HOM coupler design for High current SRF cavities

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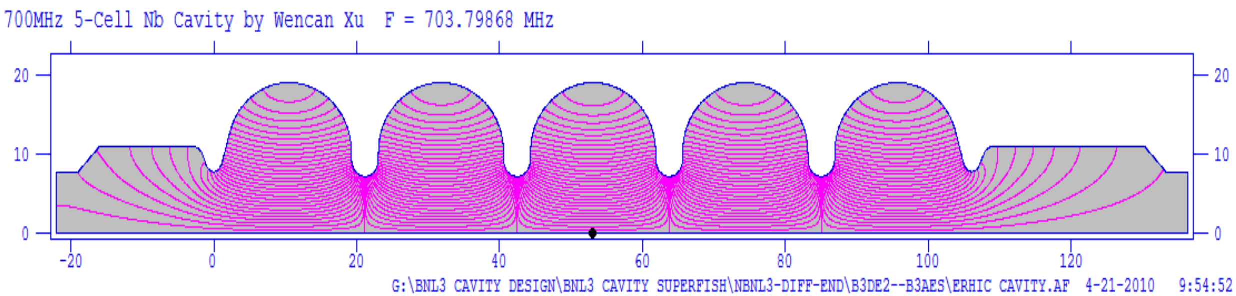
Outline

- Brief introduction of HOM damping requirement for BNL 5cell cavity
- HOM coupler design and test results
- Simple model for HOM coupler design
- Summary

BNL3 Cavity and damping requirements

5 cell cavity (BNL3) design



Parameters	BNL3
Frequency [MHZ]	703.79
beta	1
Cells No.	5
Geometry Factor	283
(R/Q) [Ω]	506.3
Epeak/Eacc	2.46
Bpeak/Eacc [mT/MV/m]	4.27
Coupling factor [%]	3.02
Loss factor(2mm) [V/pC]	3.6

- *Large coupling factor to propagate HOMs*
- *Enlarge beam pipe to propagate all HOMs but fundamental mode*
- *The beam pipe's length decay more than 30dB for fundamental mode*
- *The enlarged beam pipe is taped into a small diameter to avoid the cross talk of cavities.*

Damping requirements:

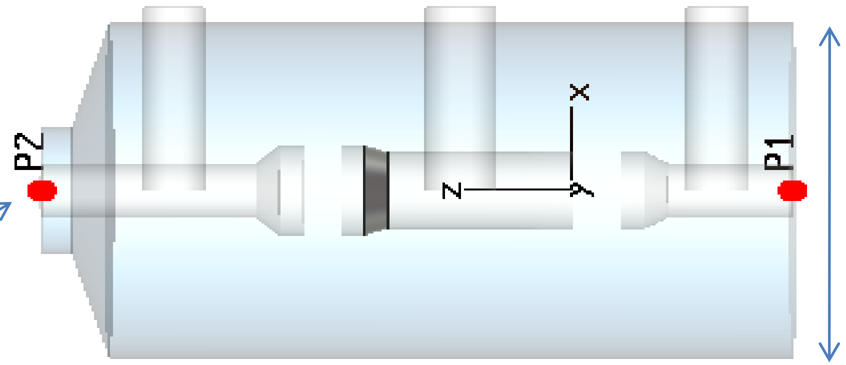
- *The average HOM power in eRHIC(50mA,6Pass ERL): 7.5 kWatt !*
- *The BBU Qext for Dipole modes is ~ 40,000*

HOM coupler design

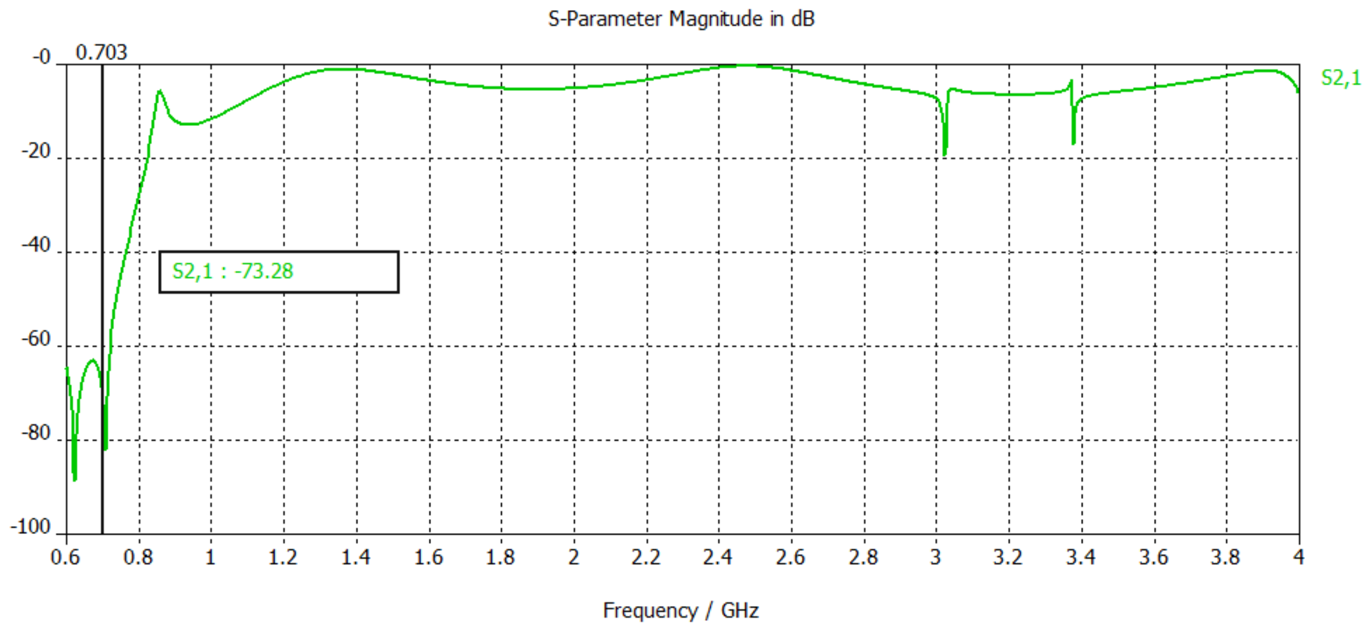
- “frequency sensitivity”
- Thermal concerning

