Status of the Wall Current Monitor (WCM) design for EUROTeV

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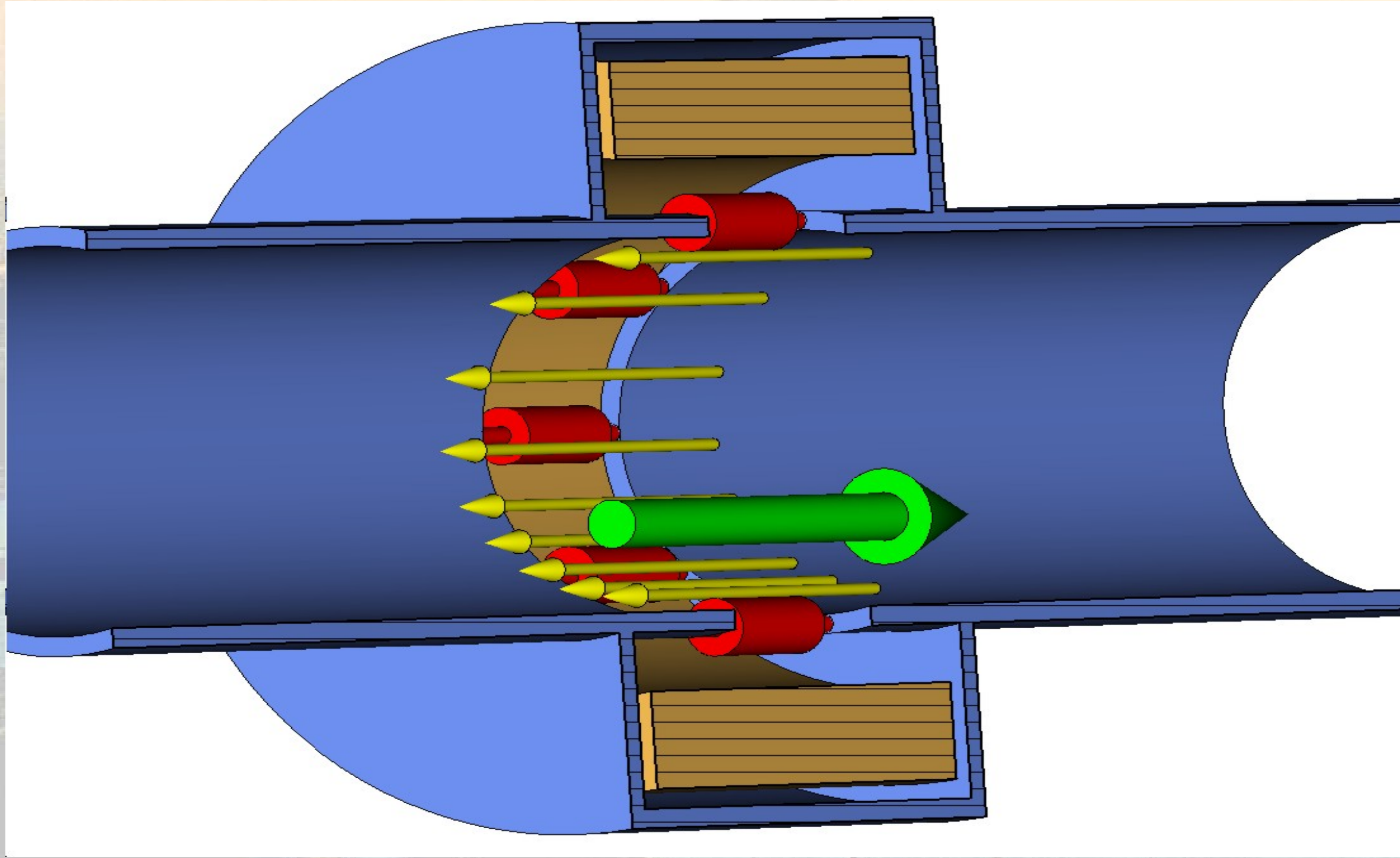
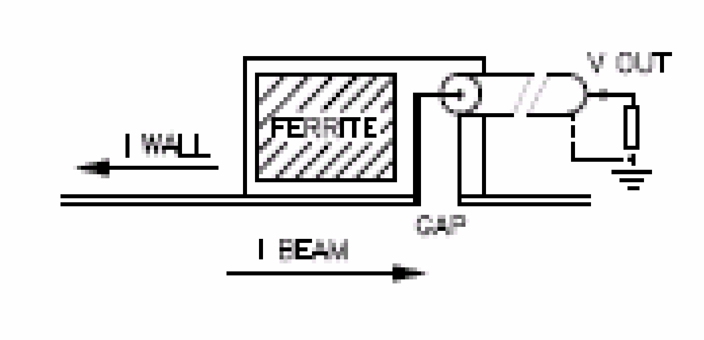
Wall Current Monitors

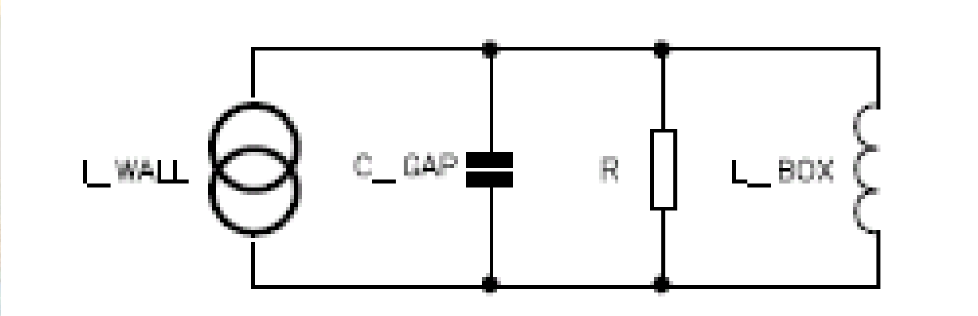
Wall Current Monitors (WCM) are commonly used to observe the time profile and spectra of a particle beam by detecting its image current.



A first approach using a simple circuit model

The presence of the ferrite is fundamental in order to decrease the low frequency cut-off of the structure





$$F_{low\,cut-off} = \frac{1}{2\pi}\frac{R}{L}$$

$$F_{high\,cut-off} = \frac{1}{2\pi}\frac{1}{RC}$$

Note: When the distance between the WCM elements becomes comparable to the free space wavelength of the propagating fields, the circuit modeling is not reliable and a study of the 3D structure has to be performed by using e-m CAD!

The 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

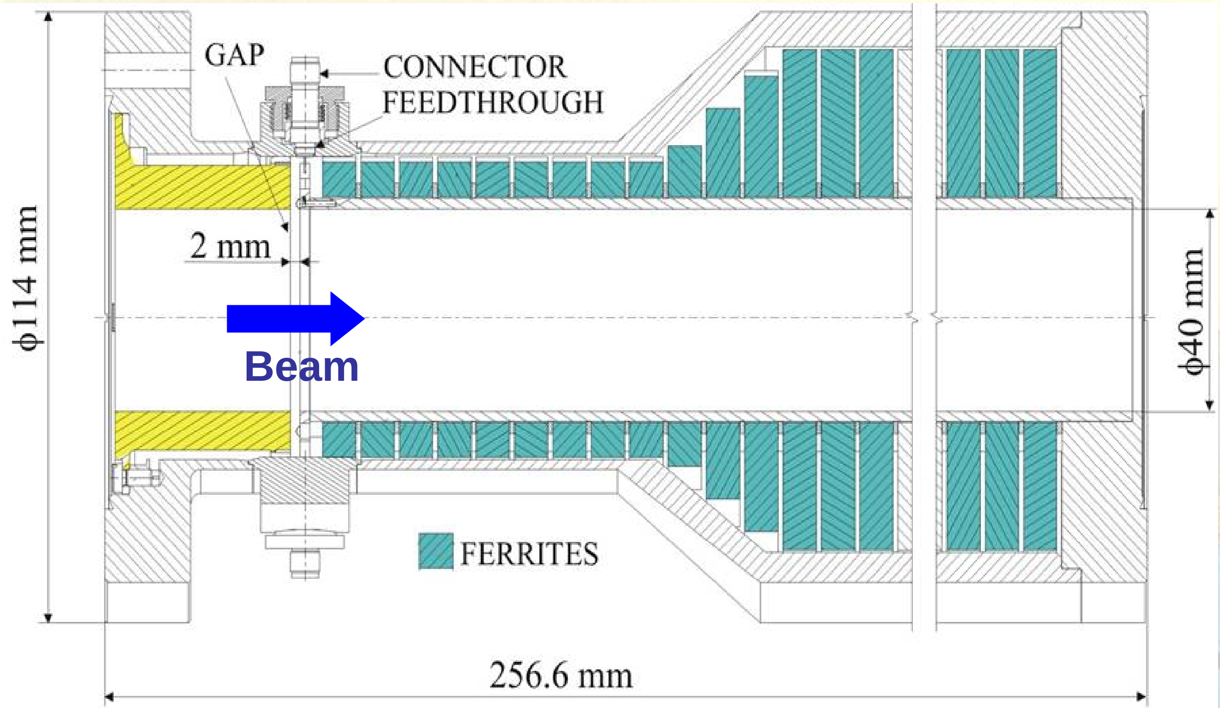
τ_r = 1.54 μs ⟶ WCM l. f. cut-off = 100 kHz

Furthermore

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

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

The existing design



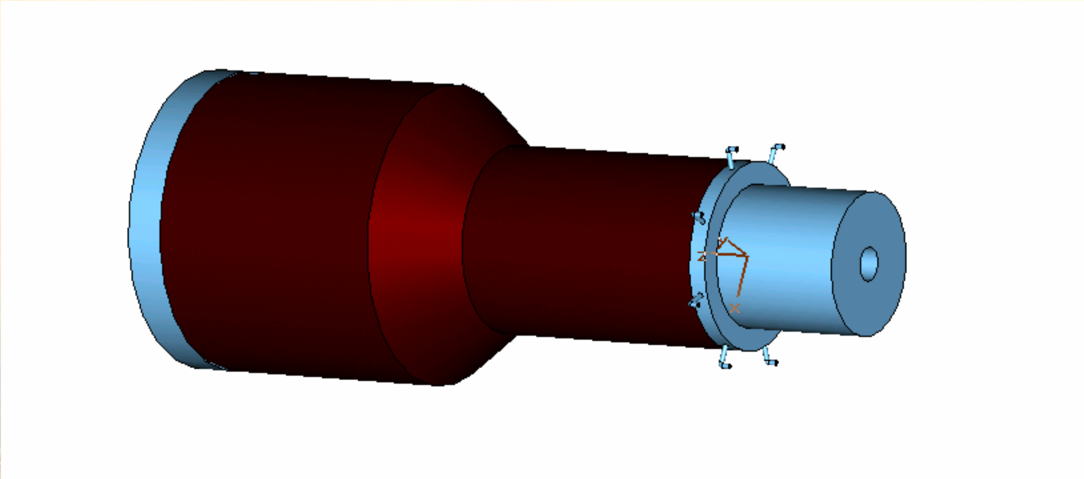
The existing design is based on a previous design for the CTF2

(63 MHz ≤ bandwidth ≤ 10 GHz)

