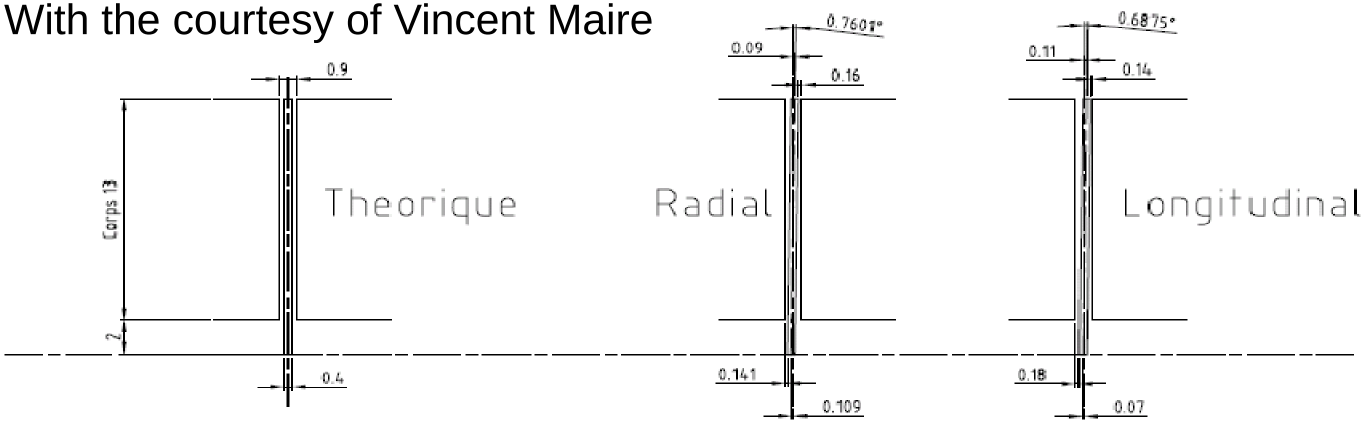
Feedthrough positioning (2)

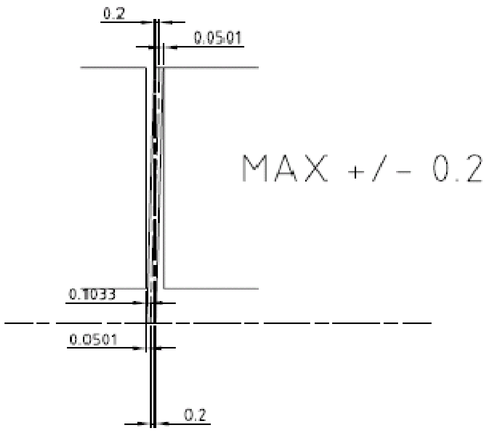


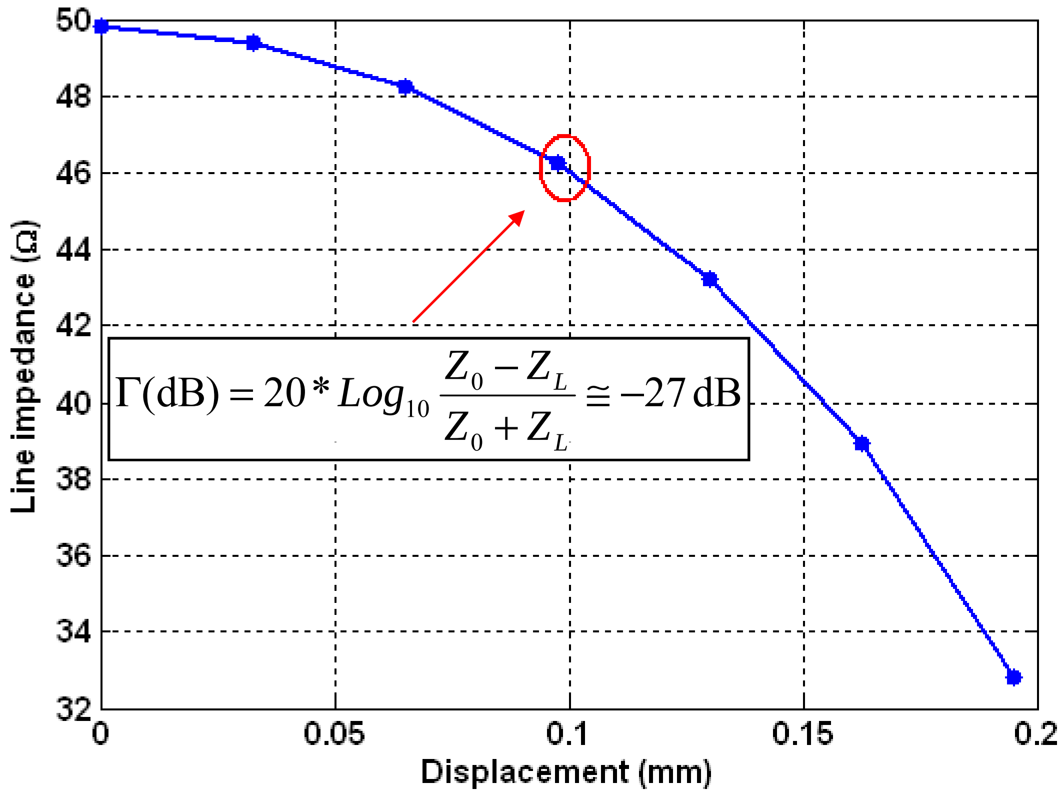
With the courtesy of Vincent Maire

Misalignement problems

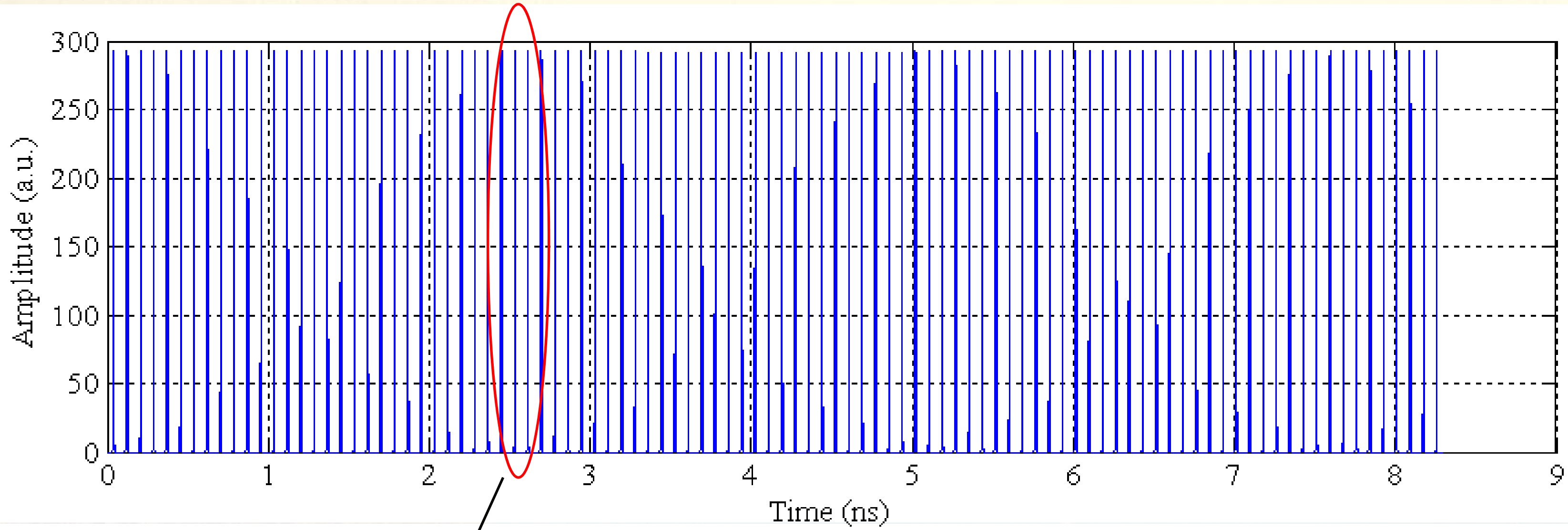
With the courtesy of Vincent Maire

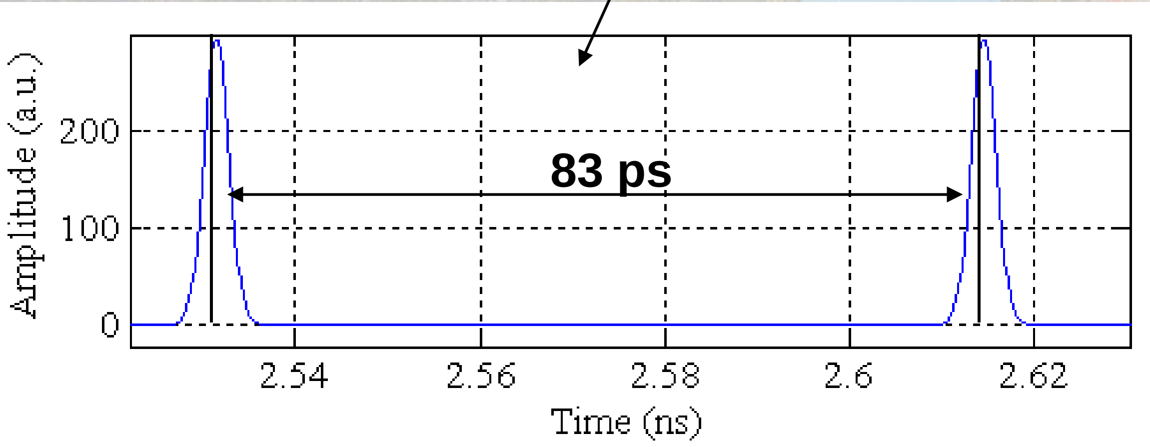






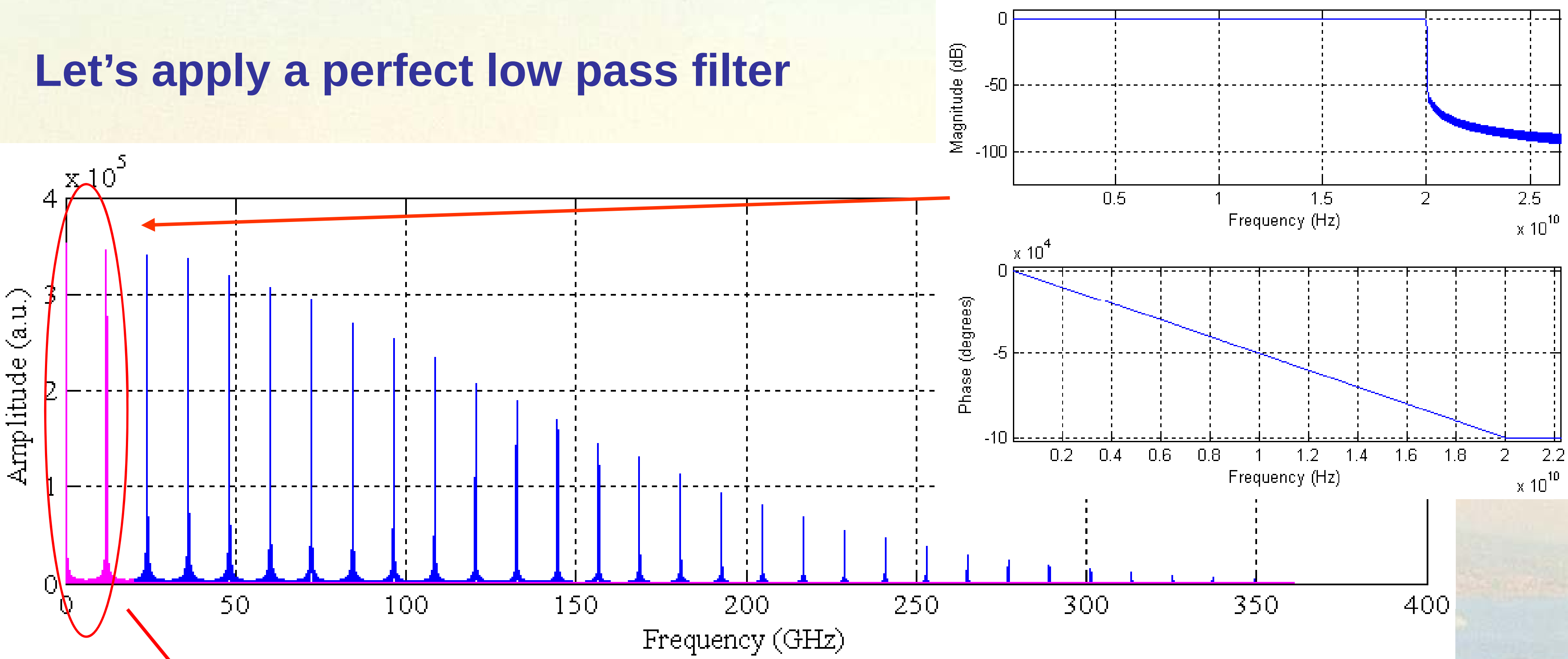
Really do we need 100kHz low freq cut-off?
Let's make some numerical experiment