2-stage HOM coupler design

50 Ω transmission line to room temperature

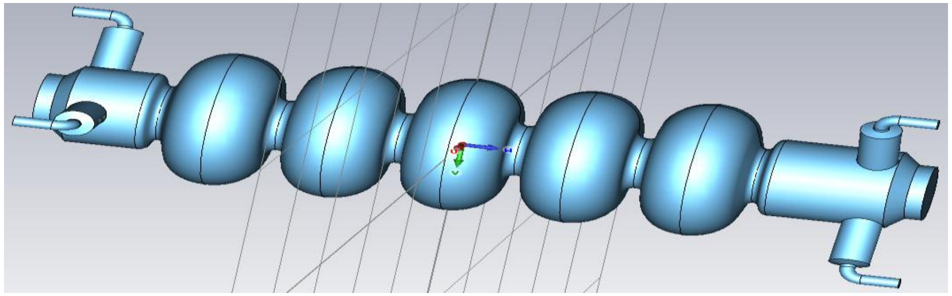


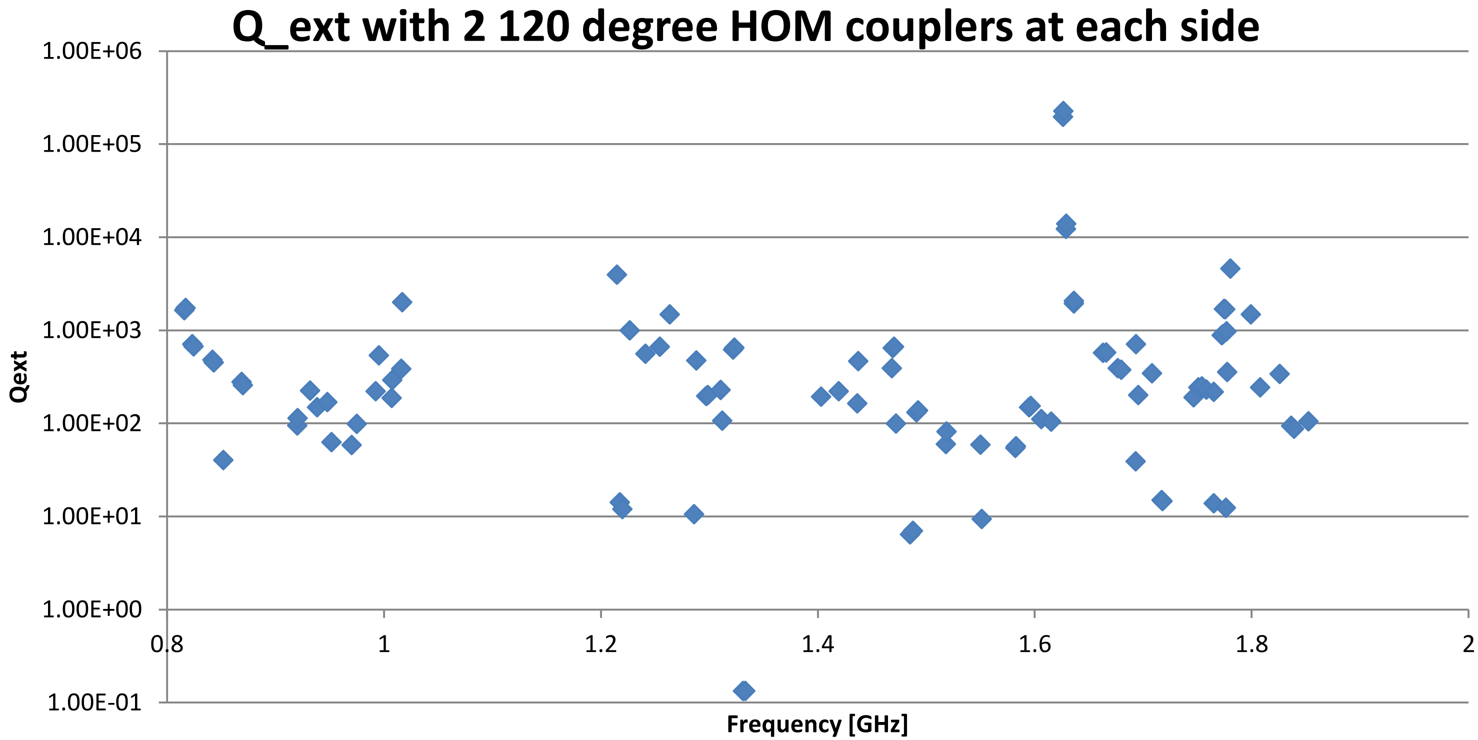
D=72mm



- Between the two notches, s21<-65 dB, 1st HOM is 0.82GHz, S21=-23dB,
- It still has good damping at high frequency
- Capacitors can be add to the transmission line to reduce the thermal conduction