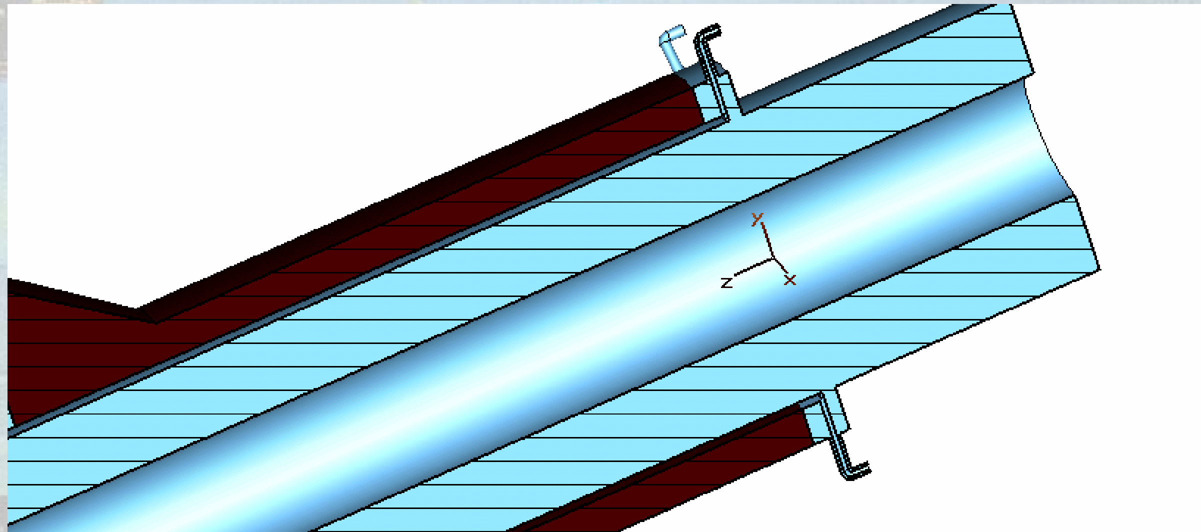
but

- 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

Simulations: geometry parameters

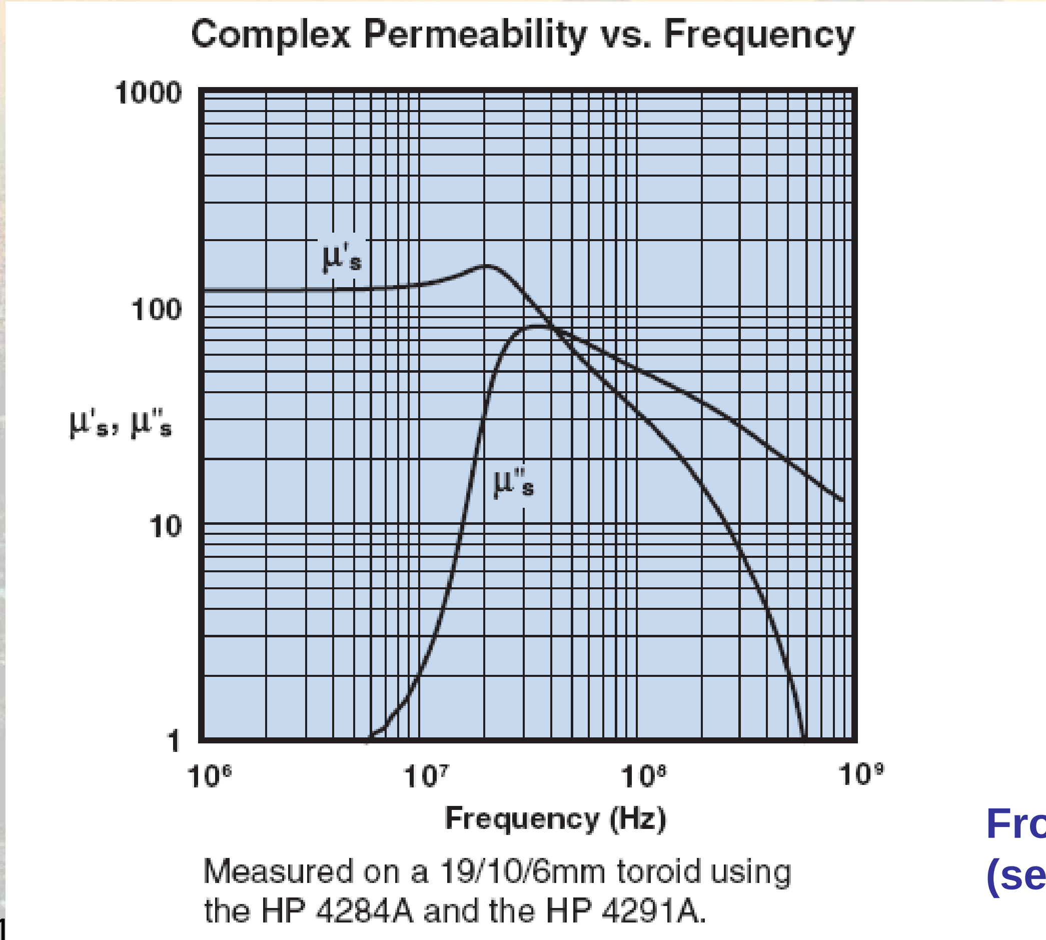


Parameter	mm
$R_{pipe\ int}$	20
$R_{pipe\ ext}$	25
R_{wire}	8.5
Pipe thickness	1
$R_{feed\ wire}$	0.3
$R_{feed\ ext}$	0.69
L_{cone}	20
gap	2
$R_{ferrite}$	20
L_{tot}	205



Simulations: ferrite parameters

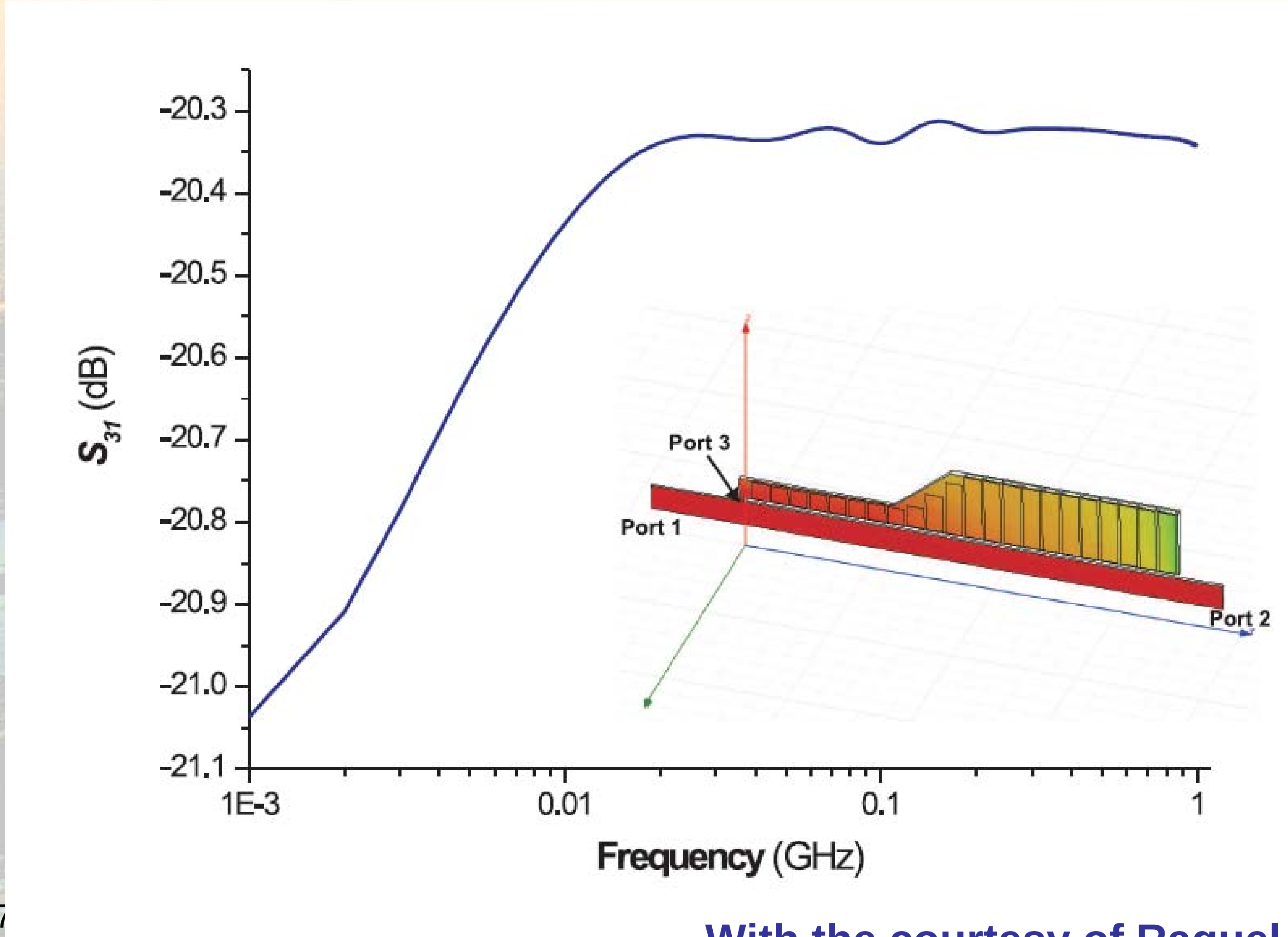
The ferrite used is the Material 61 of Fair Rite Company. From data sheet one finds the curves for complex permeability. Unfortunately the characterization is done only from 1MHz to 1GHz.



From Fair Rite 61 Material datasheet (see http://www.fair-rite.com)

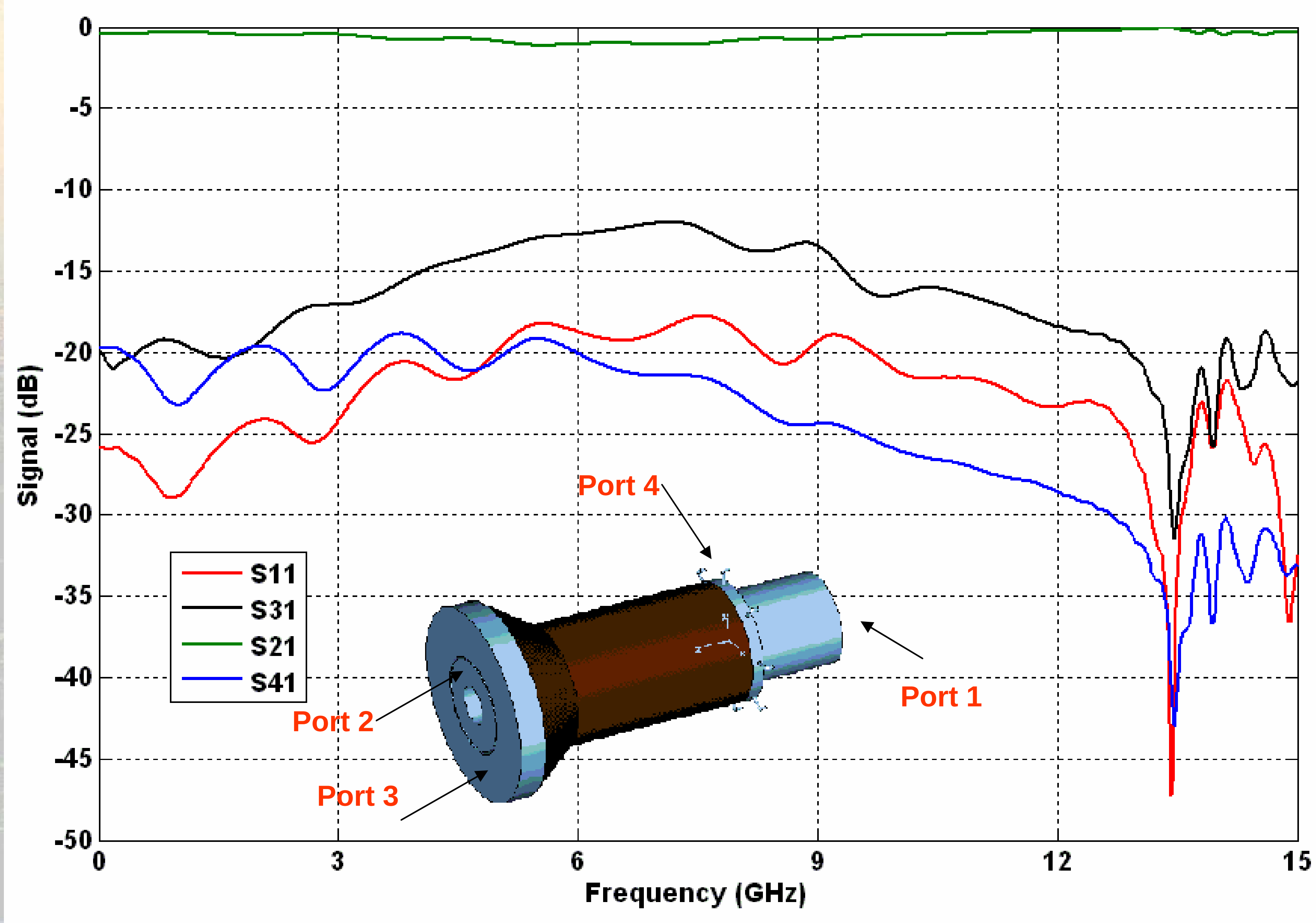
Simulations: results (1)

