PBAR NOTE NO. 601
S PARAMETER MEASUREMENTS OF THE HORIZONTAL BAND 1 PICKUP ARRAY
Dave McGinnis
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INTRODUCTION

The pickup arrays for Horizontal Band 1 (HB1) of the 4-8 GHz Debuncher Upgrade are designed to operate between 3.8 and 4.9 GHz. The lower sub-band of HB1 is centered at 4.15 GHz with a 10dB bandwidth of 300 MHz. The upper sub-band is centered at 4.6 GHz with a 10dB bandwidth of 400 MHz. Each array contains 284 slots. Each slot has a width of 0.080" and the metal space between each slot is also 0.080" wide. The total length of the slot section for each array is 45.36". The length of the slots for the lower sub-band array is 0.910". The length of the slots for the upper sub-band array is 0.800". The horizontal beam pipe aperture is 2.36". The vertical beam pipe aperture is 1.985". The width of the output waveguide is 2.290" and the height is 0.660".

The pickup sensitivity is for the sum and difference mode is shown in Figures 1 and 2, respectively. The difference mode impedance is defined as:

\[ P_{\Delta} = \frac{1}{2} \left( Z_{n_{pu}} \right)_{b} \frac{\varepsilon_{b}}{1 \pi - \text{mm} - \text{mrad}} \]  

where \( P_{\Delta} \) is the total power received from the pickup, \( i_{b} \) is the beam current, \( \varepsilon_{b} \) is the un-normalized beam emittance. The sum mode impedance is defined as:

\[ P_{\Sigma} = \frac{1}{2} Z_{\Sigma_{pu}} i_{b} \]  

S PARAMETER MEASUREMENTS

The port numbering for the S-parameter measurements is shown in Figure 3. A moment method program is used to calculate the S-parameters of the arrays. The program uses 2 slot modes, 100 waveguide modes in the horizontal direction and 20 even waveguide modes in the vertical direction. To calculate longitudinal and transverse cooling impedances, the program uses even and odd mode (sum and difference) horizontal symmetry. Placing a vertical magnetically conducting plane in the center of the array is used to solve the sum mode. Placing a vertical electrically conducting plane in the center of the array is used to solve the difference mode. The single-ended S-parameters are derived from the sum and difference S-parameters:

\[ S_{1,1} = S_{1,1\Sigma} + S_{1,1\Delta} \]

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\[ S_{2,1} = S_{2,1\Sigma} + S_{2,1\Delta} \]  \hspace{1cm} (4)

\[ S_{3,1} = S_{3,1\Sigma} - S_{3,1\Delta} \]  \hspace{1cm} (5)

\[ S_{4,1} = S_{4,1\Sigma} - S_{4,1\Delta} \]  \hspace{1cm} (6)

Figures 4 through 11 show the measured and calculated S-parameters.

The "wiggles" in the calculated and measured values of the magnitude response of \( S_{21} \) and \( S_{41} \) seem to be 180 degrees out of phase. To try to track down this discrepancy between the measured and the calculated responses, the sum and difference mode forward scattering parameters \( S_{21\Sigma} \) and \( S_{21\Delta} \) are plotted in Figures 12-15. Again the "wiggles" seem to be 180 degrees out of phase between the calculated and the measured values.

The moment method program does not calculate the S-parameters directly but calculates the "scattered" field off the slots. The total field received at the ports is the sum of the "scattered" field plus the "incident" field. The scattered field \( C_{21} \) is given as:

\[ S_{2,1\Delta} = C_{2,1\Delta} + e^{-j\beta(z_2-z_1)} \]  \hspace{1cm} (7)

\[ S_{2,1\Sigma} = C_{2,1\Sigma} + e^{-j\beta(z_2-z_1)} \]  \hspace{1cm} (8)

where \( z_1 \) and \( z_2 \) are the reference planes of ports 1 and 2, respectively. The scattered wave, \( C_{21} \), amplitudes and phases are shown in Figures 16 through 23 for the sum and difference modes.
Figure 1. Sum mode pickup impedance for Horizontal Band 1.

Figure 2. Difference mode pickup impedance for Horizontal Band 1.
Figure 3 Port setup for S-Parameter measurements.

Figure 4. S11 for the lower sub-band of HB1.
Figure 5. $S_{11}$ for the upper sub-band of HB1

Figure 6. $S_{21}$ for the lower sub-band of HB1.
Figure 7. $S_{21}$ for the upper sub-band of HB1.

Figure 8. $S_{31}$ for the lower sub-band of HB1.
Figure 9. S31 for the upper sub-band of HB1.

Figure 10. S41 for the lower sub-band of HB1.
Figure 11. $S41$ for the upper sub-band of HB1.

Figure 12. $S21\Delta$ for the lower sub-band of HB1.
Figure 13. S21Δ for the upper sub-band of HB1.

Figure 14. S21Σ for the lower sub-band of HB1.
Figure 15. $S_{21}$ for the upper sub-band of HB1.

Figure 16. Difference mode magnitude of the forward scattered wave for the lower sub-band of HB1.
Figure 17. Difference mode phase of the forward scattered wave for the lower sub-band of HB1

Figure 18. Difference mode magnitude of the forward scattered wave for the upper sub-band of HB1
Figure 19. Difference mode phase of the forward scattered wave for the upper sub-band of HB1

Figure 20. Sum mode magnitude of the forward scattered wave for the lower sub-band of HB1
Figure 21. Sum mode phase of the forward scattered wave for the lower sub-band of HB1

Figure 22. Sum mode magnitude of the forward scattered wave for the upper sub-band of HB1
**Figure 23.** Sum mode phase of the forward scattered wave for the upper sub-band of HB1