2-stage HOM couplers – on cavity



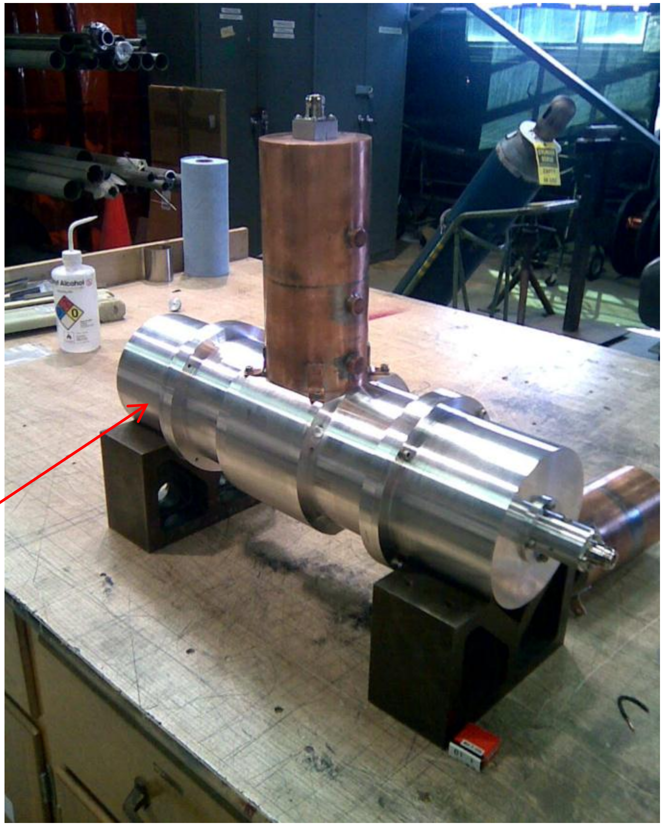


•The dipole modes at about 1.62GHz have low R/Q in order of 0.1

•"How many HOM couplers for one cavity" is still a open question right now because of the high propagating power.(*Keep in mind : 7.5kW in total*)