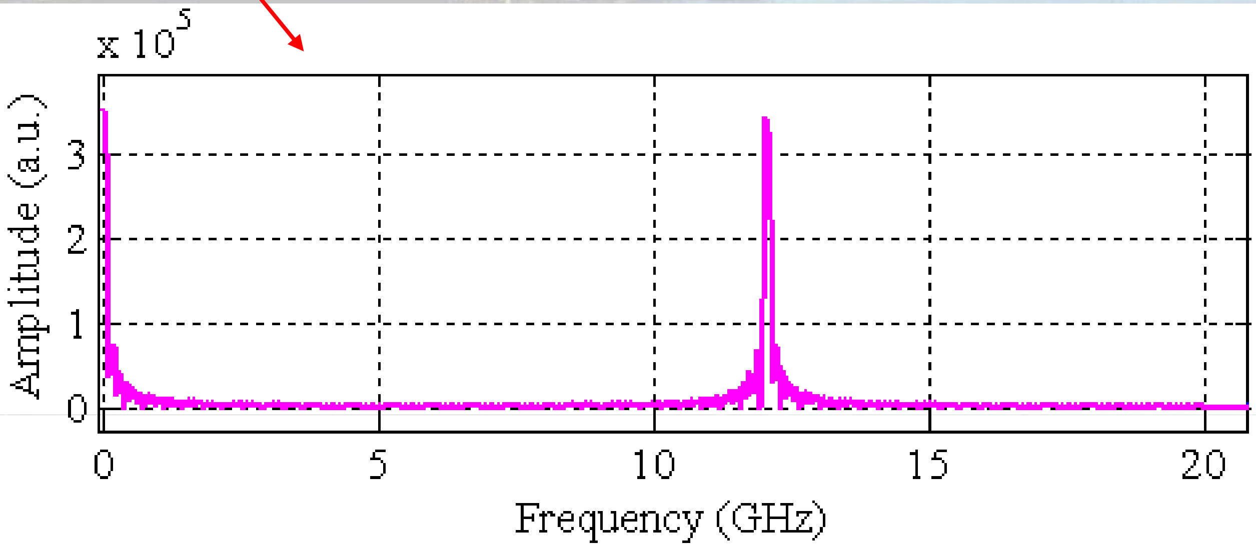




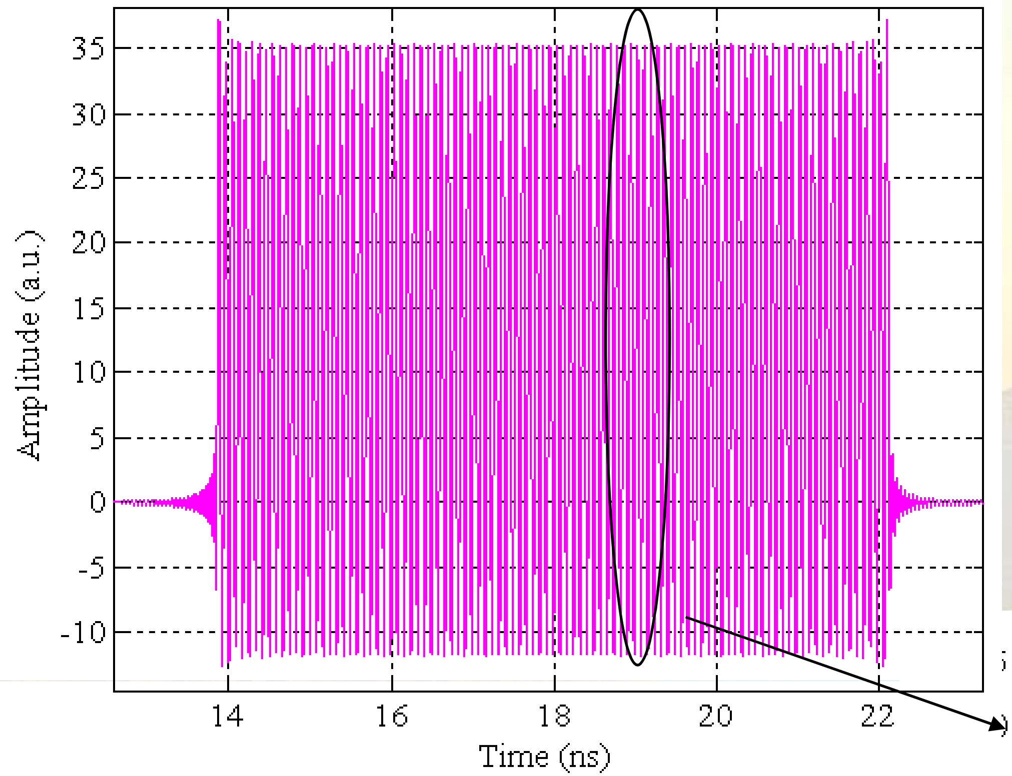
Bunch separation = 83ps
RMS bunch length = 13.3ps
Train duration = 8.3ns
Nb of bunches = 100
Peak current = 293A