HFSS simulation shows a very good l. f. cut-off

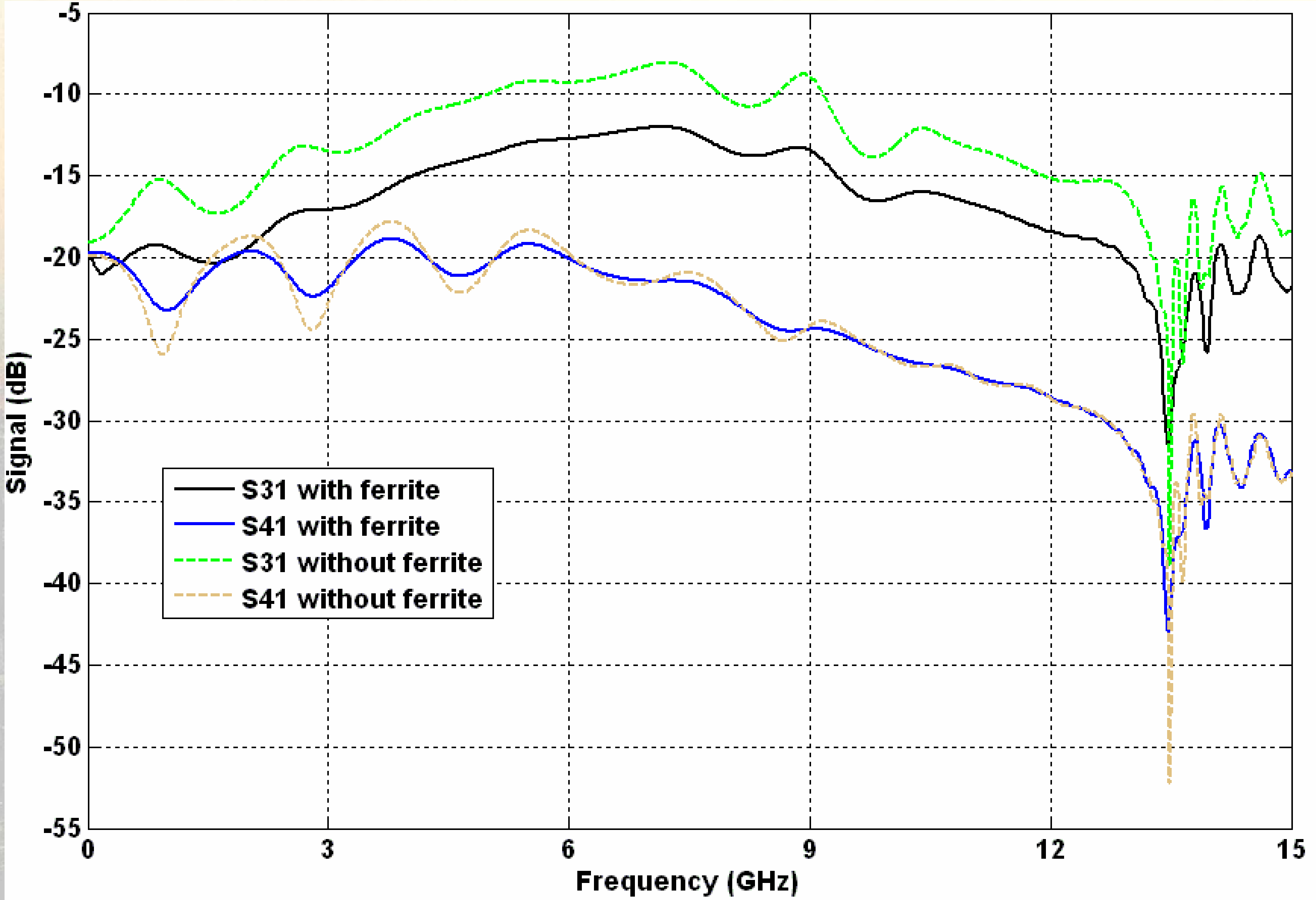


With the courtesy of Raquel Fandos

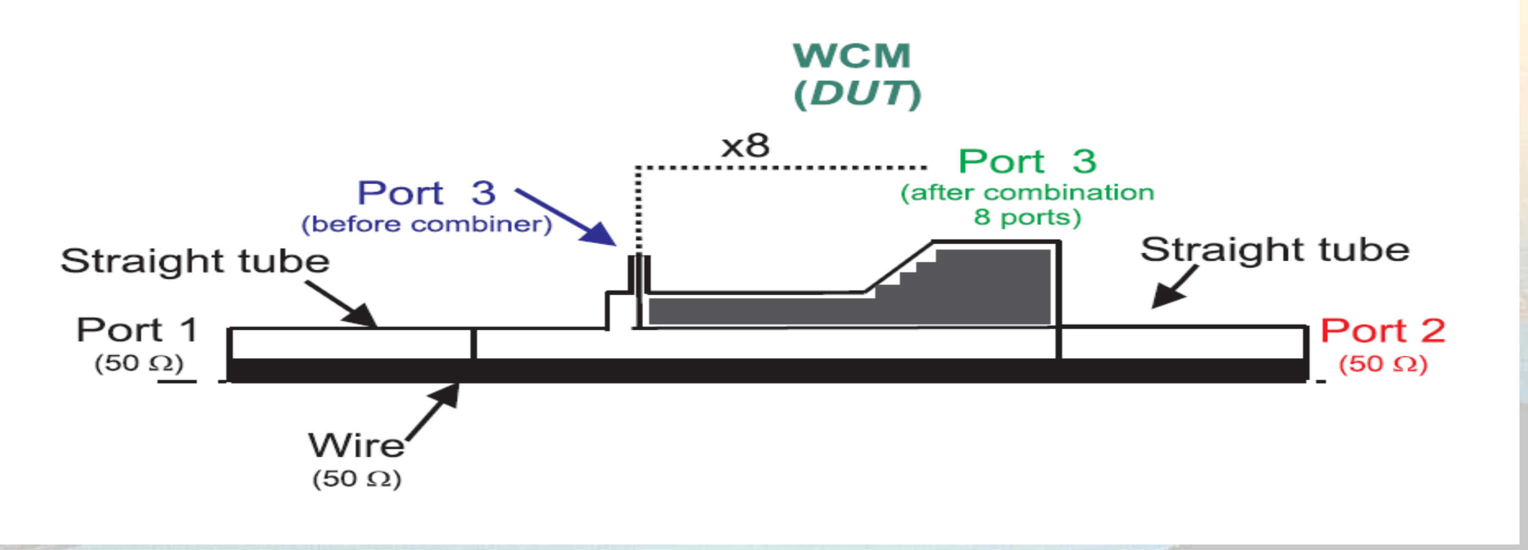
Simulations: results (2)



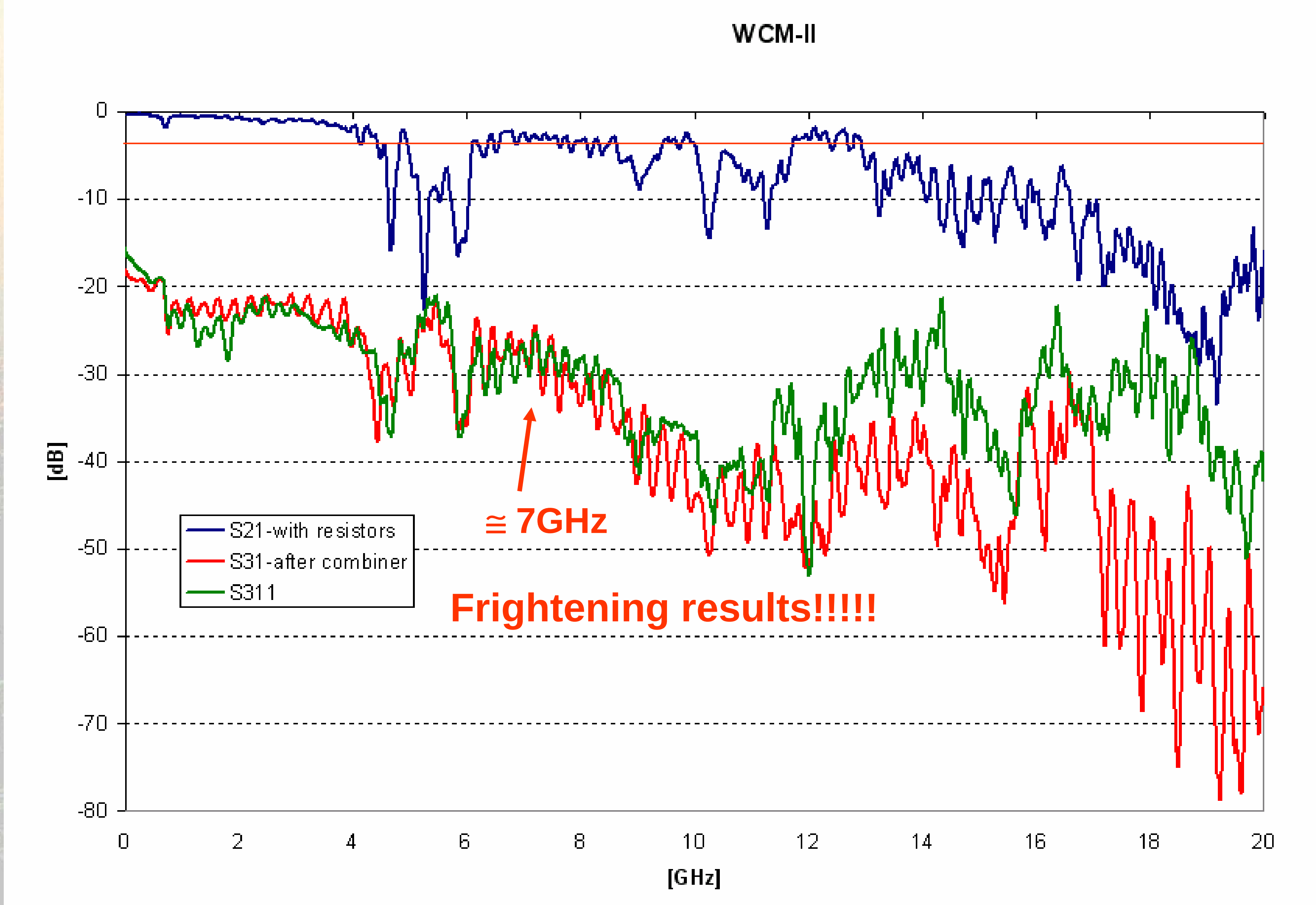
Simulation: results (3)



Experimental setup

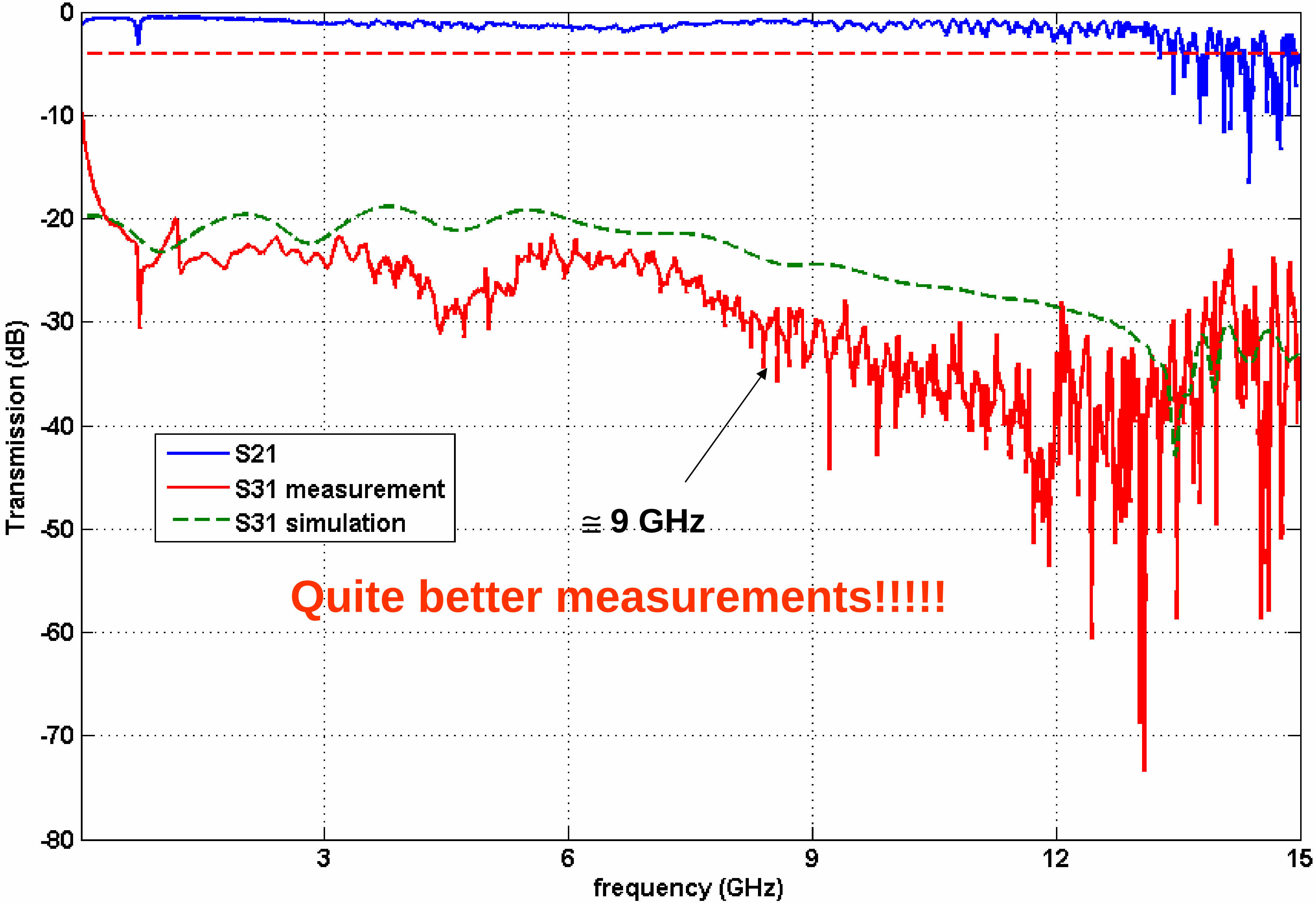


Old measurements (March 2006)