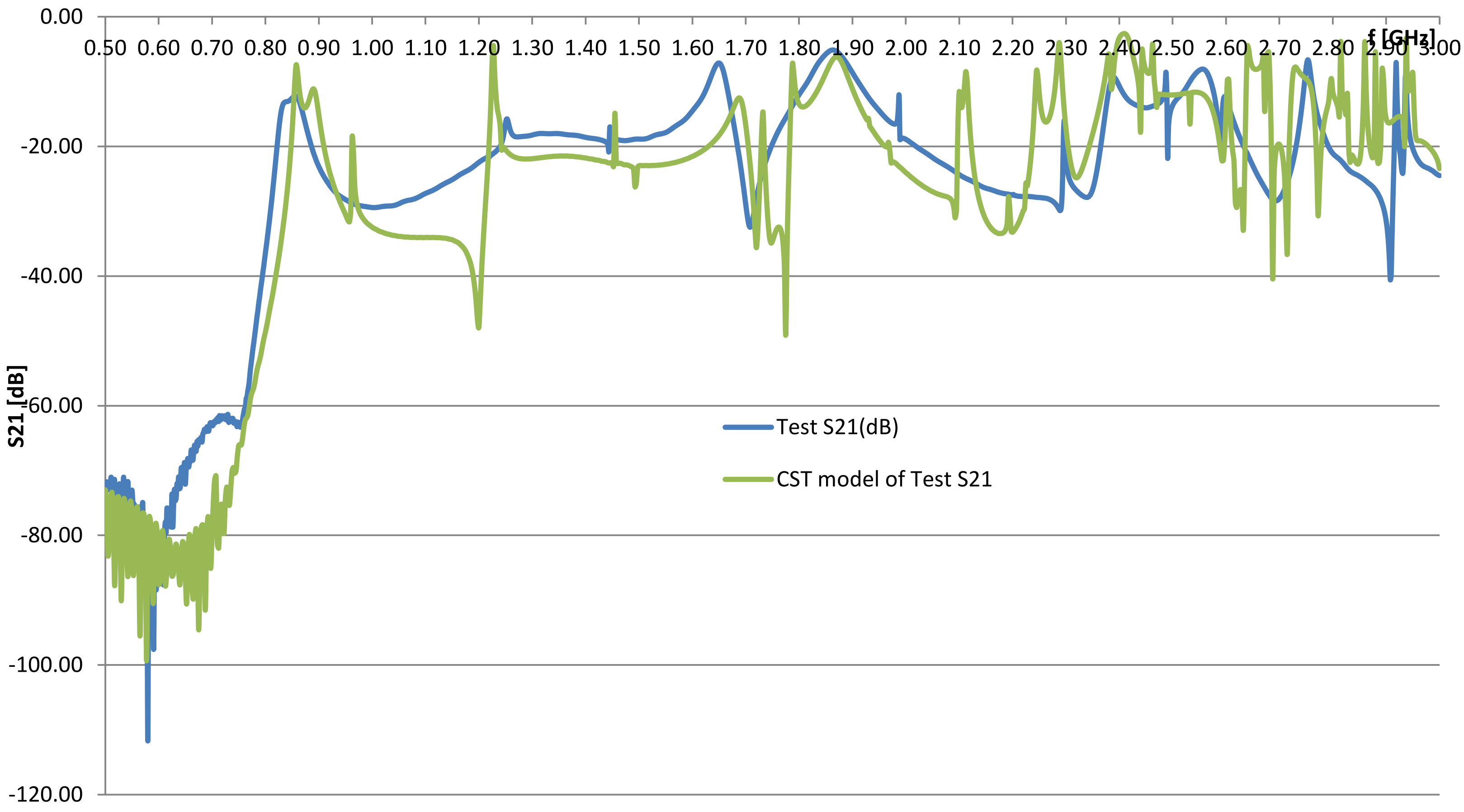
HOM couplers- cooper prototype

Antenna heads



Transmission line

2-stage HOM coupler --results

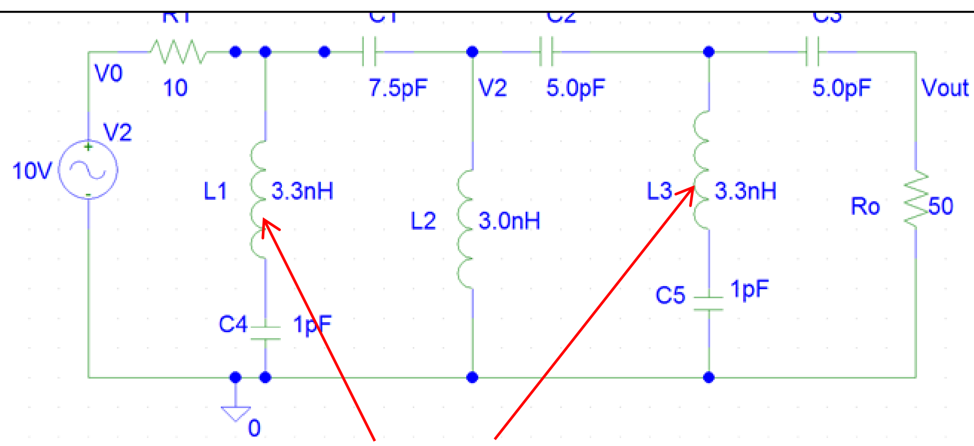


- The test by transmission line verified the design.
- Because of the big diameter(D=72mm) of the HOM couplers, the transmission line's diameter is so big that some HOM appears.

Matrix methods develop for coupler design

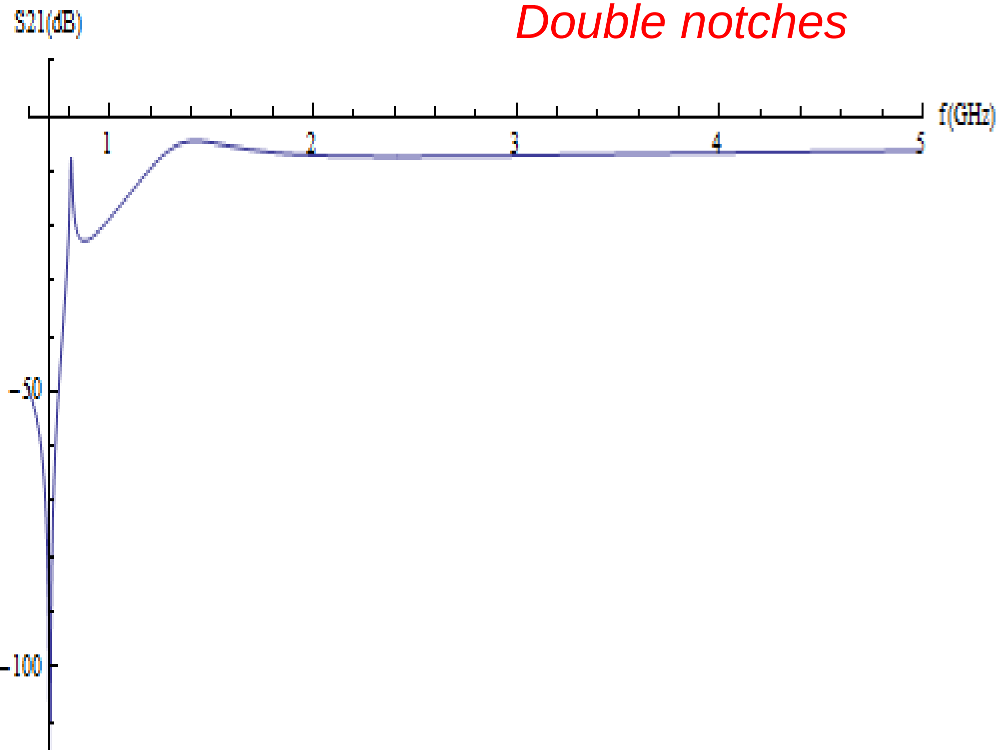
- To design the coupler from equivalent circuit concept
- To simplify the HOM coupler design by ABCD matix instead of 3D EM software