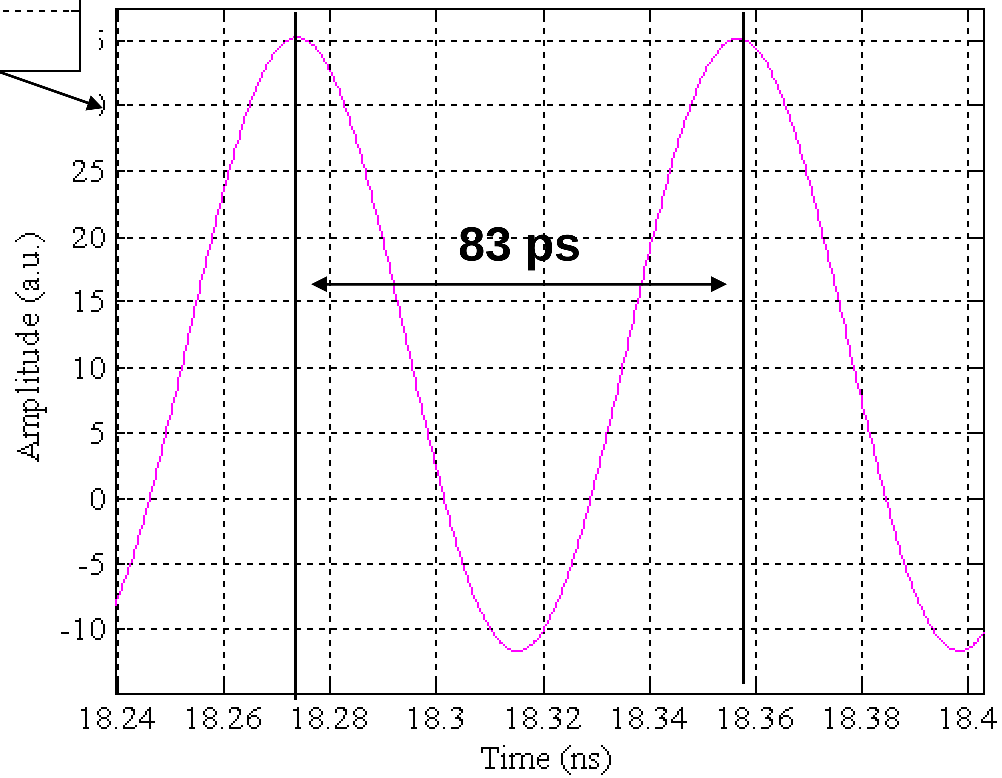
Let's apply a perfect low pass filter

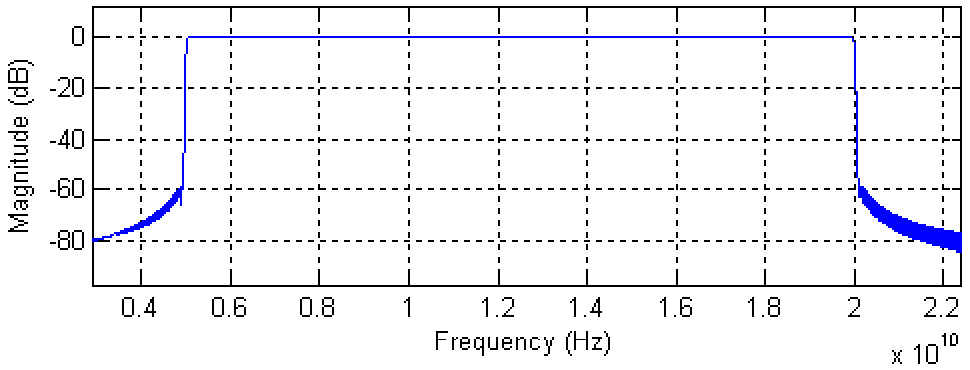


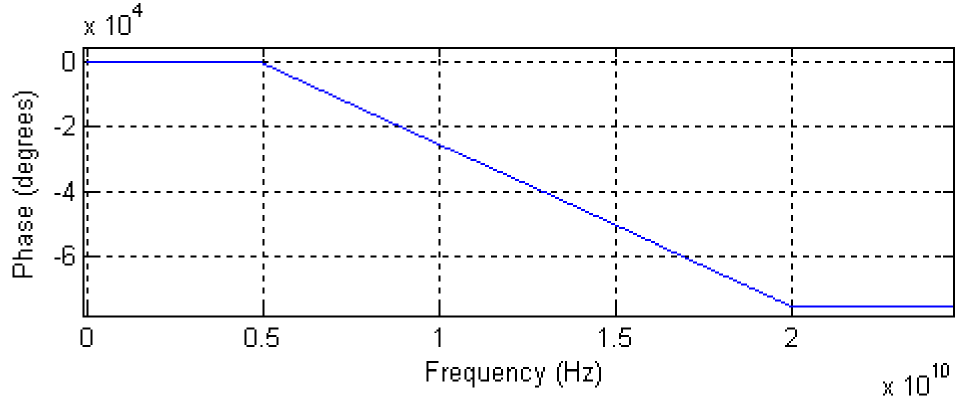


The result in time domain





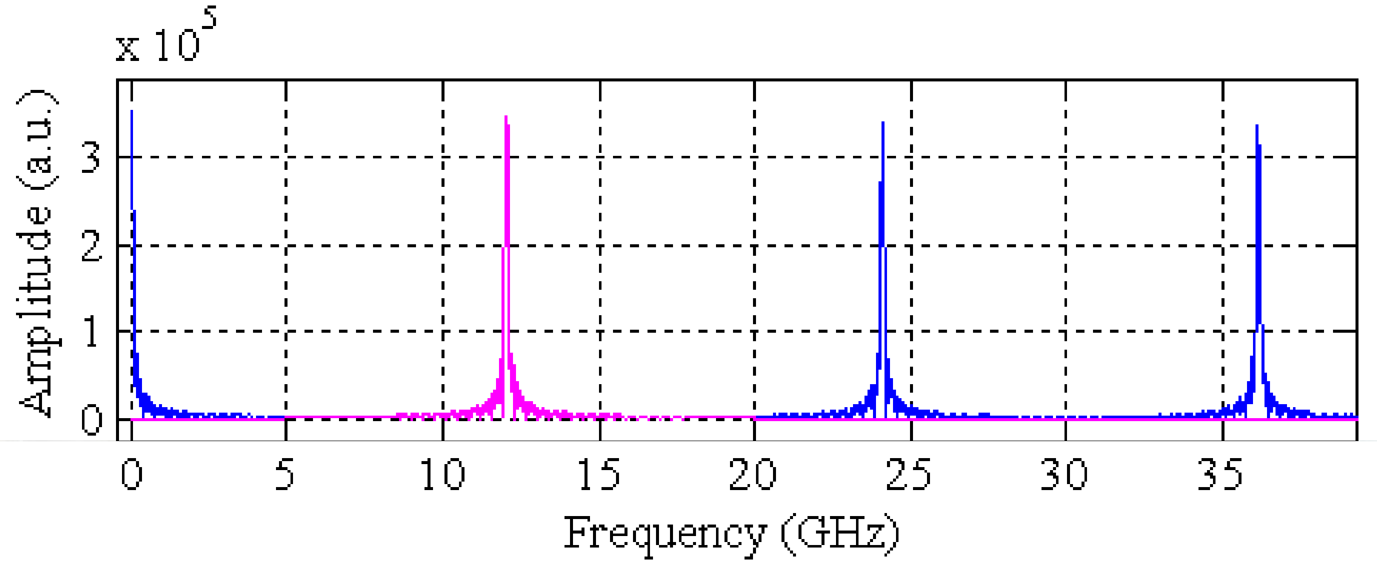


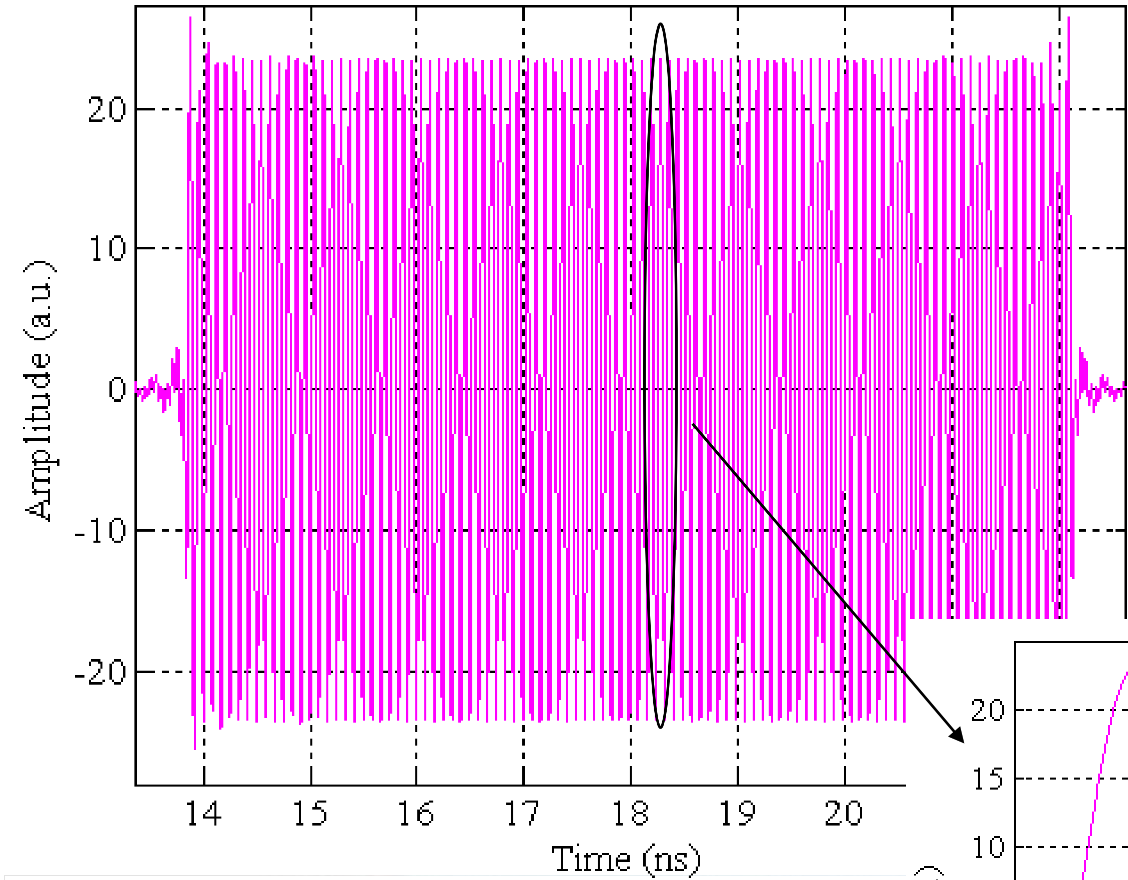


Let's apply, to the same signal as before, a filter having

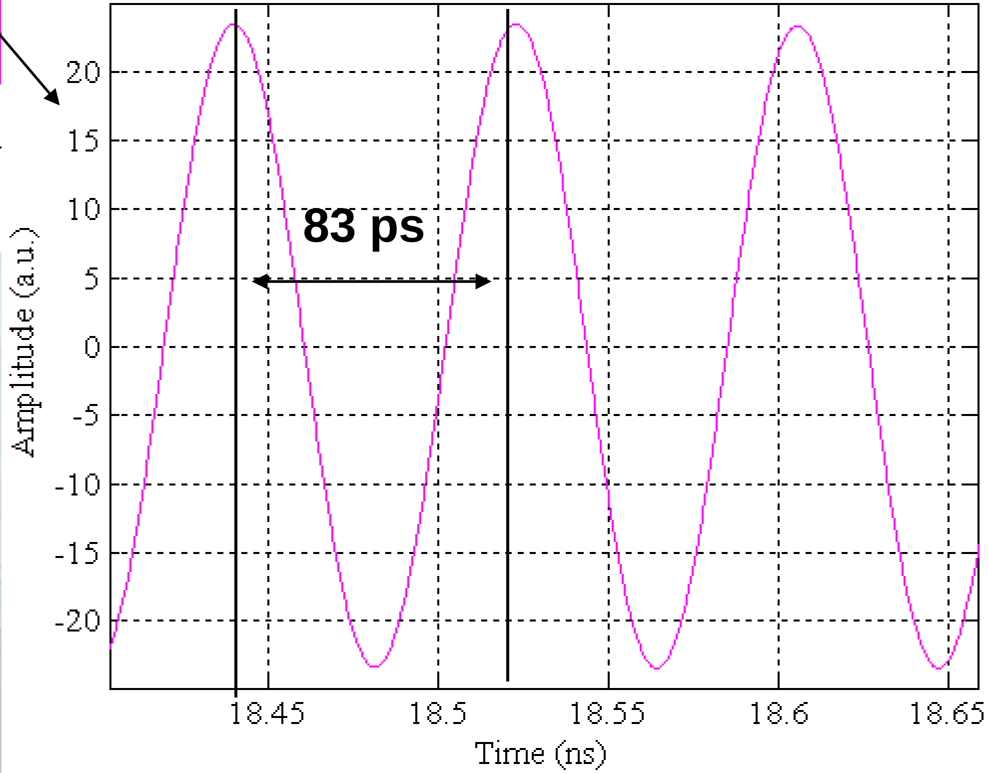
Low freq cut-off= 5GHz

High freq cut-off= 20GHz

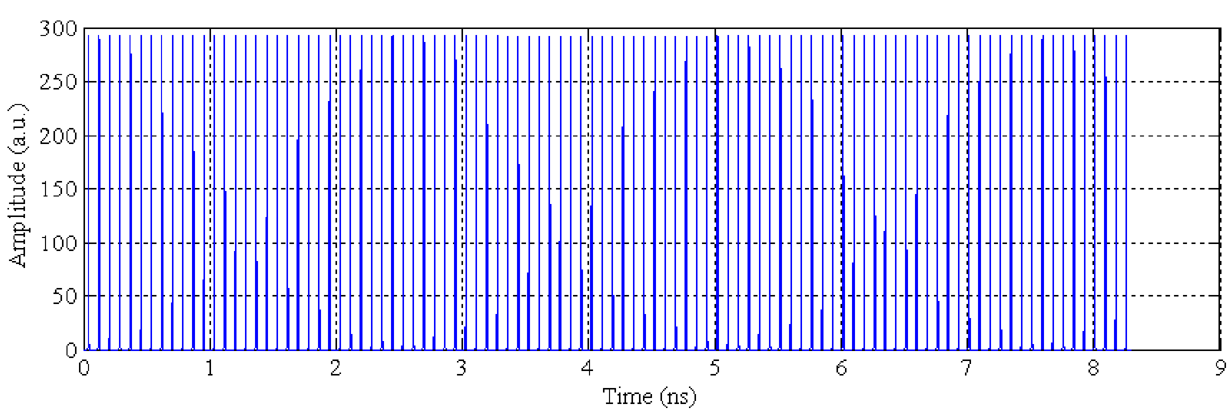


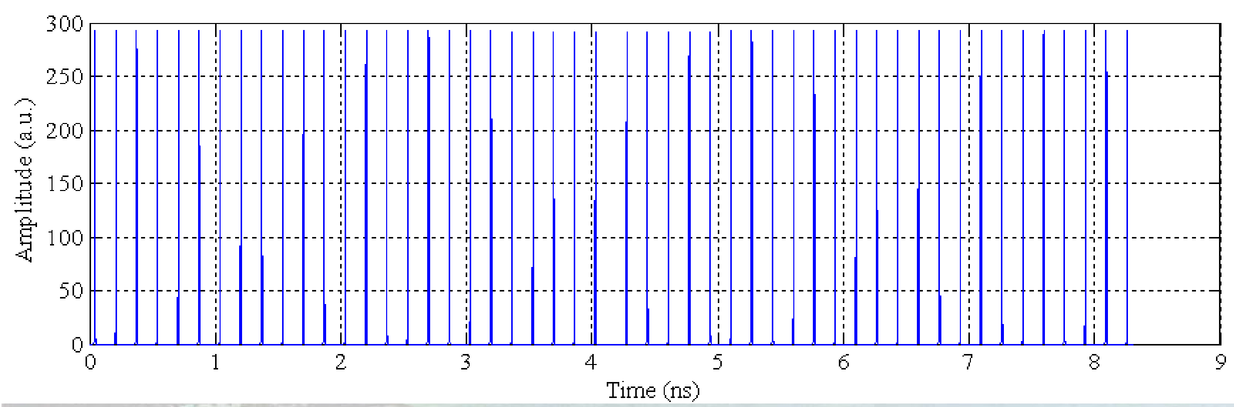


It seems that nothing changes!!!!