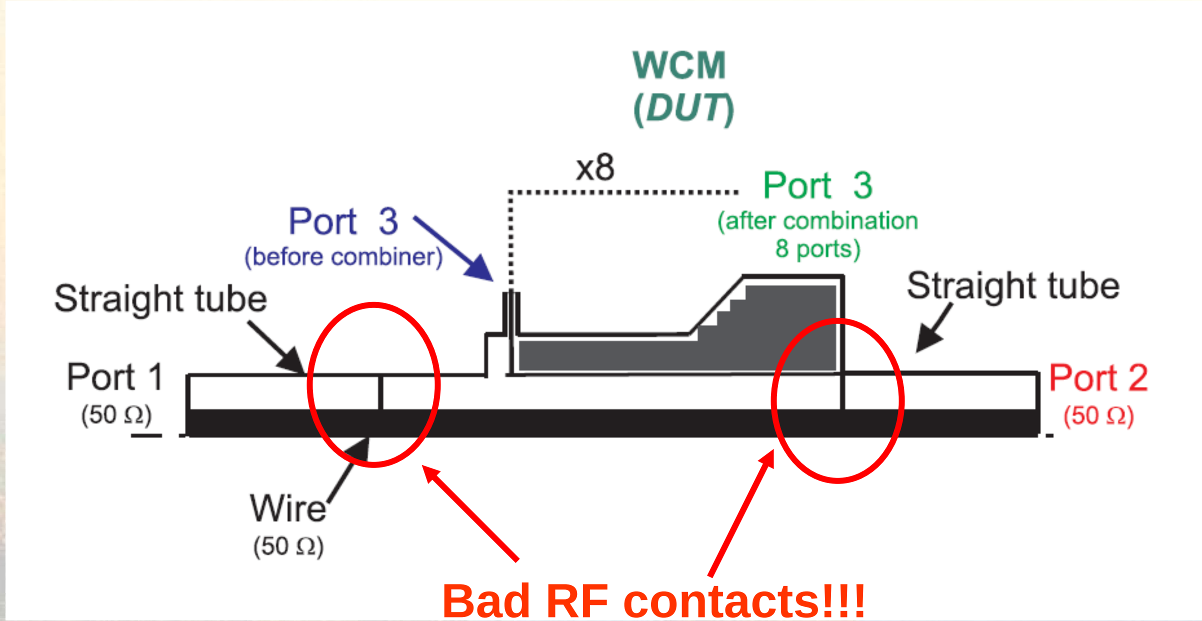


With the courtesy of Lars Soby and Ivan Podadera

New measurements (November 2006)



What was wrong?



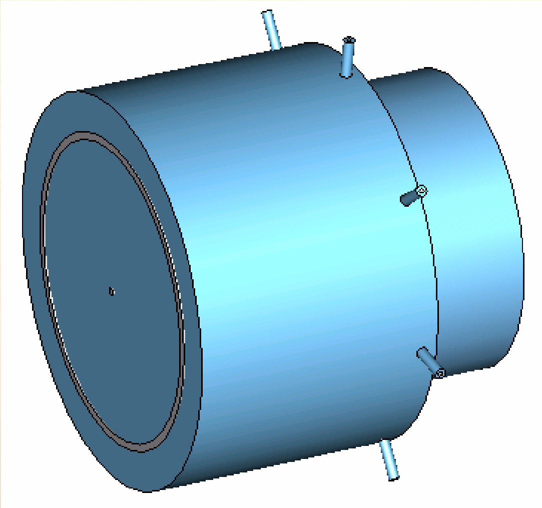
The experimental setup showed very bad RF contacts between WCM and the two external straight tubes. In order to improve the contacts some pasty stripes of conducting material has been used…. Unfortunately it cannot be used in vacuum….

For frequencies higher than 12 GHz it is possible that strong reflections occur because of our SMA connectors are adapted up to 12.5 GHz.

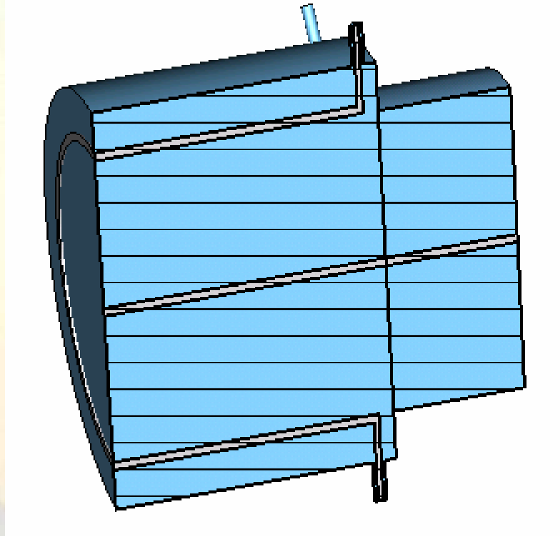
In any case the S31 signal has to be improved (problems with the ferrite? Problems with the feedthrough? Both?)!

Going beyond 10 GHz

Several new structures (biconical structure, several kind of coaxial structures….) were deeply studied in order to extend the frequency bandwidth of the WCM, between them, the one giving the best results, is a structure realized at the cost of few changes in the existing WCM structure.