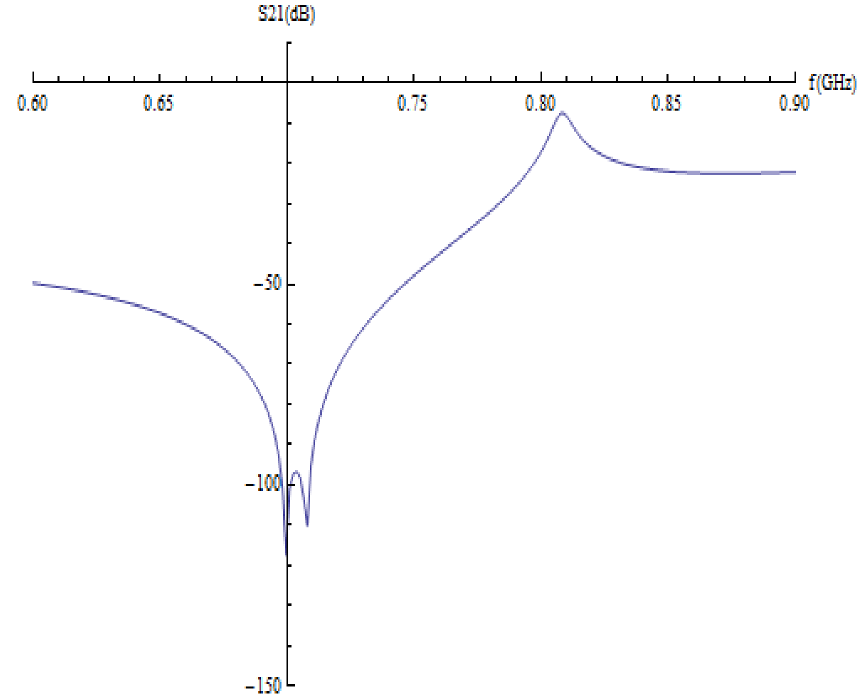
Double-notches(band-stop) equivalent circuit model



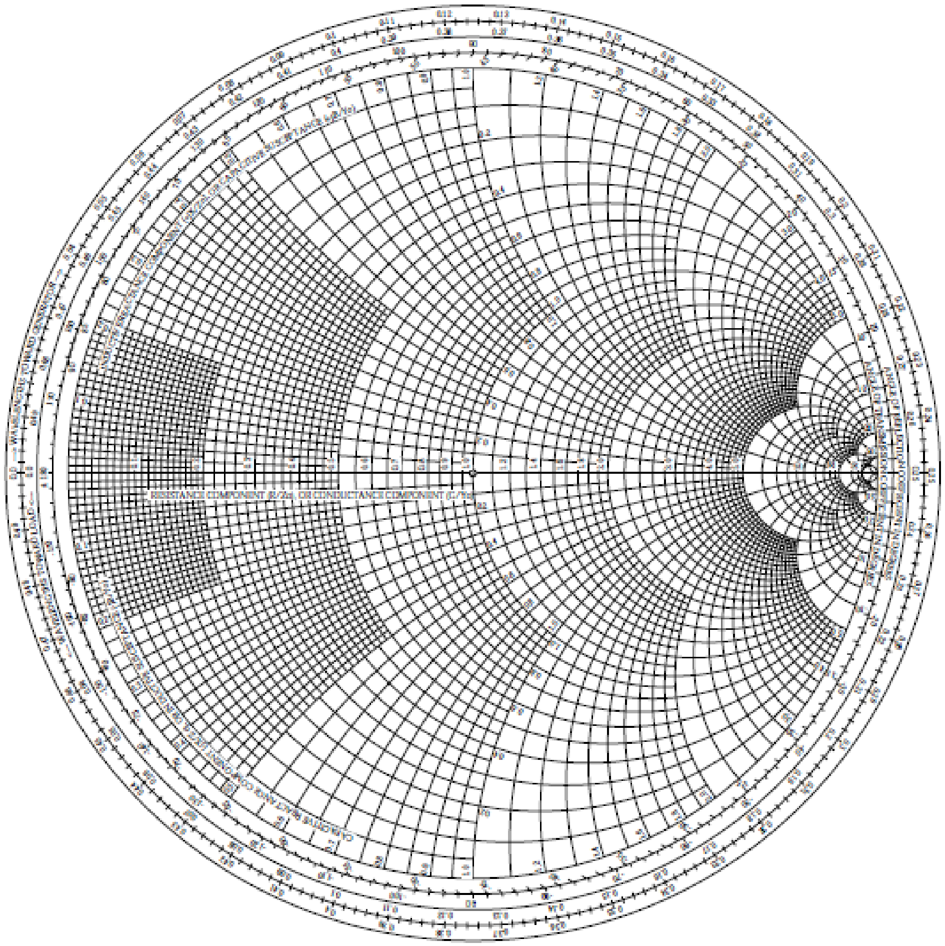
The question is:
"How to realize this circuit in 3D HOM coupler"

Double notches

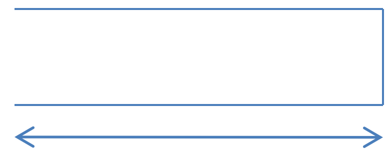




From circuit to Transmission line 1st



Short:

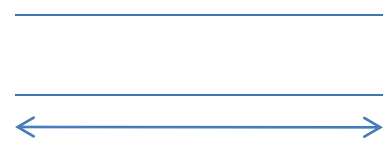


Lsc

0<Lsc< **λ/4** **= Inductor**

λ/4 <Lsc< **λ/2** **= Capacitor**

Open:



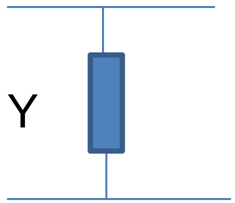
Loc

0<Loc< **λ/4** **= Copacitor**

λ/4 <Loc< **λ/2** **= Inductor**

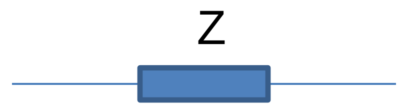
Matrix model for HOM design

Parallel:



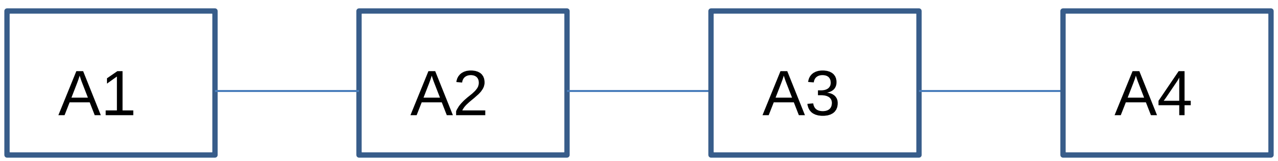
$$\begin{pmatrix} 1 & 0 \\ Y & 1 \end{pmatrix}$$

Series:



$$\begin{pmatrix} 1 & Z \\ 0 & 1 \end{pmatrix}$$

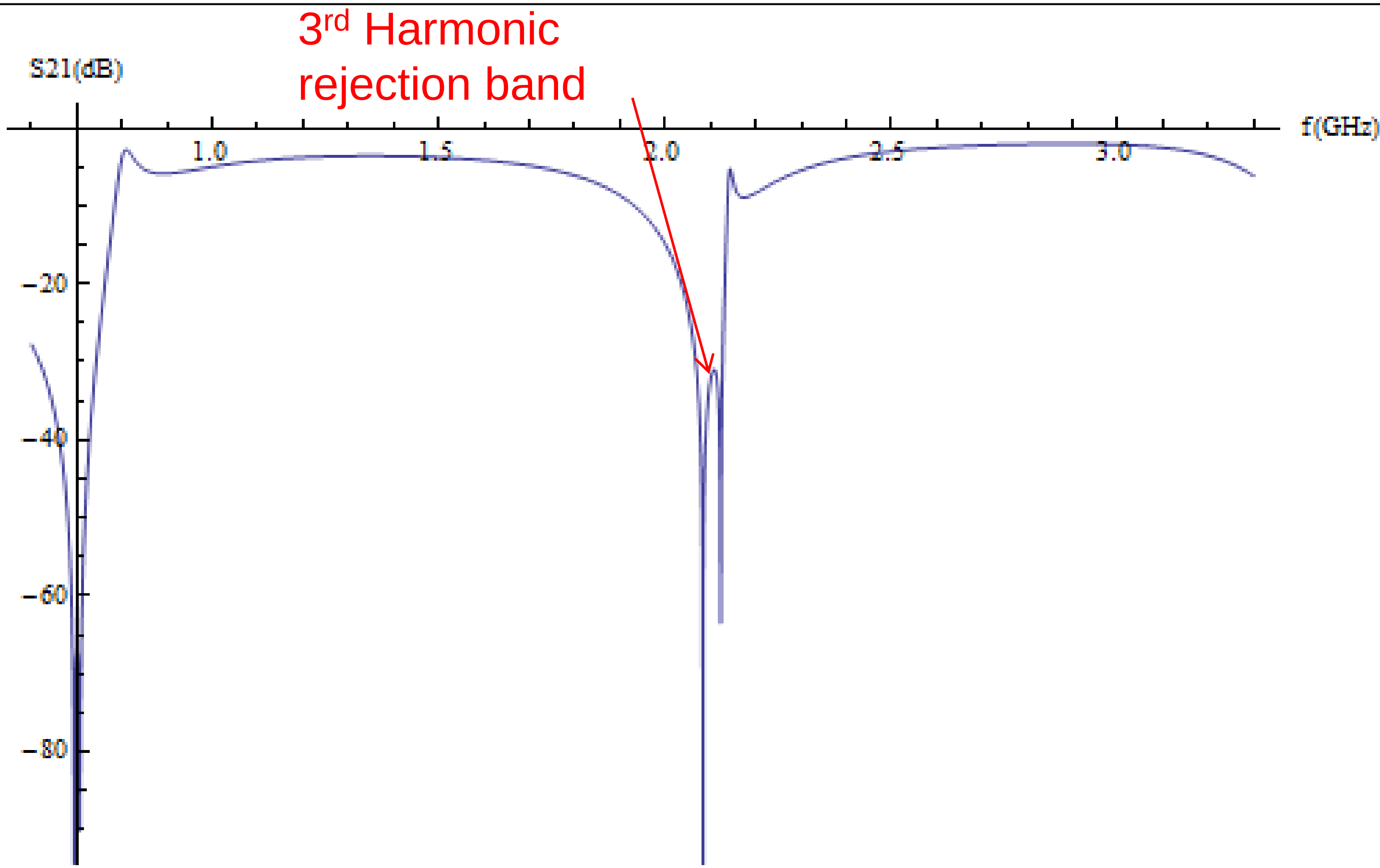
Combining all components:



Atotal= A1*A2*A3*A4

$$S_{21} = 20 * Lg \frac{2 * Det[Atotal]}{Atotal[1,1] + Atotal[1,2] / Z0 + Atotal[2,1] + Atotal[2,2]}$$