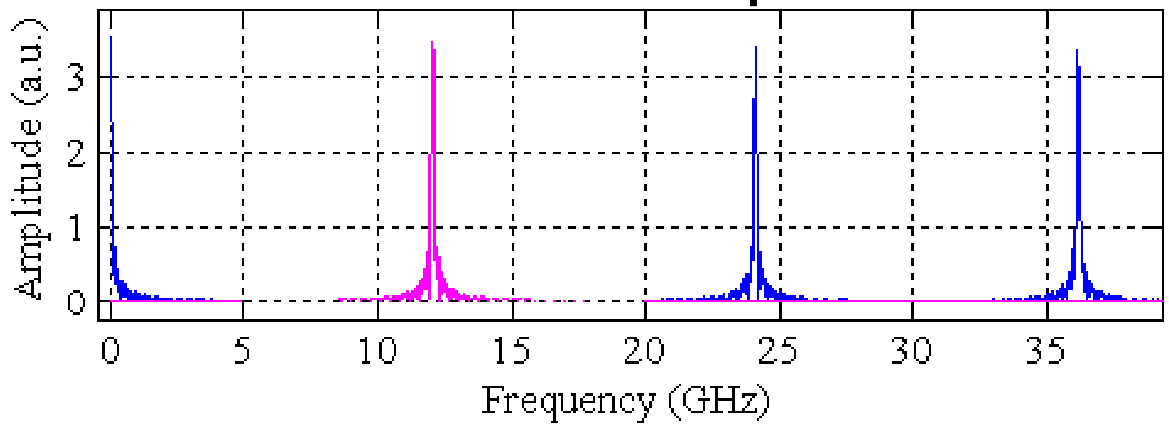
An interesting exercise

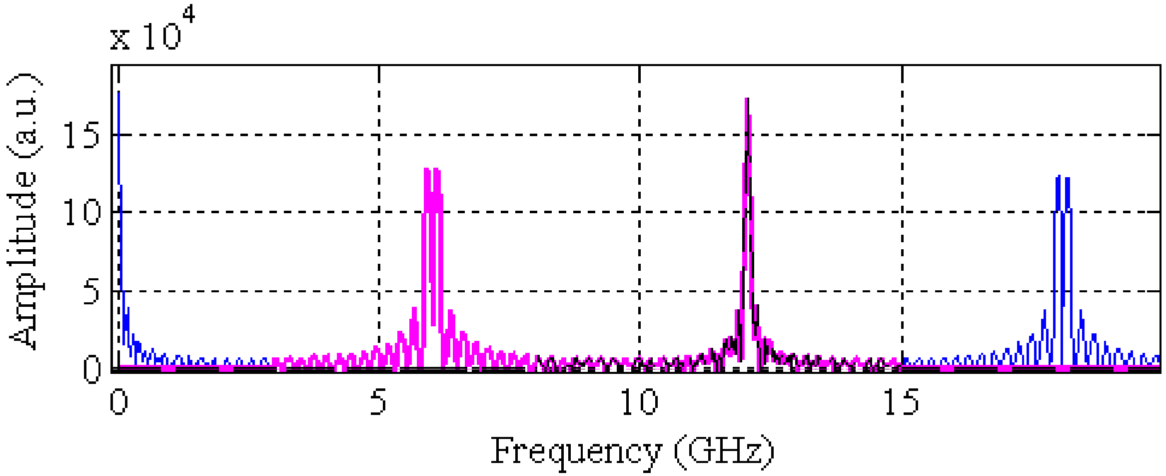




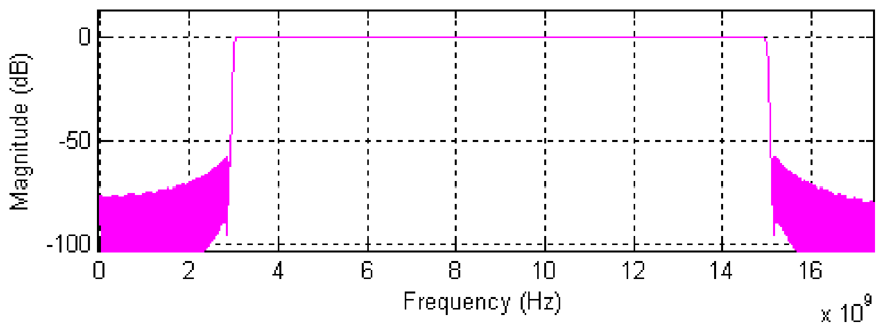
Same condition of before, but some bunches are missed (about 50%)

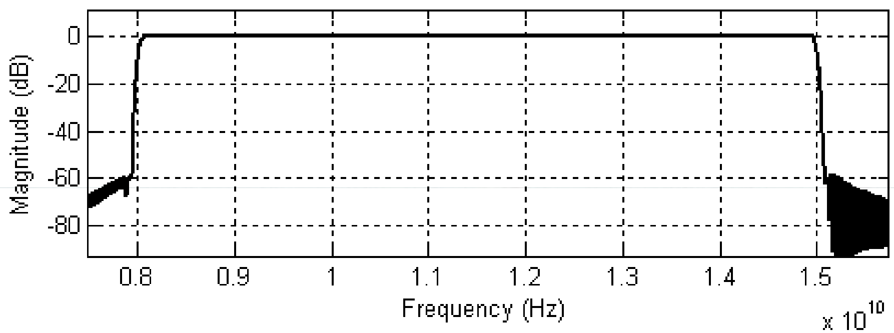
Perfect 100 bunches spectrum

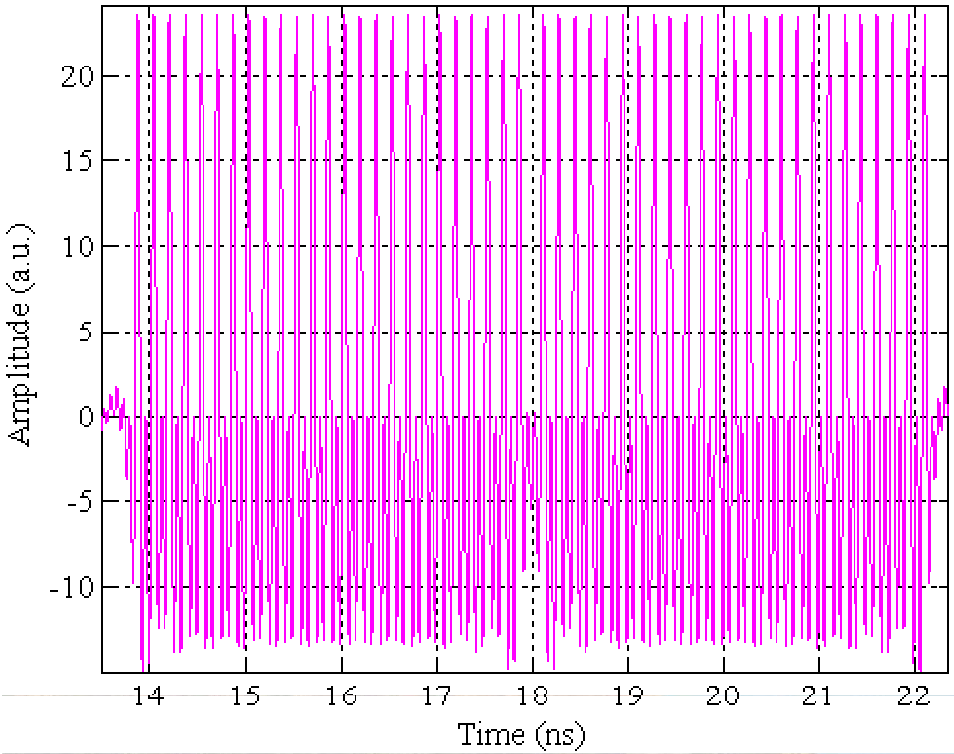




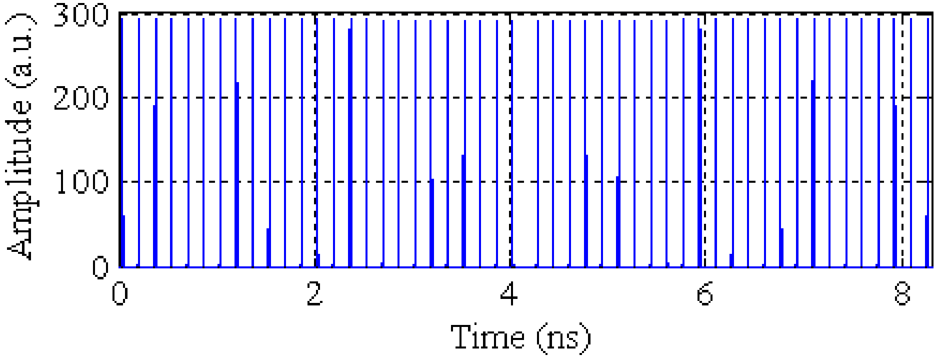
Because of the different, larger, bunch spacing, in the spectrum some new peaks appear at lower frequencies





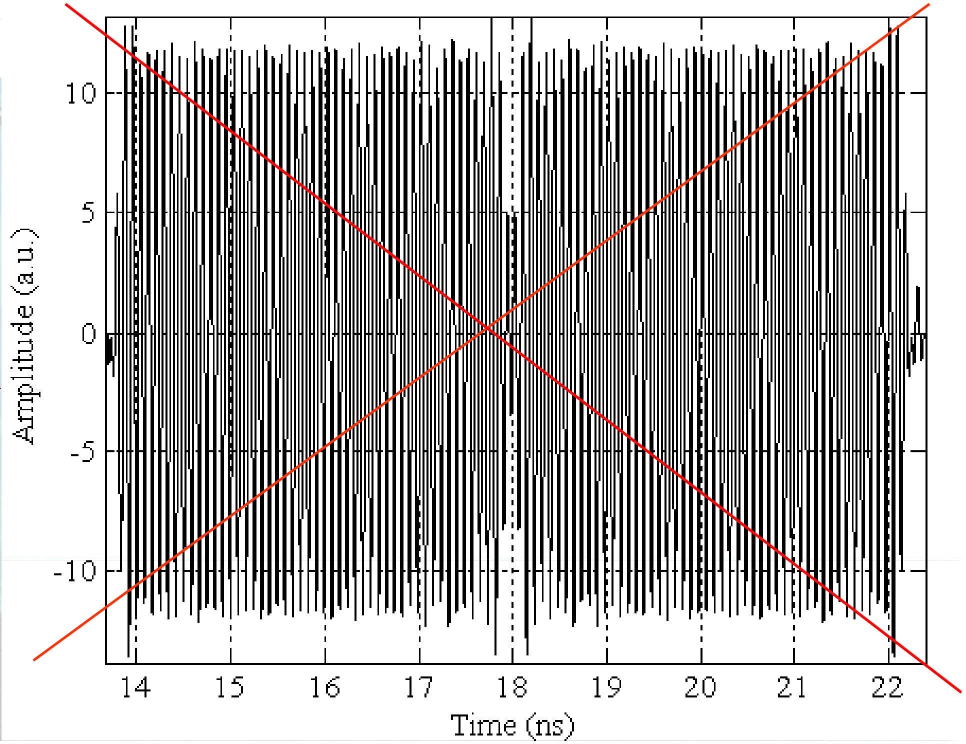


Original signal



Correct signal recovering!!!

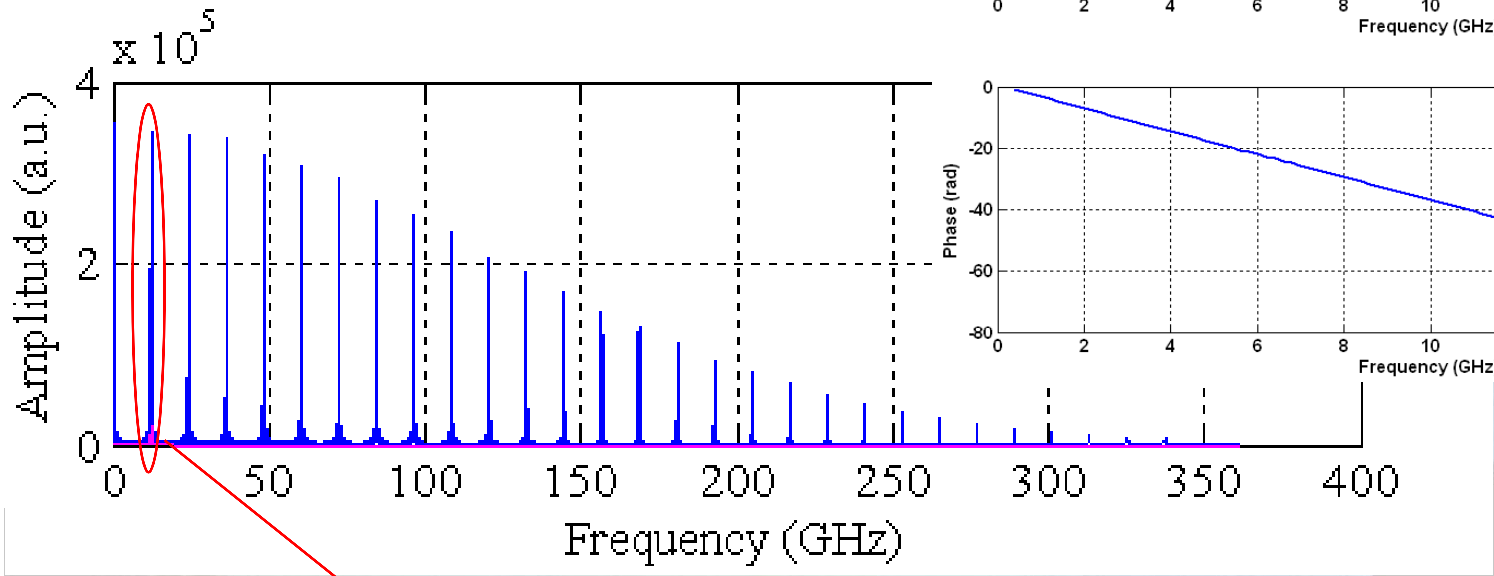
Wrong signal recovering!!!