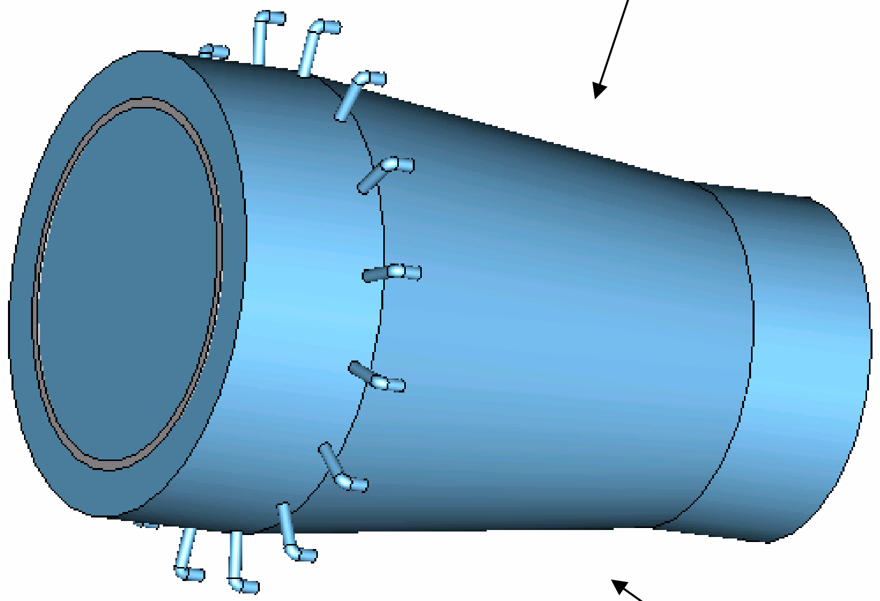


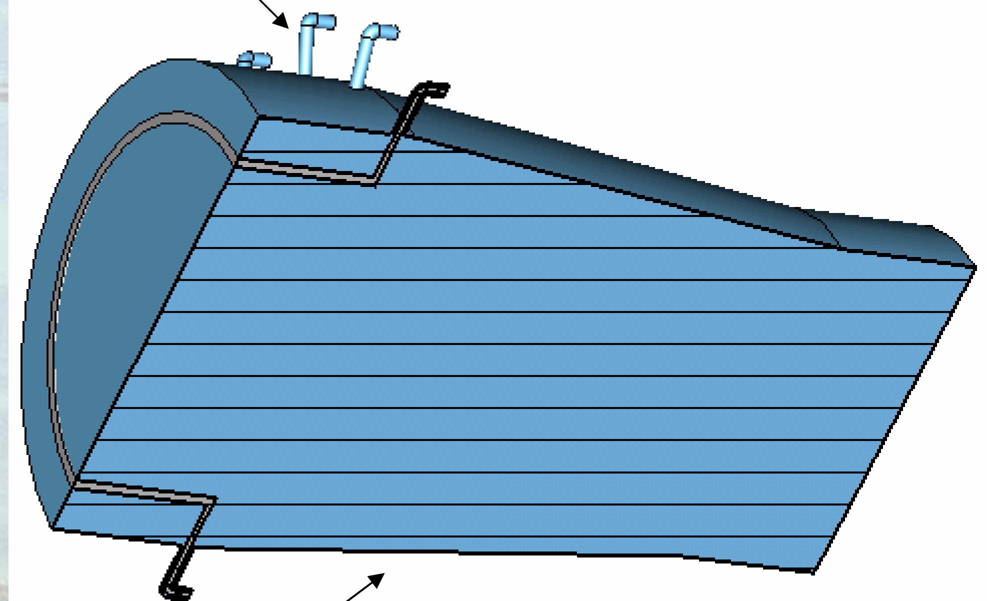
Old WCM



Tapering

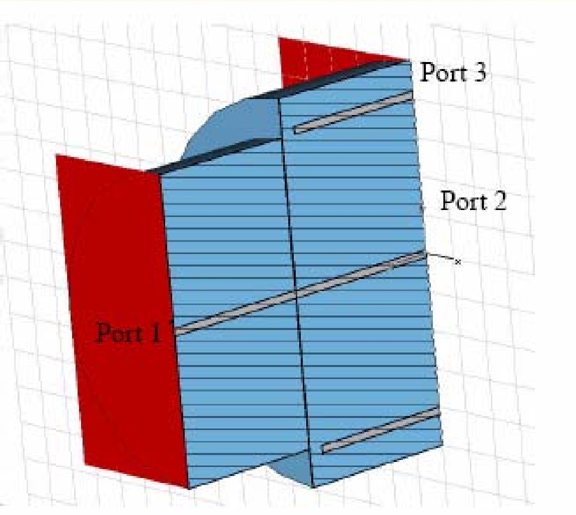
16 feedthroughs

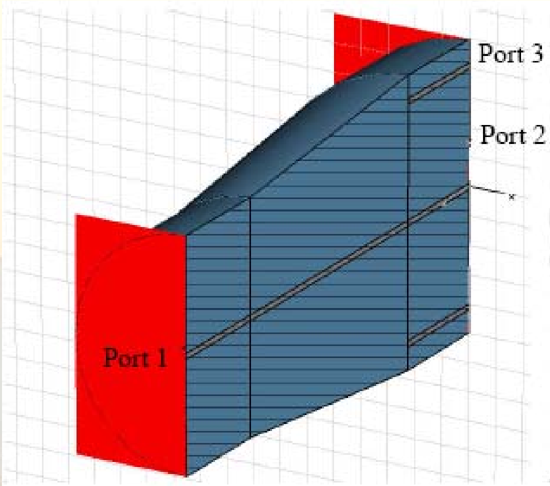


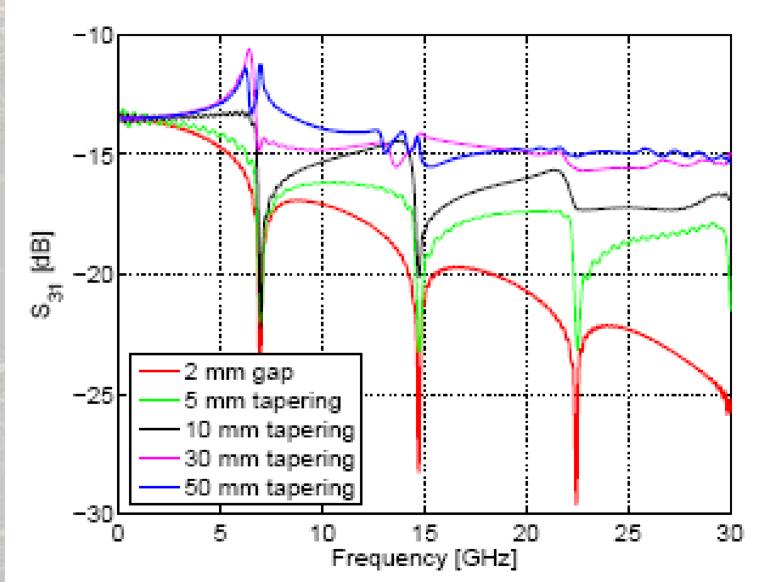


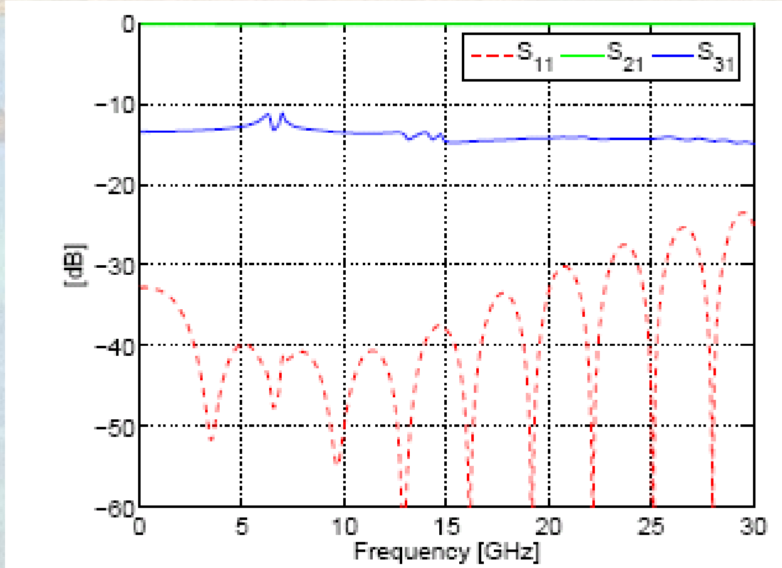
New WCM

The gap resonances









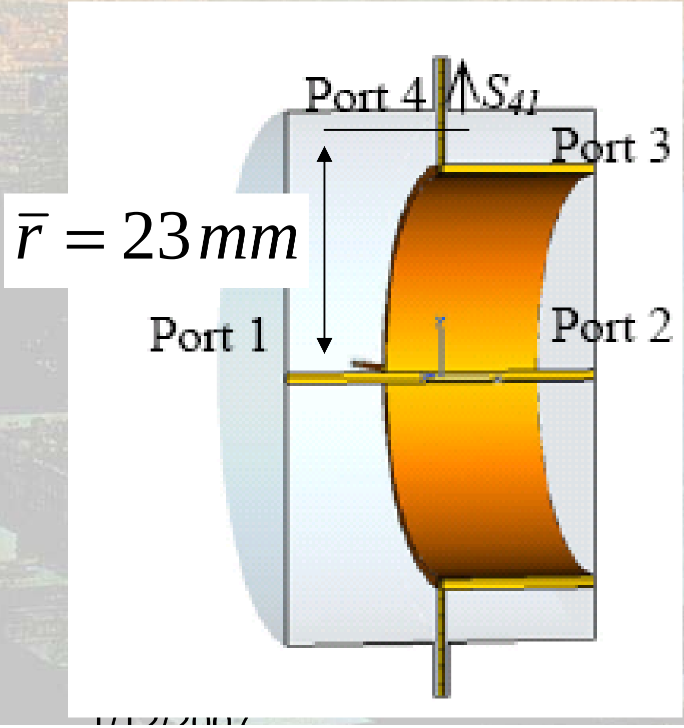
With the courtesy of Tom Kroyer ("*A Structure for a Wide Band Wall Current Monitor*", AB-Note-2006-040 RF)

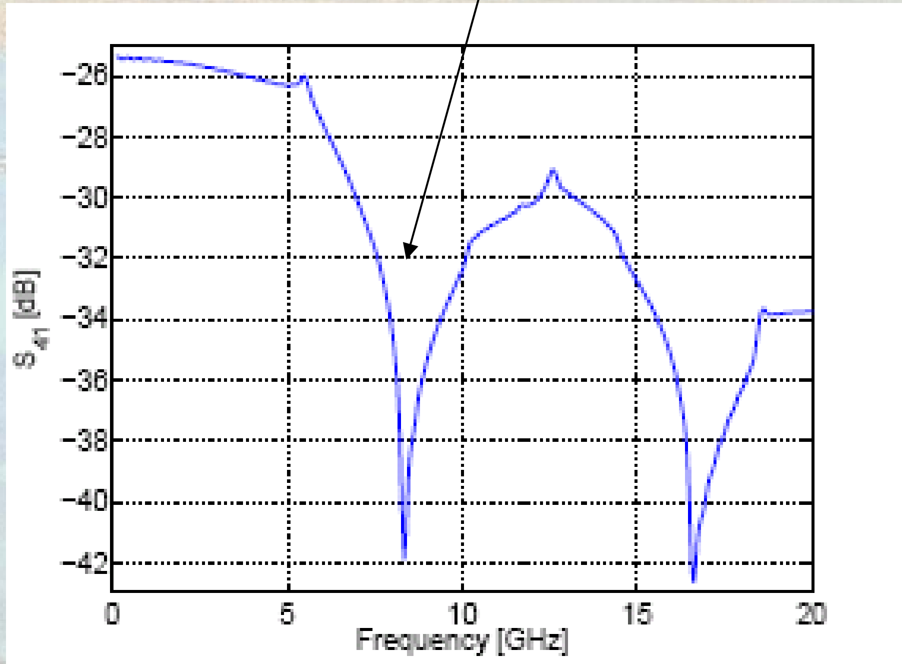
Feedthrough resonances

When the distance between two feedthroughs becomes equals 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

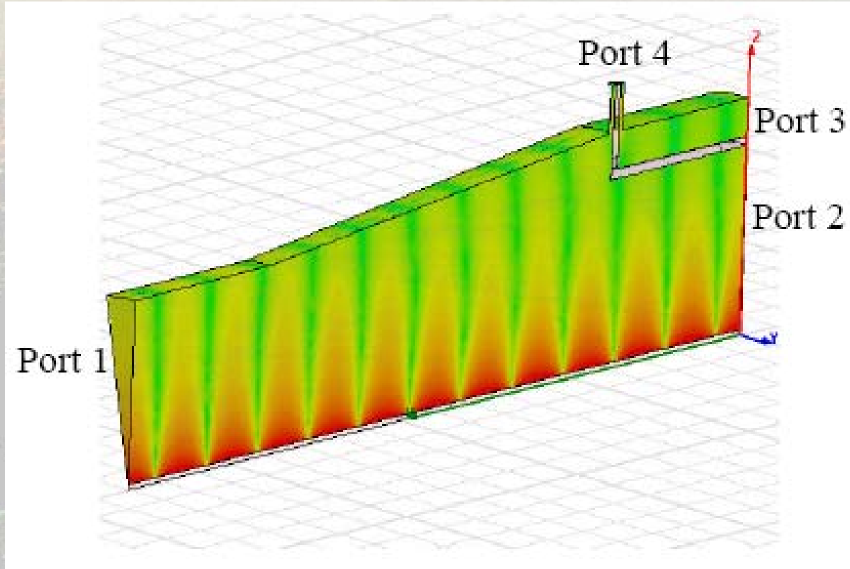


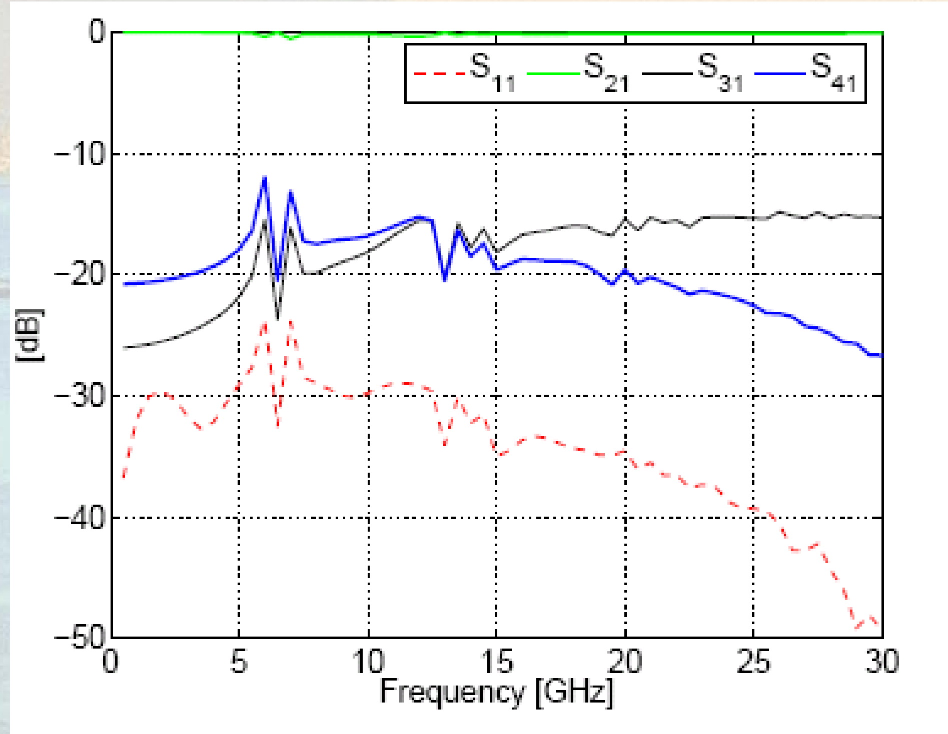


With the courtesy of Tom Kroyer ("*A Structure for a Wide Band Wall Current Monitor*", AB-Note-2006-040 RF)

The whole structure

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





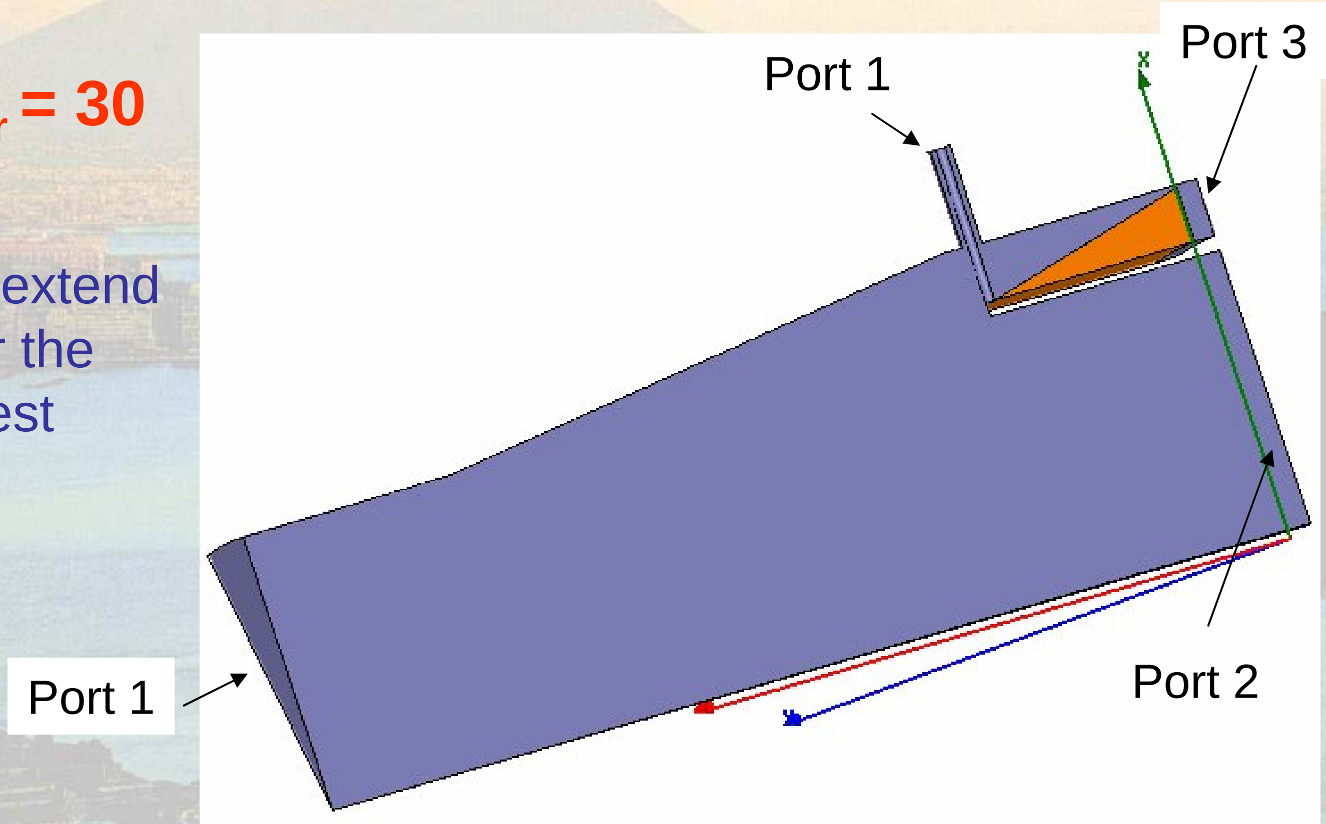
With the courtesy of Tom Kroyer ("*A Structure for a Wide Band Wall Current Monitor*", AB-Note-2006-040 RF)