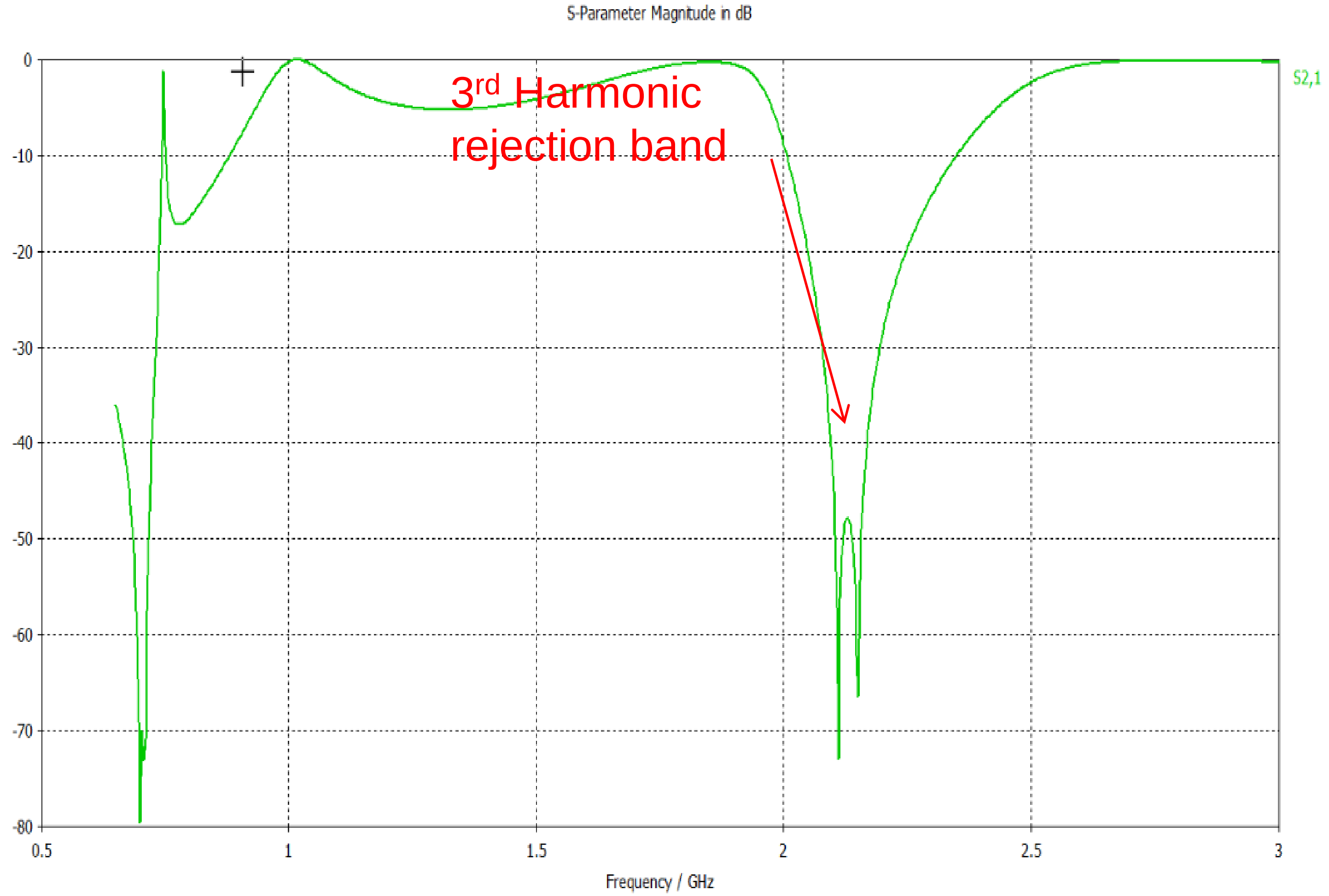
Band-stop(Quarter wave) circuit—by matrix Model



$$\mathrm{Atemp} = \begin{pmatrix} 1 & I*Z0*\mathrm{Tan}[\beta*L1] \\ 0 & 1 \end{pmatrix} . \begin{pmatrix} 1 & 0 \\ \frac{1}{-I*200*\mathrm{Cot}[\beta*L6]} & 1 \end{pmatrix} . \begin{pmatrix} 1 & -I*c2*\mathrm{Cot}[\beta*L2] \\ 0 & 1 \end{pmatrix} . \begin{pmatrix} 1 & 0 \\ \frac{1}{-I*200*\mathrm{Cot}[\beta*L8]} & 1 \end{pmatrix} . \begin{pmatrix} 1 & I*Z0*\mathrm{Tan}[\beta*L3] \\ 0 & 1 \end{pmatrix} .$$