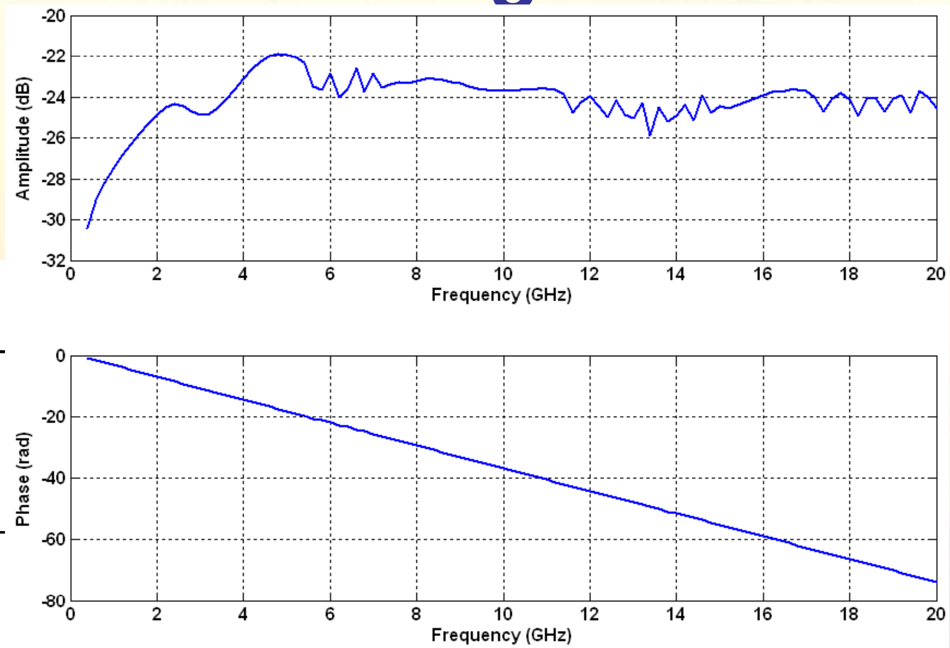


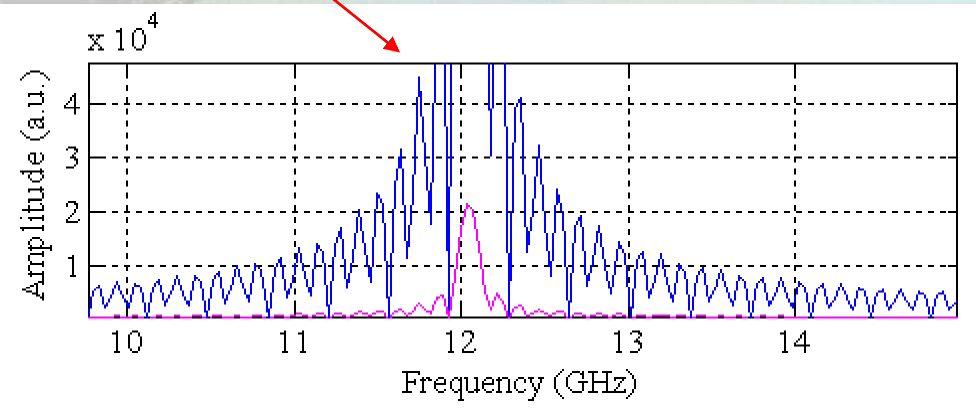
Some consideration

If some bunches are missed, we need a proper low frequency cut-off in order to solve the larger bunch spacing appearing in the spectrum like new peaks at lower frequencies. Therefore the low frequency cut-off should be settled up in relation to the maximum expected missed bunch ratio.

Applying the WCM "real" signal





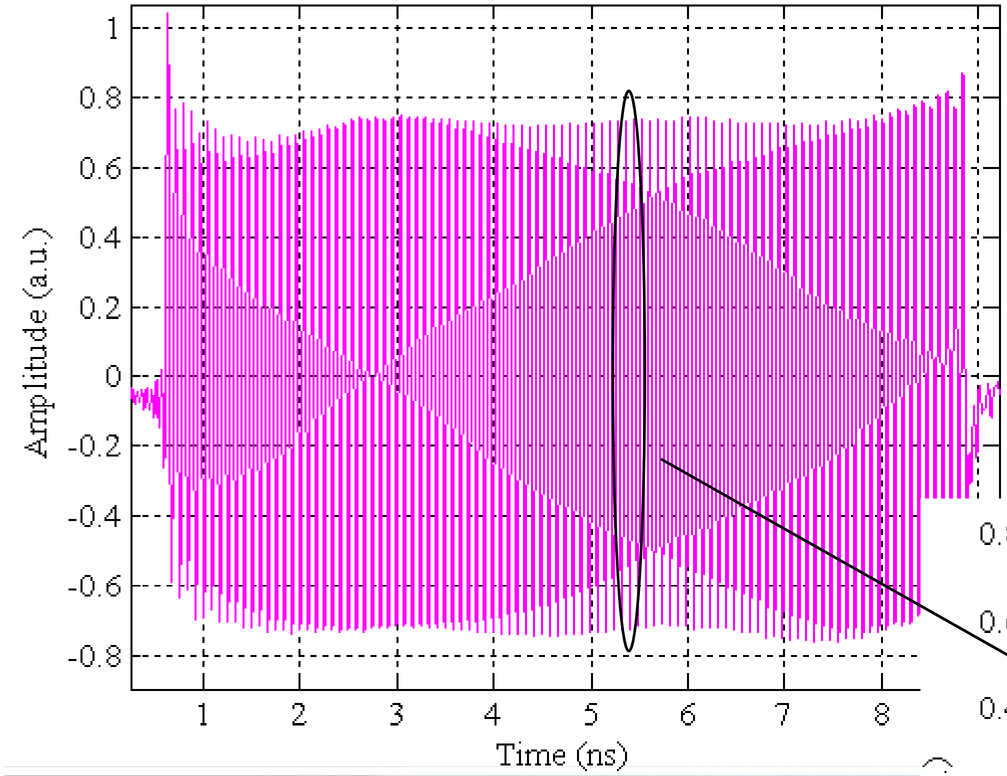


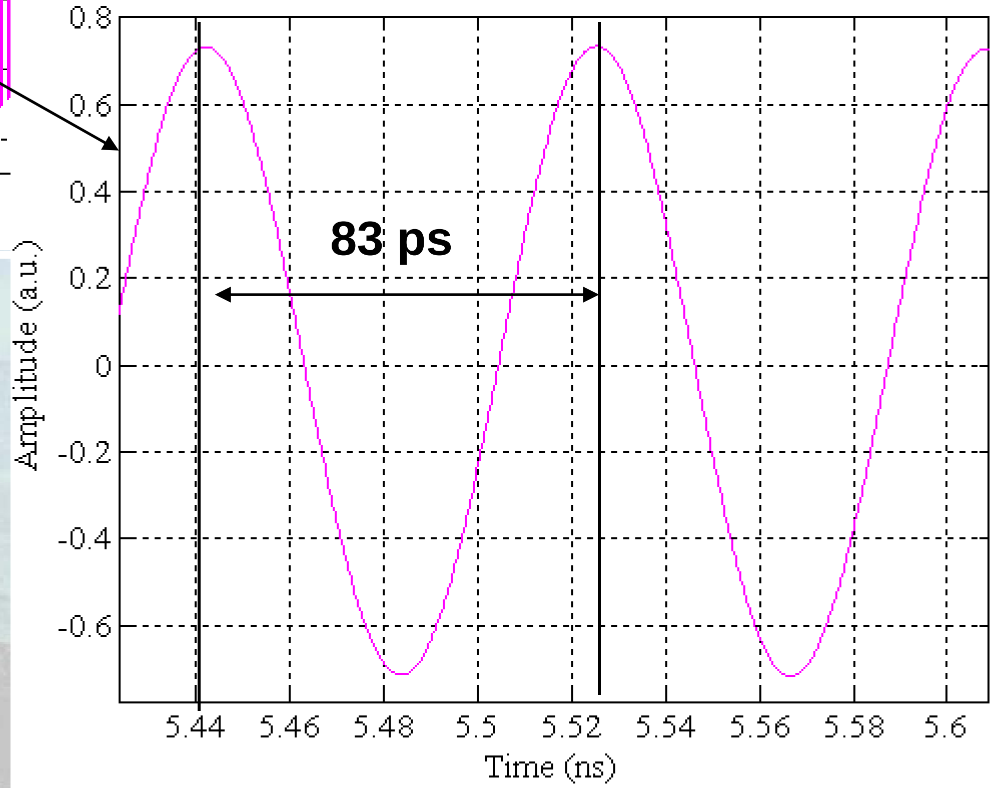
Low freq cut-off ≅ 2GHz

500 ps ≅ 6 bunches missed

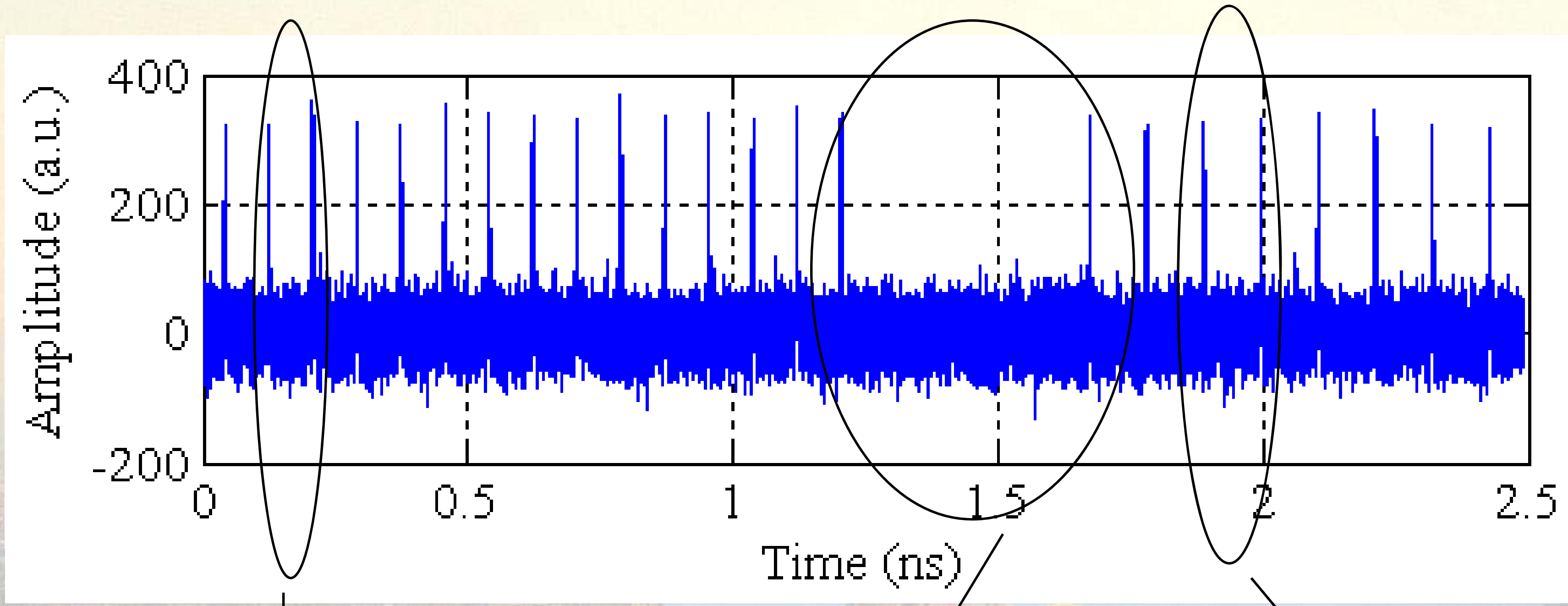
(Or 30 by compensating down to 400 MHz)