A first simulation with SiC

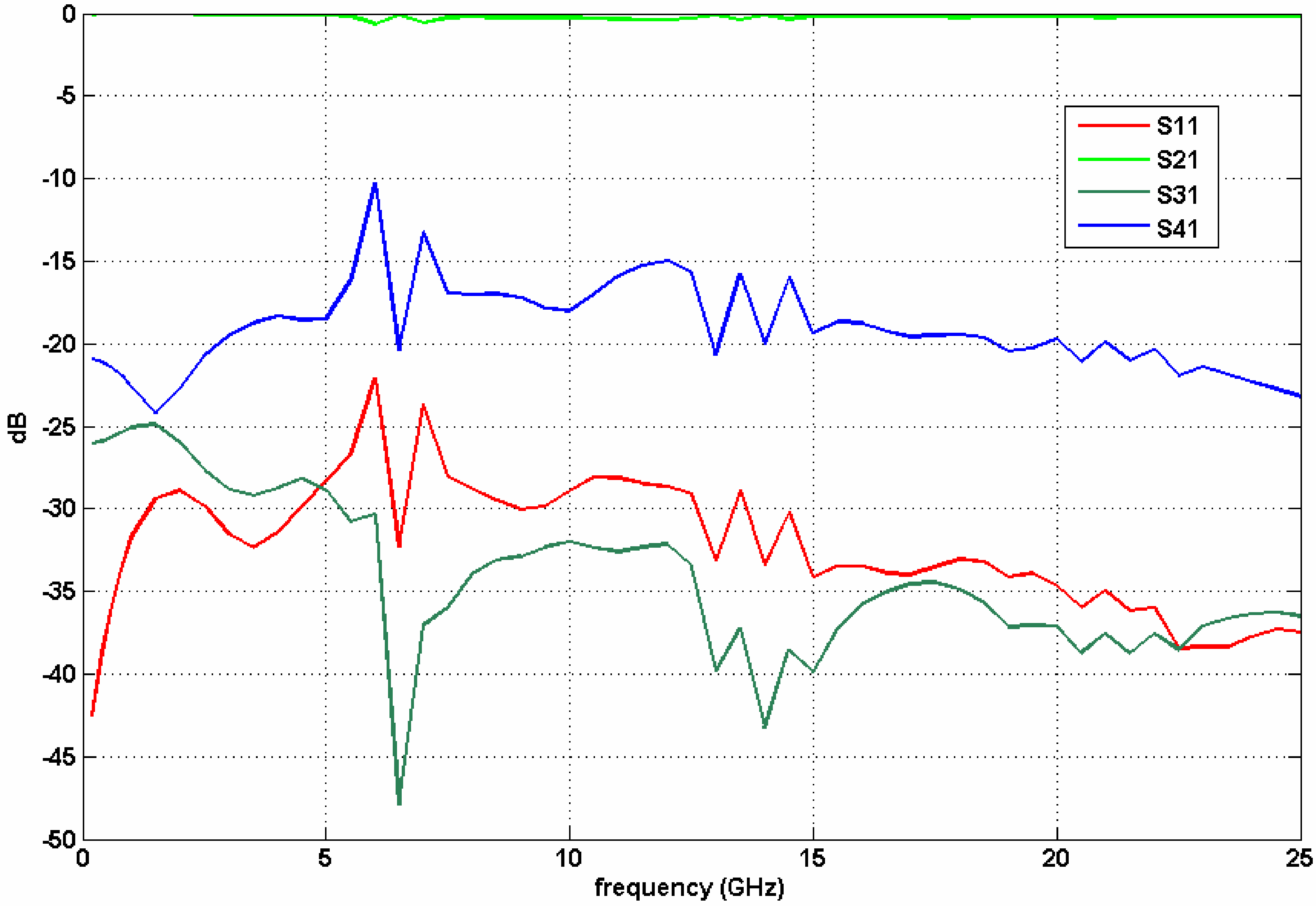
Same geometrical parameters but a cone of SiC has been introduced in the model of a longitudinal length of ≅19 mm. The parameters in the range 21GHz-33GHz of SiC are:

tang δ = 0.3 ε_r = 30

In the simulation we extend these parameters for the whole range of interest (1GHz-25GHz)

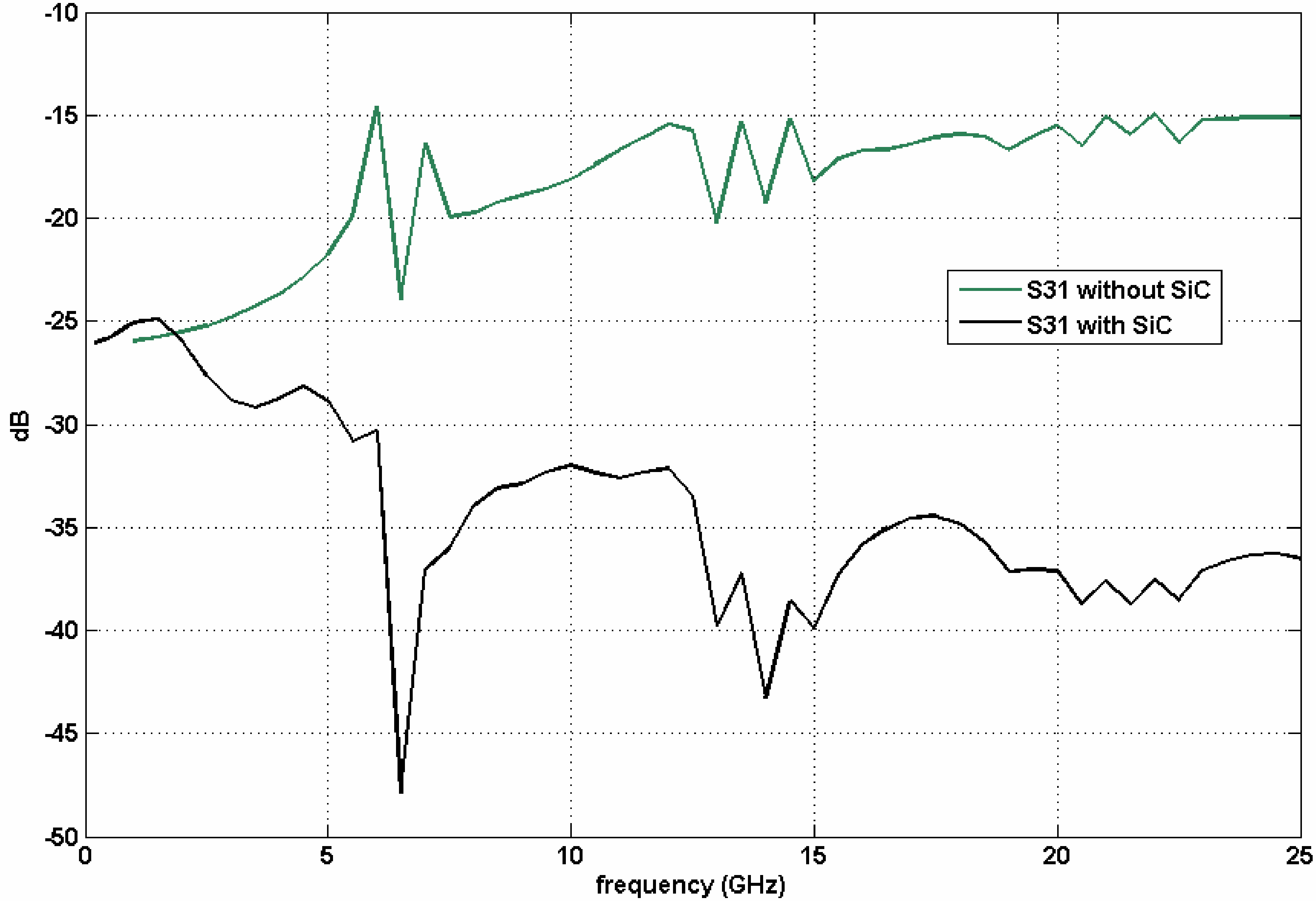


Results



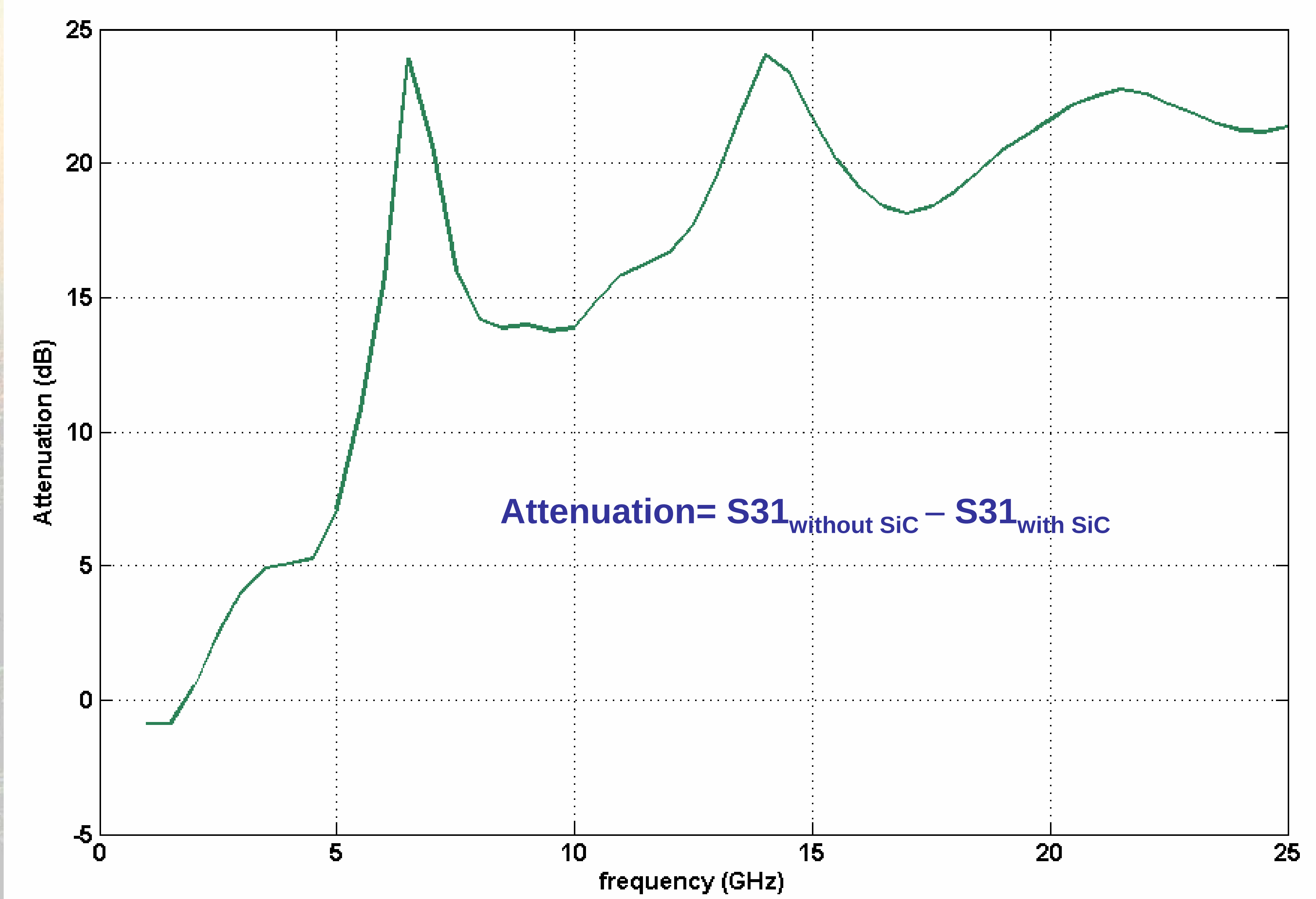
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
dB
0
5
10
15
20
25
frequency (GHz)
S11
S21
S31
S41

Results

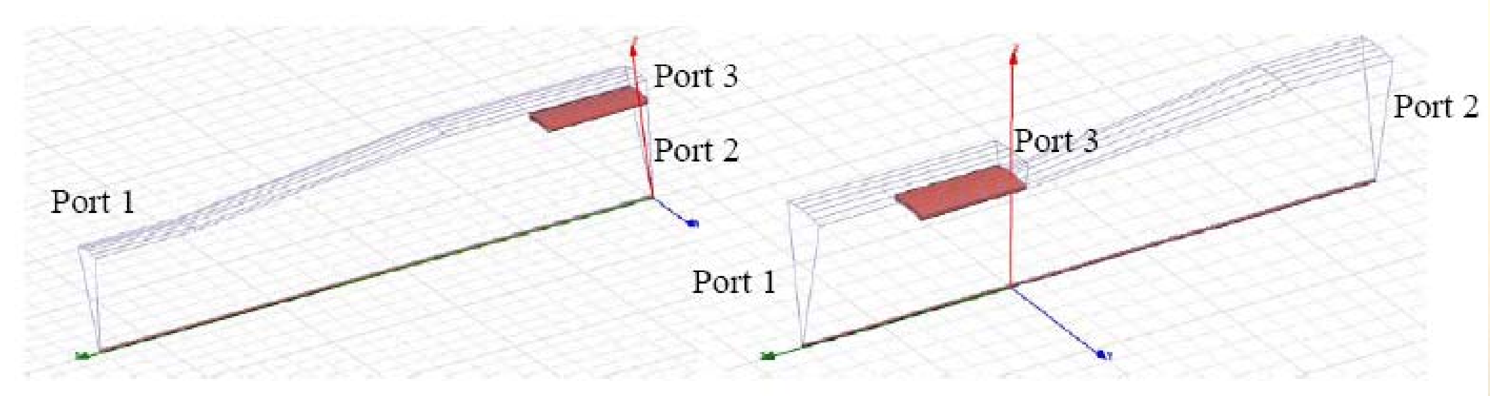


-10
-15
-20
-25
-30
-35
-40
-45
-50
dB
0
5
10
15
20
25
frequency (GHz)
S31 without SiC
S31 with SiC