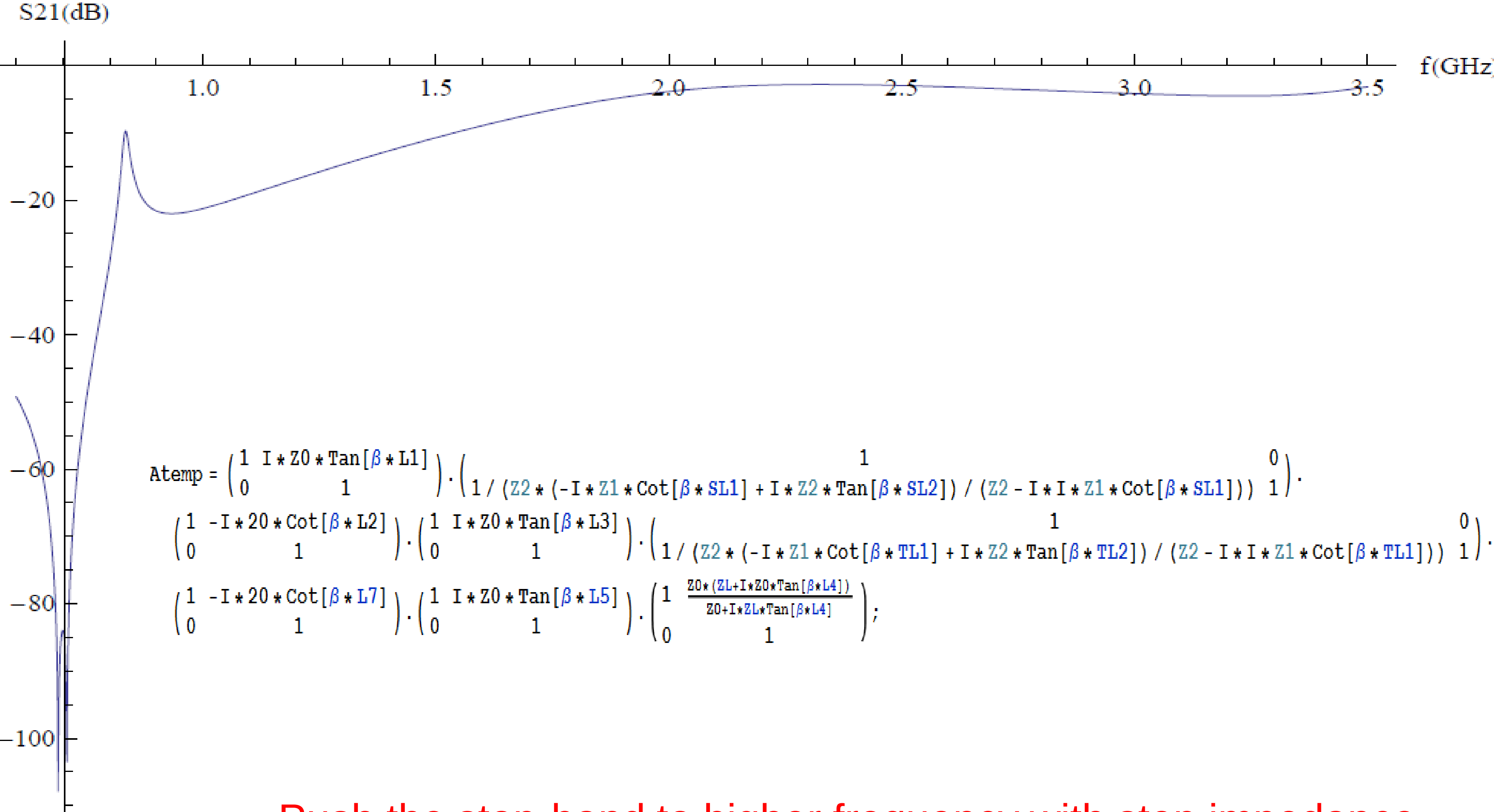
$$\begin{pmatrix} 1 & -I*c7*\mathrm{Cot}[\beta*L7] \\ 0 & 1 \end{pmatrix} . \begin{pmatrix} 1 & I*Z0*\mathrm{Tan}[\beta*L5] \\ 0 & 1 \end{pmatrix} . \begin{pmatrix} 1 & \frac{Z0*(ZL+I*Z0*\mathrm{Tan}[\beta*L4])}{Z0+I*ZL*\mathrm{Tan}[\beta*L4]} \\ 0 & 1 \end{pmatrix};$$

Band-stop(Quarter wave) model—by Microwave Studio



- It is the same with CST microwave studio results!!
- But the transmission line model simplifies the design and save a lot of time with tunable code!

Band-stop (Step impedance) circuit—Matrix model



$$\text{Atemp} = \begin{pmatrix} 1 & I*Z0*\text{Tan}[\beta*L1] \\ 0 & 1 \end{pmatrix} . \begin{pmatrix} 1 & 0 \\ 1/(Z2*(-I*Z1*\text{Cot}[\beta*SL1] + I*Z2*\text{Tan}[\beta*SL2])/(Z2 - I*I*Z1*\text{Cot}[\beta*SL1])) & 1 \end{pmatrix} .$$

$$\begin{pmatrix} 1 & -I*20*\text{Cot}[\beta*L2] \\ 0 & 1 \end{pmatrix} . \begin{pmatrix} 1 & I*Z0*\text{Tan}[\beta*L3] \\ 0 & 1 \end{pmatrix} . \begin{pmatrix} 1 & 0 \\ 1/(Z2*(-I*Z1*\text{Cot}[\beta*TL1] + I*Z2*\text{Tan}[\beta*TL2])/(Z2 - I*I*Z1*\text{Cot}[\beta*TL1])) & 1 \end{pmatrix} .$$

$$\begin{pmatrix} 1 & -I*20*\text{Cot}[\beta*L7] \\ 0 & 1 \end{pmatrix} . \begin{pmatrix} 1 & I*Z0*\text{Tan}[\beta*L5] \\ 0 & 1 \end{pmatrix} . \begin{pmatrix} 1 & \frac{Z0*(ZL+I*Z0*\text{Tan}[\beta*L4])}{Z0+I*ZL*\text{Tan}[\beta*L4]} \\ 0 & 1 \end{pmatrix};$$

- Push the stop-band to higher frequency with step impedance design, which is also simplify the design
- Will use CST to verify the design

Summary

- HOM damping is one of biggest challenge for eRHIC project at BNL.
- New HOM couplers design with broaden rejection band has been designed, tested and verified.
- A simple model for HOM coupler design has been developed at BNL and verified by CST. The model work is still going on..

Thank you !