The result in time domain





A last academic exercise



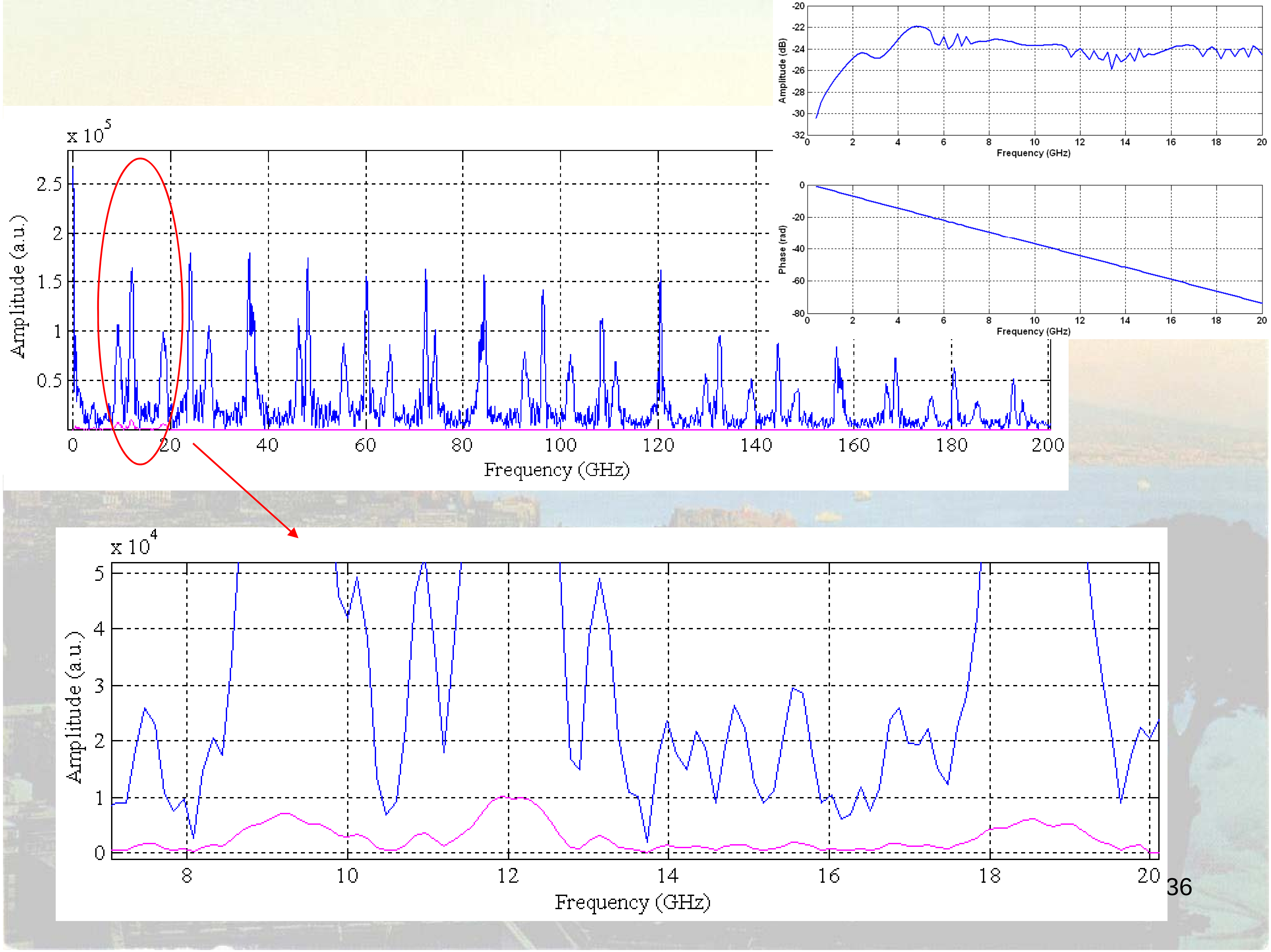
83 ps

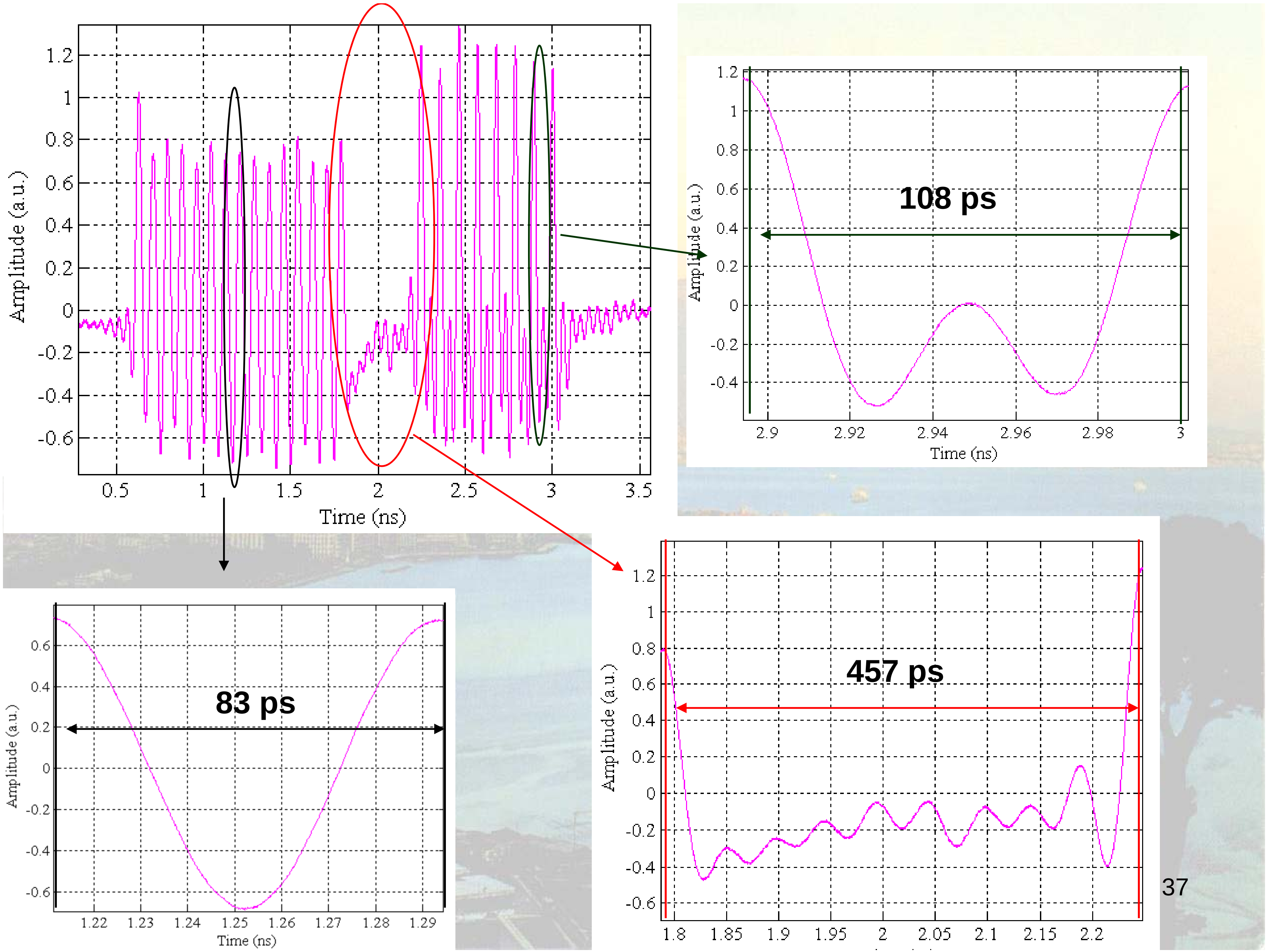
457 ps

108 ps

RMS bunch length = 13.3ps
Train duration = 2.5ns
Nb of bunches = 23
Peak current = 293A

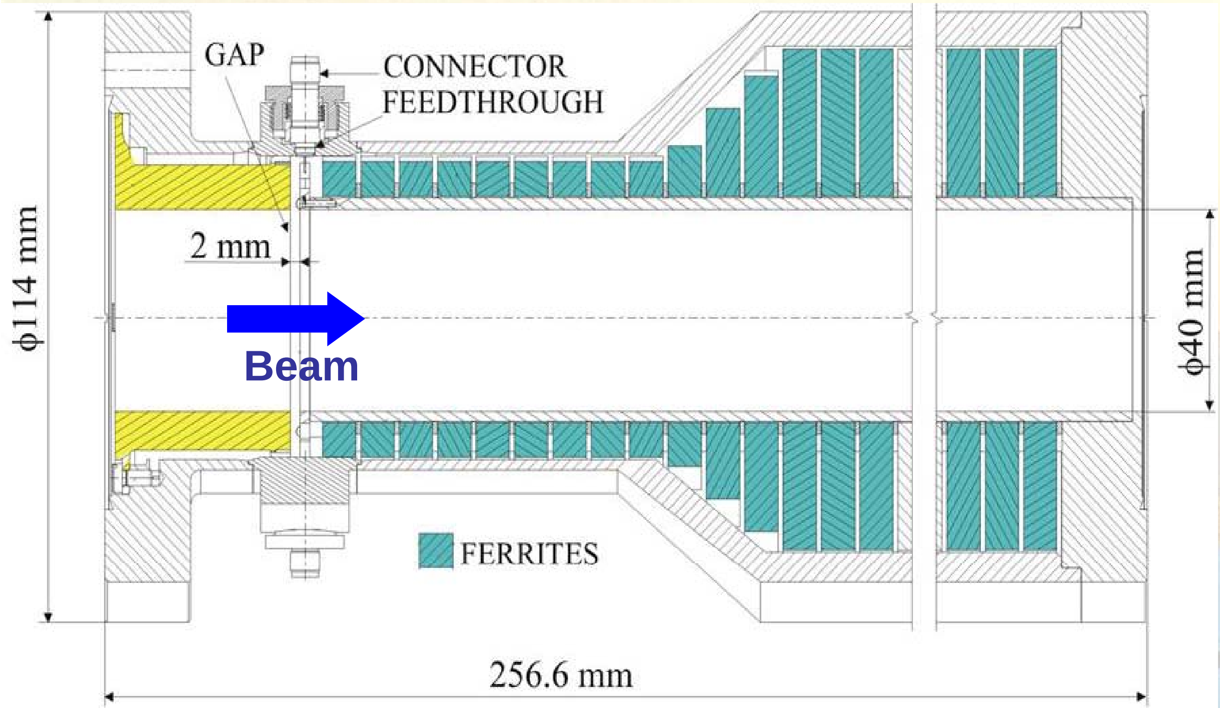
Just to have more fun it has been added also a random noise level of about 10% with respect to the signal amplitude


x 10^5
Amplitude (a.u.)
Frequency (GHz)
Amplitude (dB)
Frequency (GHz)
Phase (rad)
Frequency (GHz)
x 10^4
Amplitude (a.u.)
Frequency (GHz)



