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

- 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

- Between the two notches, $s_{21} < -65$ dB, 1$^{st}$ HOM is 0.82GHz, $S_{21} = -23$ dB,
- It still has good damping at high frequency
- Capacitors can be added to the transmission line to reduce thermal conduction

50 Ω transmission line to room temperature

D = 72 mm
• 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 an 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
The test by transmission line verified the design. Because of the big diameter ($D=72\text{mm}$) 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 matrix instead of 3D EM software
Double-notches (band-stop) equivalent circuit model

The question is: “How to realize this circuit in 3D HOM coupler”
From circuit to Transmission line $1^{st}$

Short:

Lsc

$0 < Lsc < \lambda/4$ = Inductor

$\lambda/4 < Lsc < \lambda/2$ = Capacitor

Open:

Loc

$0 < Loc < \lambda/4$ = Copacitor

$\lambda/4 < Loc < \lambda/2$ = Inductor
Matrix model for HOM design

Combining all components:

\[ \text{Parallel:} \quad Y \]

\[ \text{Series:} \quad Z \]

\[ \det \text{Atotal} = S \text{Lg} \text{Atotal} + \text{Atotal} Z \text{Atotal} + \text{Atotal} \text{Atotal} \]

\[ \text{Atotal} = A_1 \times A_2 \times A_3 \times A_4 \]

\[ S_{21} = 20 \times \text{Lg} \frac{2 \times \det \text{Atotal}}{\text{Atotal}[1, 1] + \text{Atotal}[1, 2] / Z_0 + \text{Atotal}[2, 1] + \text{Atotal}[2, 2]} \]
Band-stop (Quarter wave) circuit—by matrix Model

$A_{temp} = \begin{pmatrix} 1 & I \ast Z0 \ast \tan(\beta \ast L1) \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ -I \ast 200 \ast \cot(\beta \ast L6) & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & -I \ast c2 \ast \cot(\beta \ast L2) \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ -I \ast 200 \ast \cot(\beta \ast L8) & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & I \ast Z0 \ast \tan(\beta \ast L3) \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & I \ast Z0 \ast \tan(\beta \ast L5) \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & \frac{Z0 \ast (ZL+I\ast Z0 \ast \tan(\beta \ast L4))}{Z0+I\ast ZL\ast \tan(\beta \ast L4)} \\ 0 & 1 \end{pmatrix}$
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

- 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 !