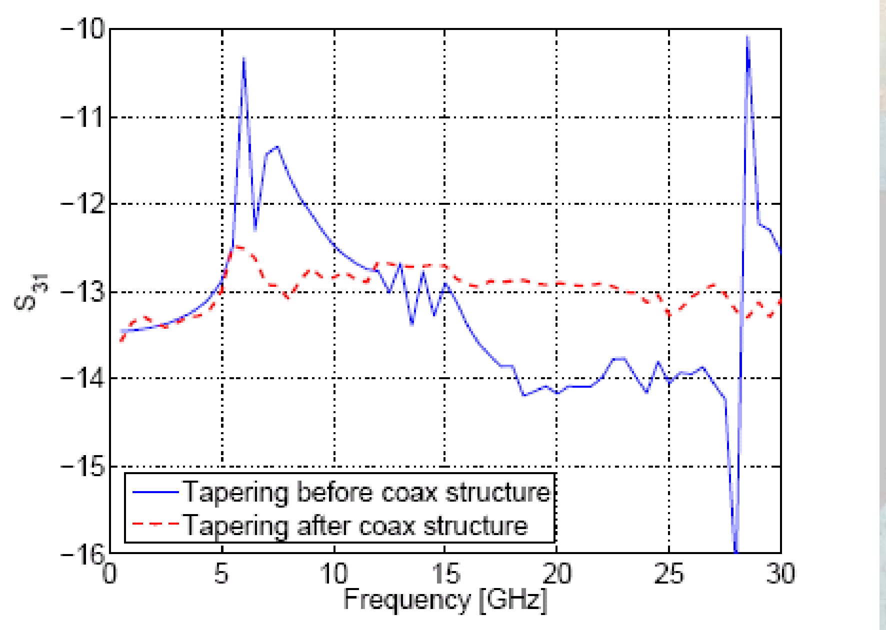
Signal attenuation at Port 3 due to SiC



An interesting proposal



If an aperture restriction can be tolerated, the inner pipe may be inserted into the beam pipe and a taper added after the coaxial section.



This structure is advantageous since higher order modes excited at the edge of the inner pipe can run back into the beam pipe without encountering discontinuities, No trapped modes will thus appear.

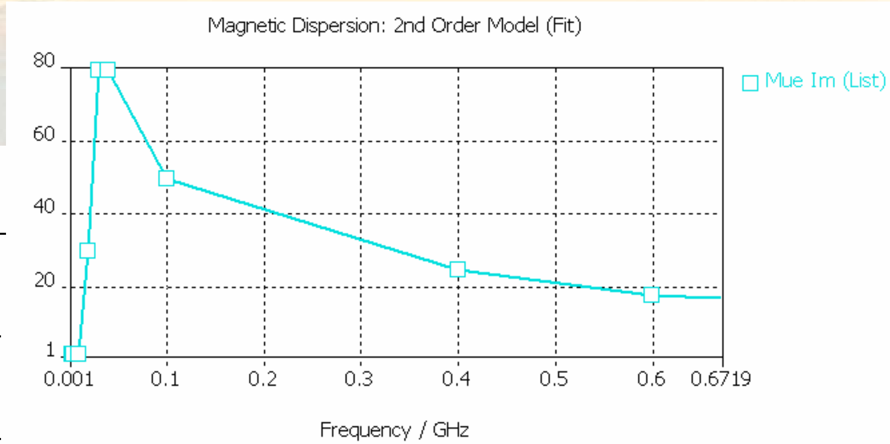
With the courtesy of Tom Kroyer ("*A Structure for a Wide Band Wall Current Monitor*", AB-Note-2006-040 RF)

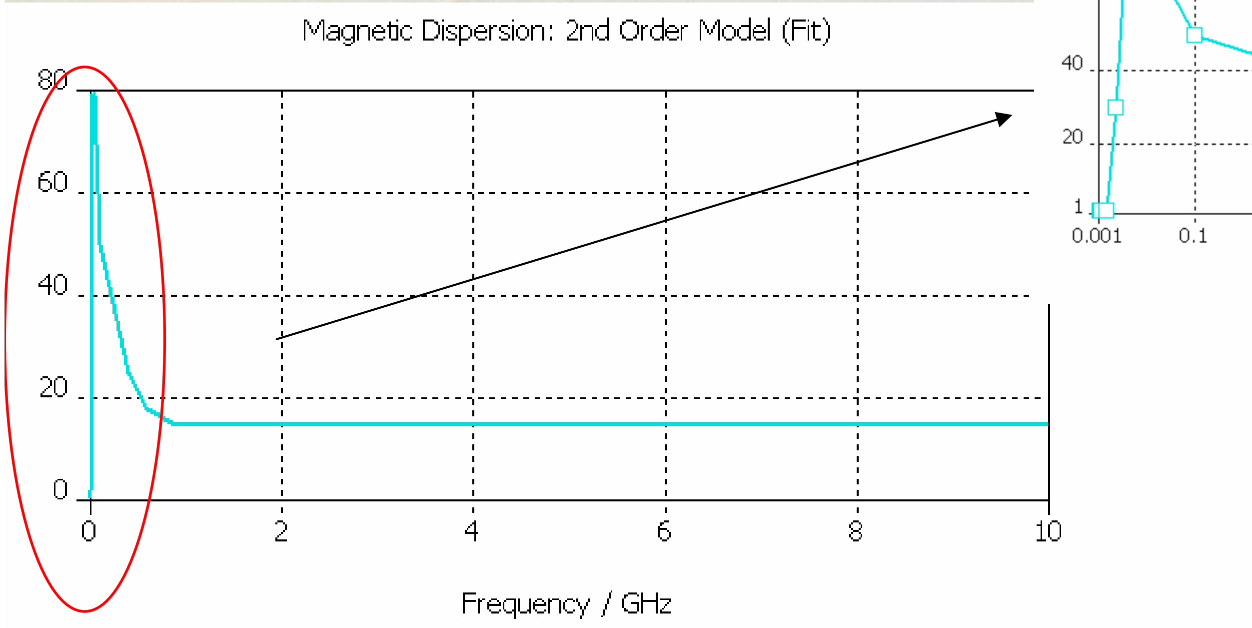
Conclusions... and a "few" of remaining problems

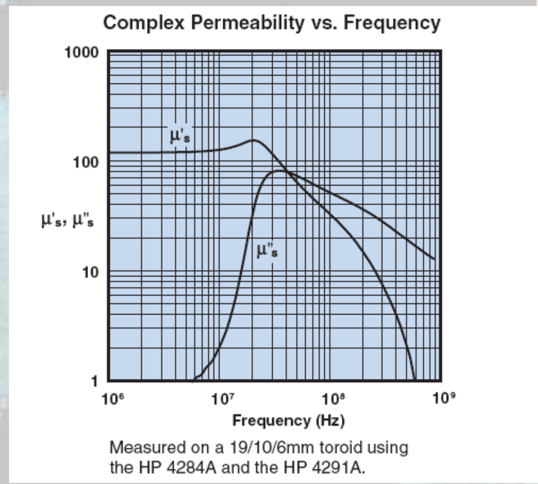
- The test bench has been improved
- The new proposed geometry at the cost of few changing in the old one shows a quite good response for our aims: apart of the TM01 mode at about 5.5 GHz a quite good flat response it is foreseen up to 25 GHz with the possibility of extending the bandwidth up to 30 GHz for future applications
- More accurate studies on the real feedthrough are needed
- Development of a new testbench only for feedthrough
- Feedthrough vacuum leakage
- Reliable ferrite and SiC models in CST MicroWave and/or HFSS
- We are confident, on February, of producing a preliminary mechanical design

Microwave vs Ferrite!

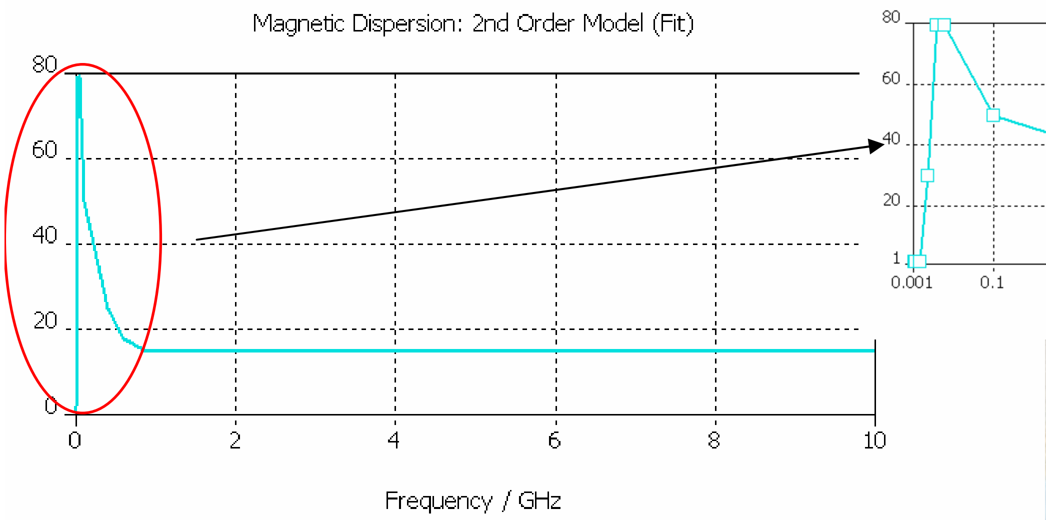
Imaginary part of permeability μ: input data

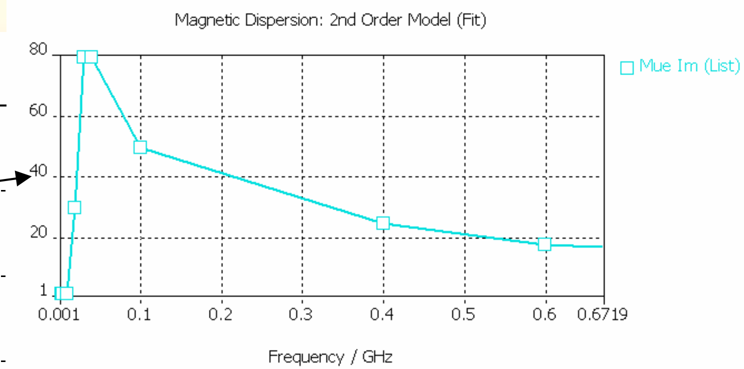




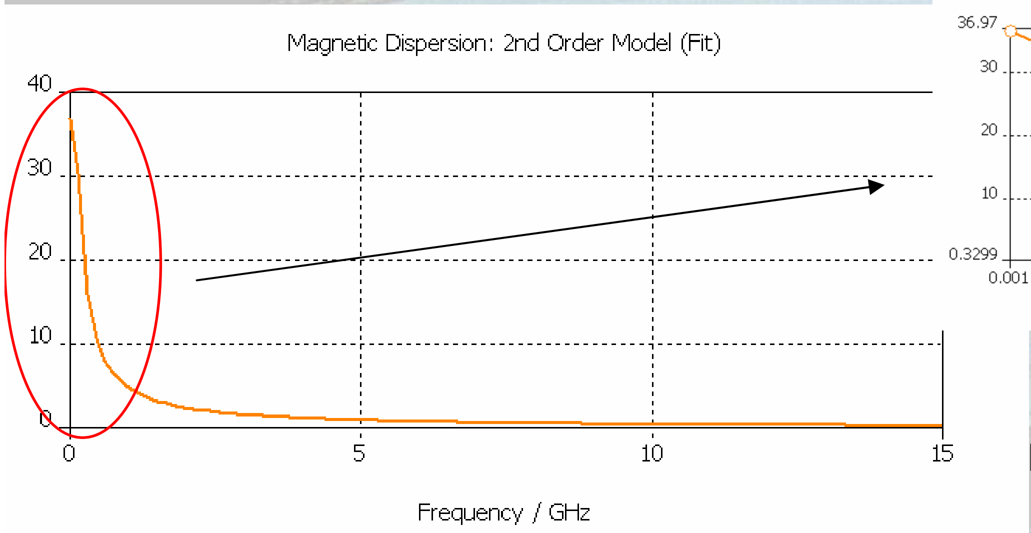


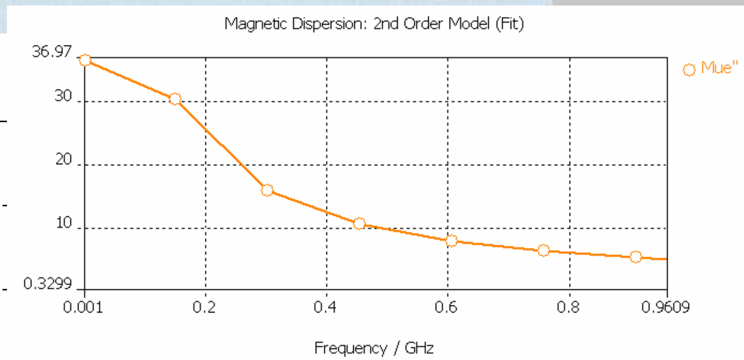
Microwave vs Ferrite!