Amplitude (a.u.)
Time (ns)
108 ps
83 ps
457 ps

Measurements on the existing design



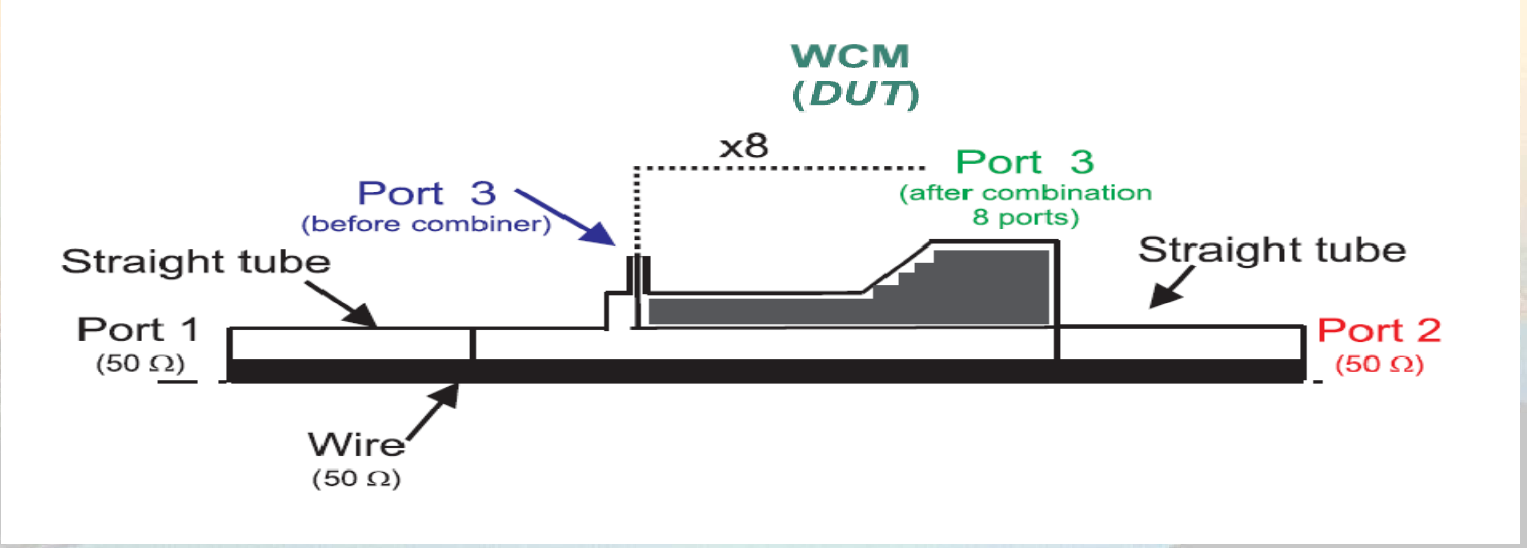
The existing design is based on a previous design for the CTF2

(63 MHz ≤ bandwidth ≤ 10 GHz)

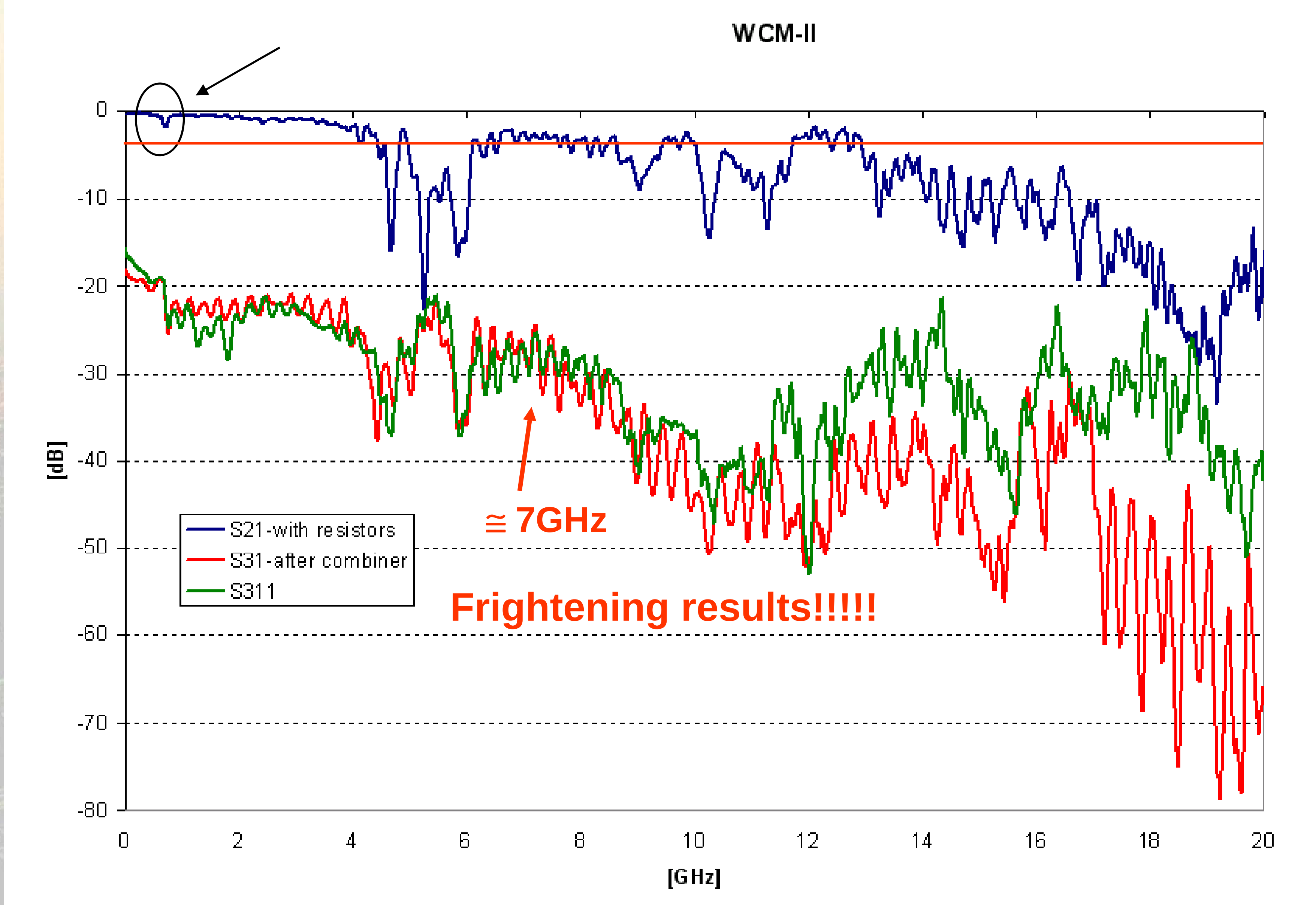
but

- Bigger volume of ferrite in order to lower the l. f. cut-off to 100 kHz
- The miniature feedthrough modified in order to extend their bandwidth beyond 20 GHz

Experimental setup and testbench

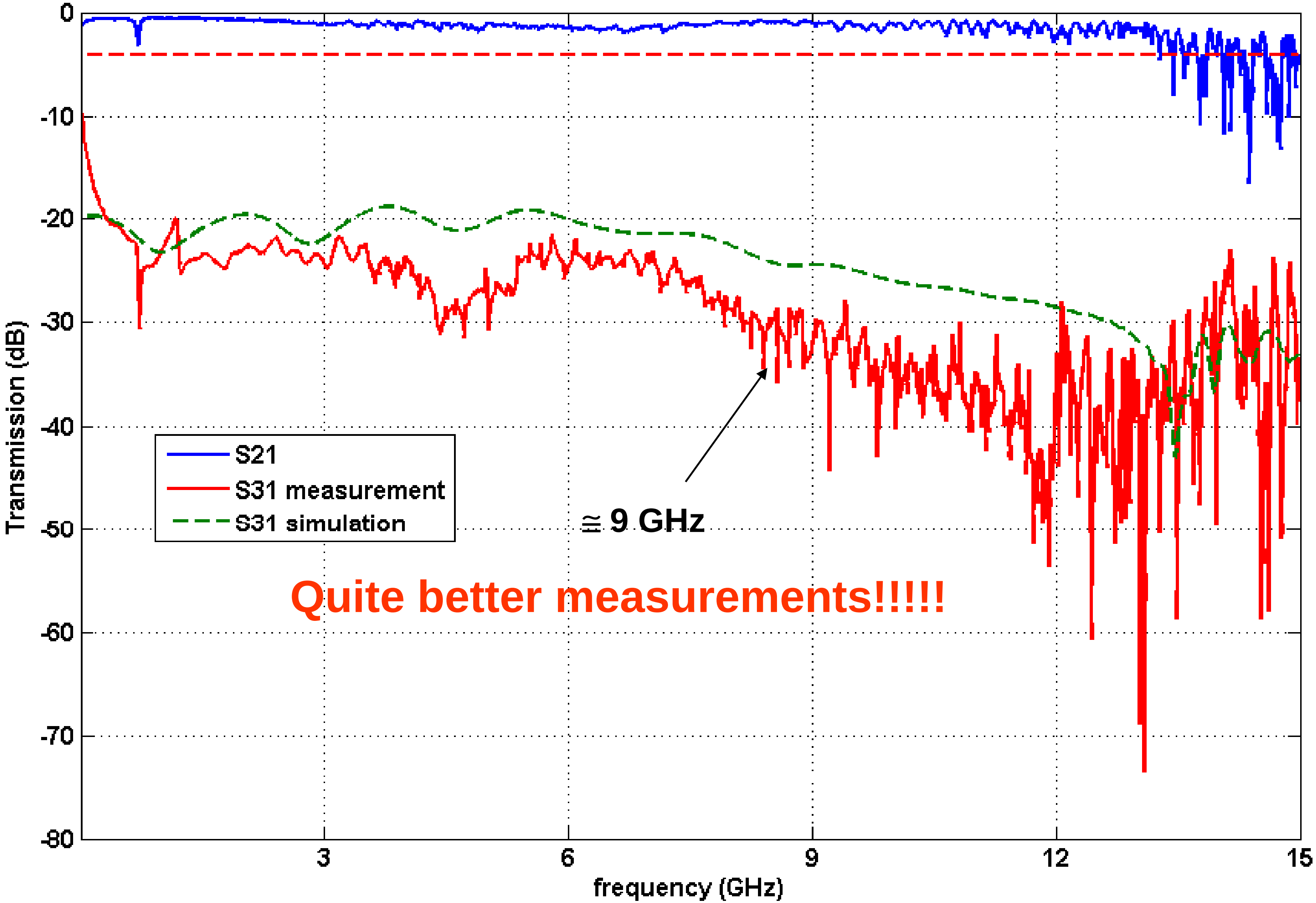


Old measurements (March 2006)

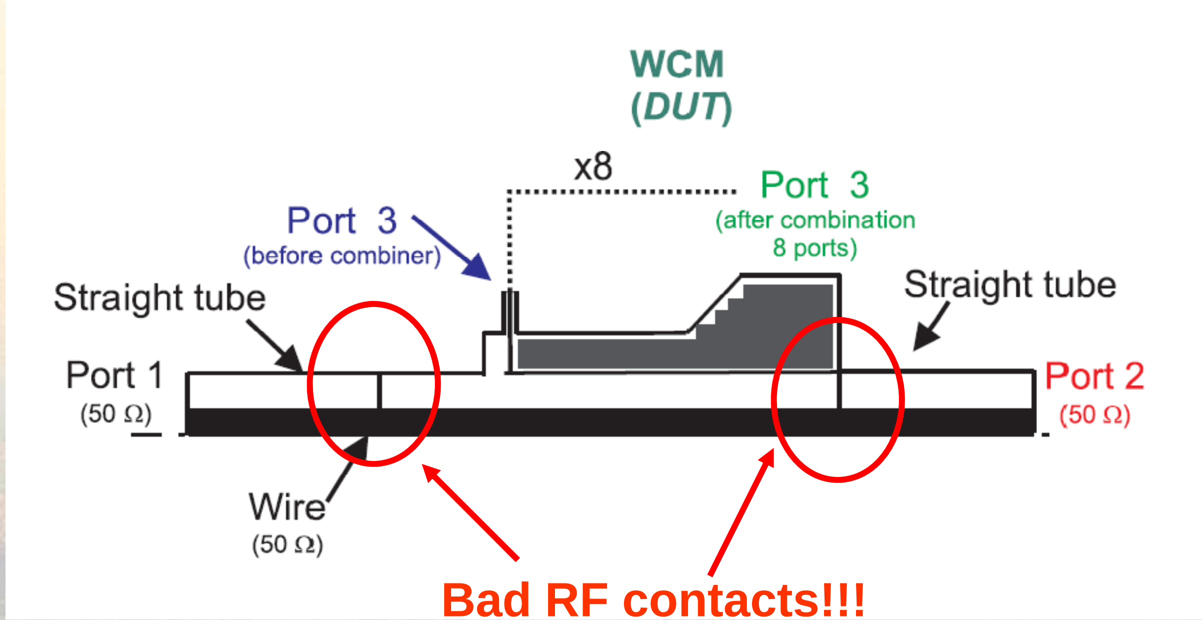


With the courtesy of Lars Soby and Ivan Podadera

New measurements (November 2006)

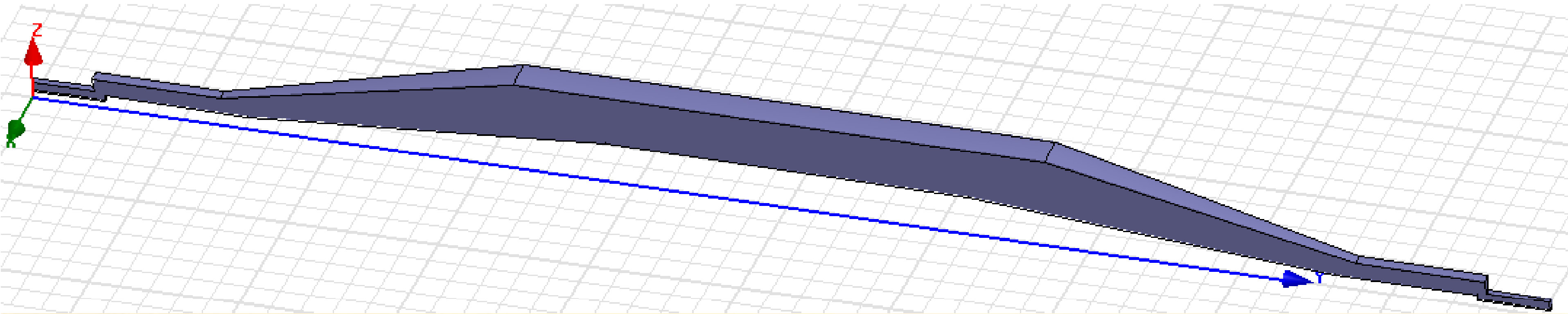


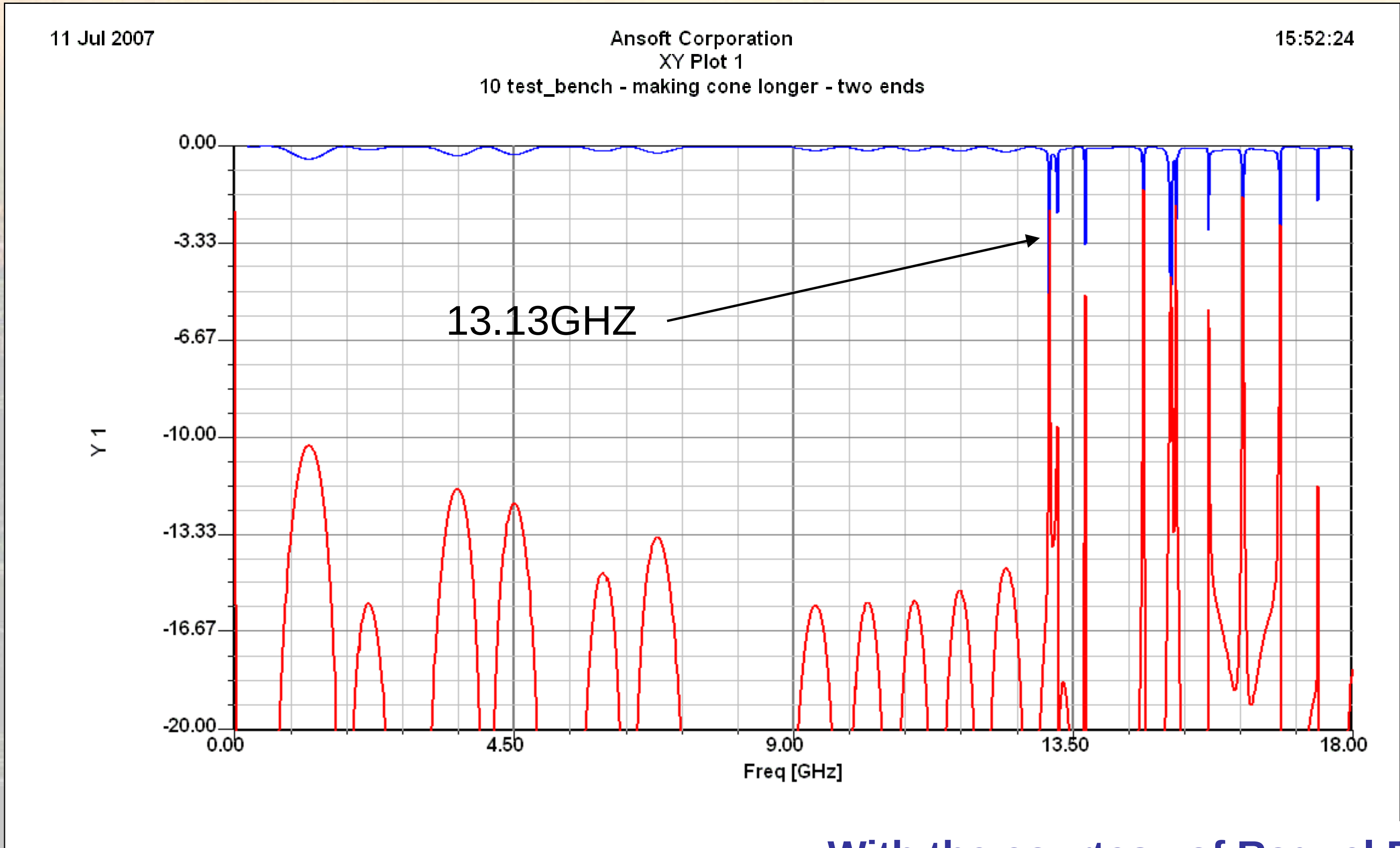
What was wrong?



The experimental setup showed very bad RF contacts between WCM and the two external straight tubes. In order to improve the contacts some pasty stripes of conducting material has been used…. Unfortunately it cannot be used in vacuum….

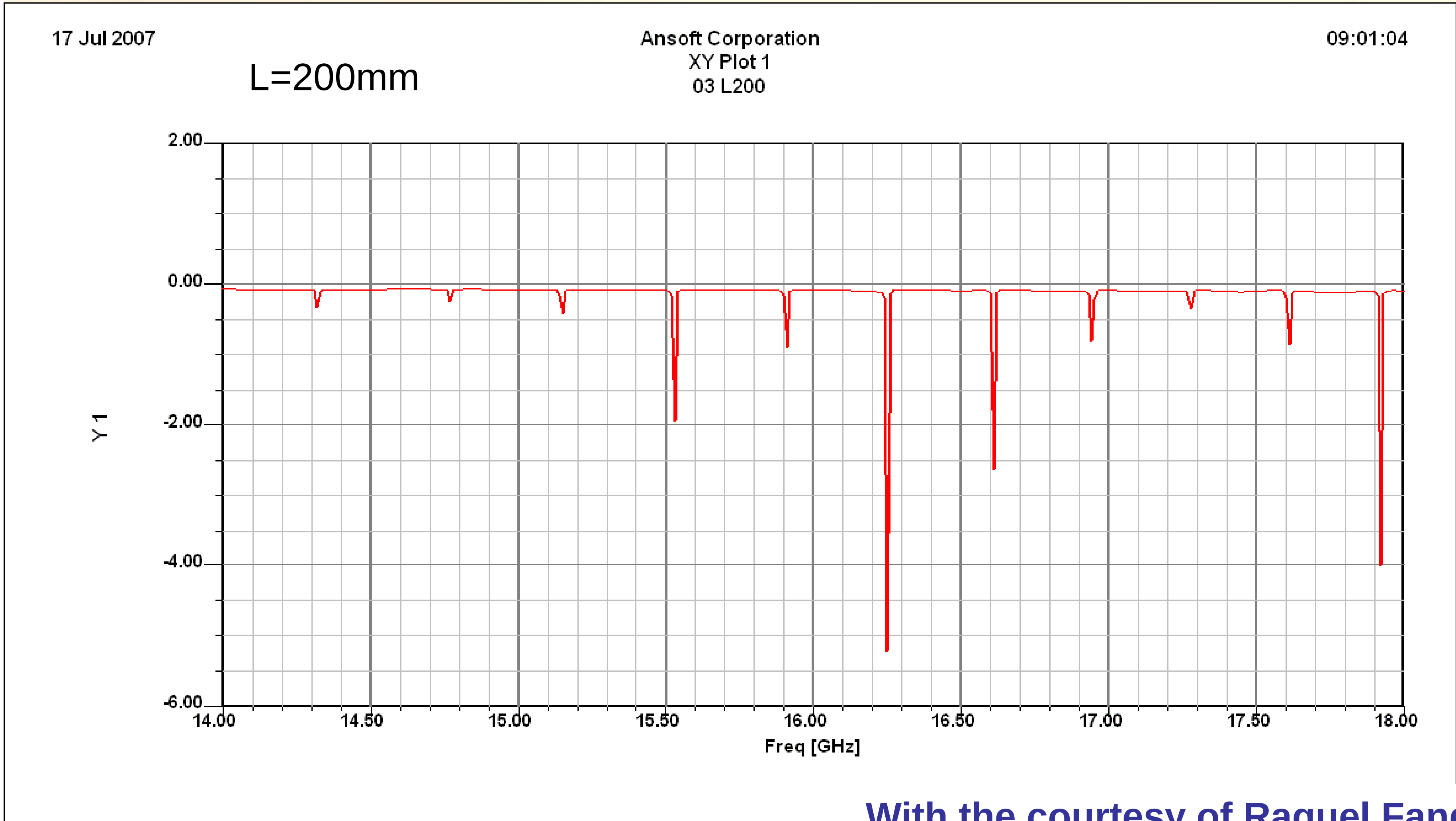
For frequencies higher than 12 GHz strong reflections occur because of the adapting cone are not enough smoothed.





With the courtesy of Raquel Fandos

By making the transitions longer the resonances get less dramatic



With the courtesy of Raquel Fandos

Conclusions and outlooks

- WCM specifications has been reviewed in a more critical way, showing less stringent constraints
- The e-m design is accomplished, giving pretty good results
- At the end of the next week the mechanical designs will be sent to the mechanical workshop to start the machining and the assembling
- The testbench has been improved
- On December the first measurements and the characterization are foreseen