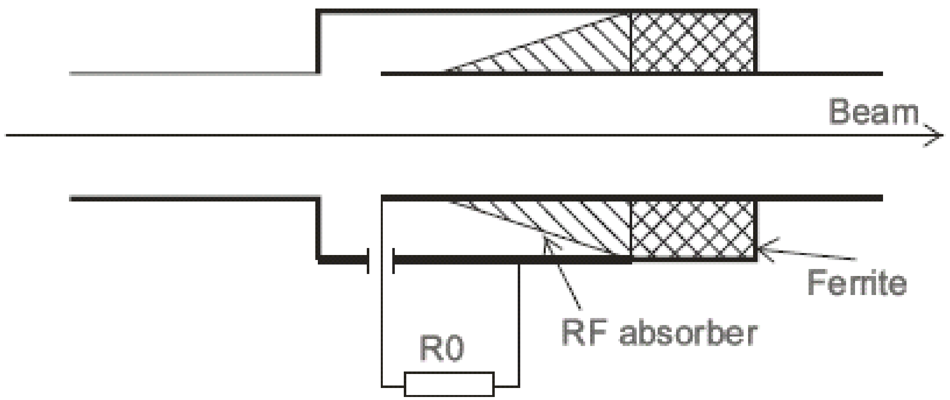
Imaginary part of permeability □: output data

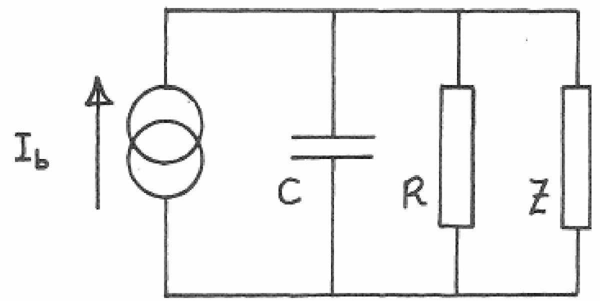




Working principle

The electromagnetic field dragged by the bunches passes in a small longitudinal gap made on the wall pipe and it is “cut”: this field portion is captured and used to diagnose the beam properties





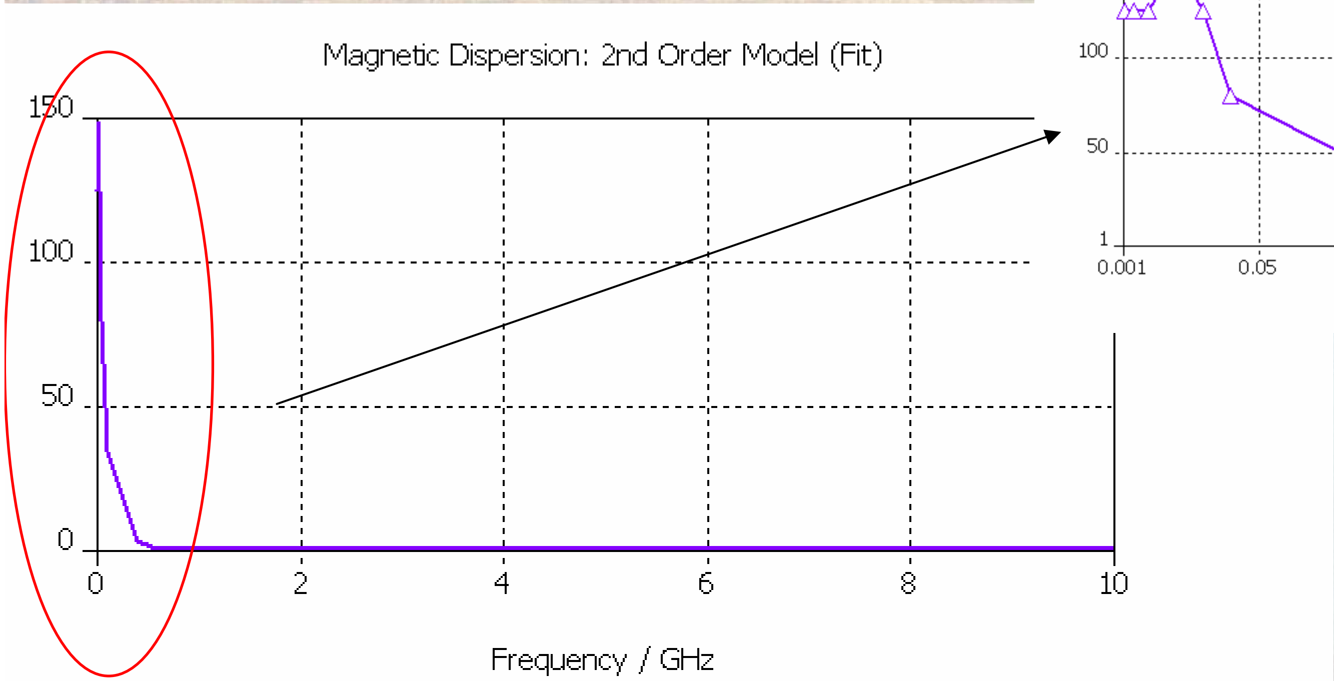
In the circuit representation is

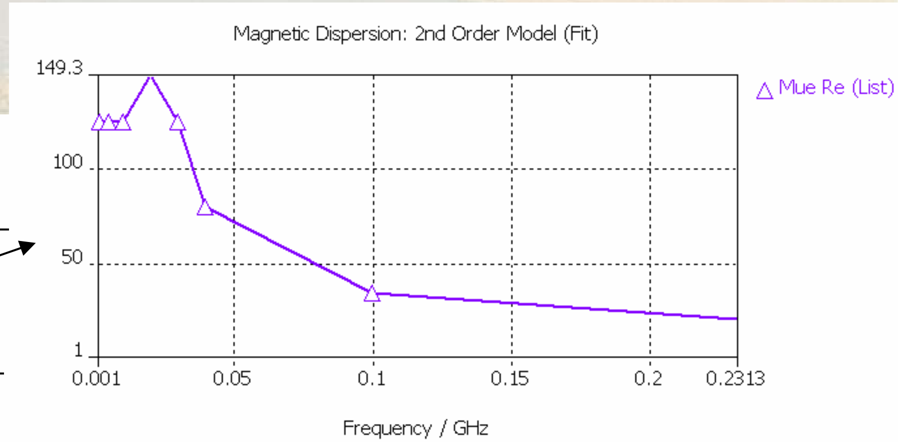
- R the measuring resistance
- Z the impedance of the box seen at gap
- C the capacitance across gap

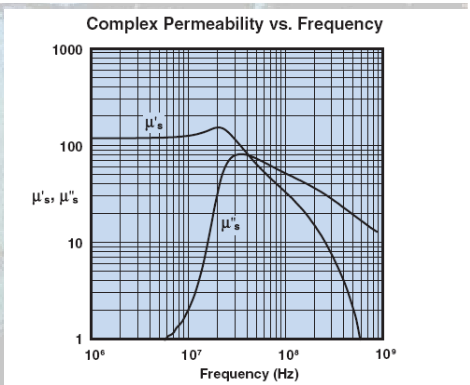
CST Microwave vs Ferrite!

In order to carry out the behaviour of the ferrite for higher frequencies, I extend the datasheet curves given by Fair Rite for continuity…. But……

Real part of permeability μ: input data

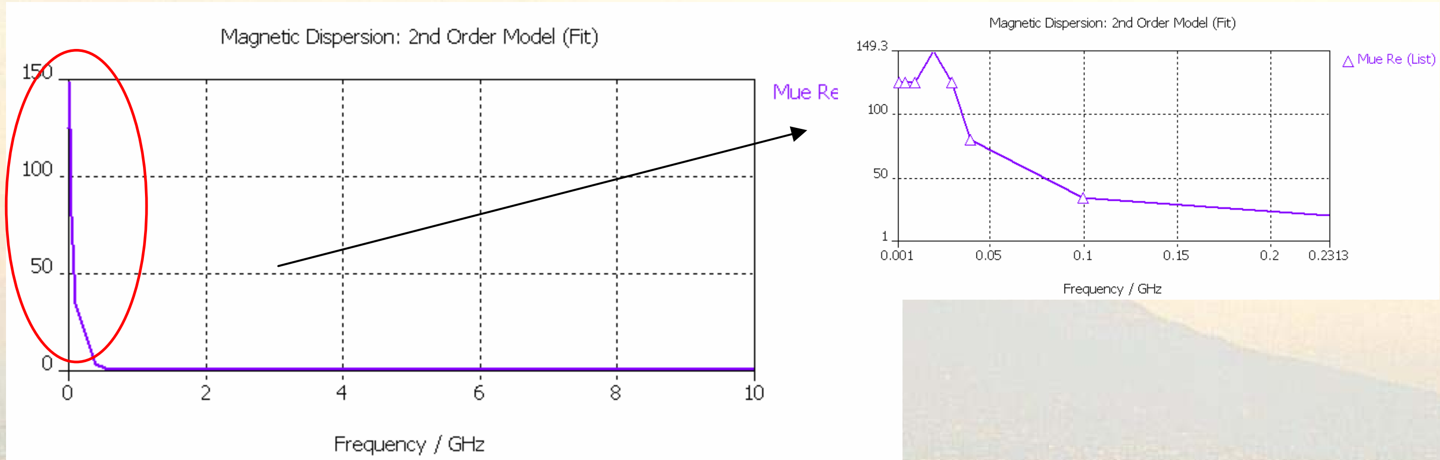




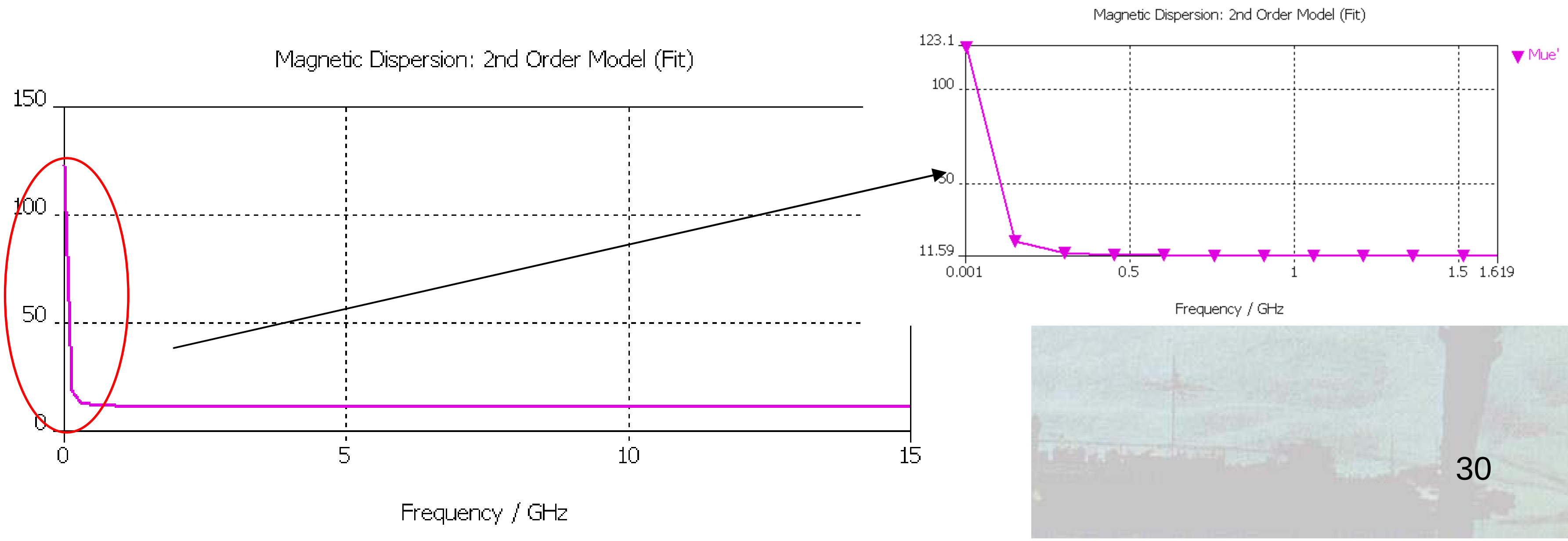


Measured on a 19/10/6mm toroid using the HP 4284A and the HP 4291A.

CST Microwave vs Ferrite!



Real part of permeability μ: output data



Thoughts for the beam tests

The proposal is to put the WCM in the zone of TL2 because of there the bunches will be spaced of 67 ps and it will be possible to perform a complete test of its performances