P Note #356

CALCULATION OF IMPEDANCES AND SENSITIVITIES IN SUM AND DIFFERENCE MODES FOR 1-2 GHz AND 2-4 GHz PICKUP ELECTRODES

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I. Introduction

To better understand power absorption by the pickup (PU) electrodes, we calculated the characteristic impedances and sensitivities in both sum and difference modes for the 1-2 GHz and 2-4 GHz PU electrodes. Since the design for the 1-2 GHz system essentially has been settled, our investigations are of more importance for the 2-4 GHz design which has not been finalized. One main feature of our results is that sum ($Z_S$) and difference ($Z_D$) mode impedances are not equal,
as is often assumed.

In our method, we numerically solve the 2-dimensional Laplace's equation to obtain the electric field and potential using the CERN-Poisson Program Package. As shown in Fig. 1, the boundary conditions for a given PU geometry are $V=0$ on the walls, $V=+1$ on the top electrode, and $V=+1 (-1)$ on the bottom electrode in the $\Sigma (A)$ mode.

On a contour surrounding one of the PU electrodes, we apply the 2-dimensional Gauss' Law.
\[ \varepsilon_0 \oint E_z \, dl = \frac{Q}{m} \left( \frac{\text{Coulomb}}{\text{meter}} \right) . \]  \hspace{1cm} (1) 

And since the capacitance/length is 
\[ C = \frac{Q}{V_{\text{electrode}}} \]  \hspace{1cm} (2) 

and \( V = 1 \) \( V_{\text{electrode}} \), the characteristic impedance is 
\[ Z = \frac{1}{cC} = \frac{1}{cQ/m} . \]  \hspace{1cm} (3) 

We define \( E \)-mode sensitivity \( s(0,0) \) as the potential \( V(0,0) \) at the center of the PU geometry. Likewise, the \( \Delta \)-mode sensitivity \( d(0,0) \) is 
\[ E(0,0) / V_{\text{electrode}} / h \]  and \( E(0,0) = \sqrt{E_x^2 + E_y^2} \).
II. 1-2 GHz PU System

In Fig. 2, we show the geometry of the 1-2 GHz PU system. Our numerical analysis gives

\[ Z_0 = 108.5 \Omega \]
\[ s(90) = 0.853 \]
\[ Z_A = 70.0 \Omega \]
\[ \Omega(90) = 1.927 \]
III. 2-4 GHz PU System

In this case, we considered a variety of geometries in an effort to increase power absorption in the A-mode. The present 2-4 GHz geometry is shown in Fig. 3.

We tried different pocket widths \( w \):

<table>
<thead>
<tr>
<th>( w ) (cm)</th>
<th>( Z_\varepsilon )</th>
<th>( s(0o) )</th>
<th>( Z_A )</th>
<th>( d(%) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>96.6</td>
<td>0.593</td>
<td>82.7</td>
<td>1.58</td>
</tr>
<tr>
<td>3.5</td>
<td>102.3</td>
<td>0.625</td>
<td>85.0</td>
<td>1.62</td>
</tr>
<tr>
<td>4.0</td>
<td>105.7</td>
<td>0.652</td>
<td>85.5</td>
<td>1.66</td>
</tr>
<tr>
<td>4.5</td>
<td>106.6</td>
<td>0.674</td>
<td>84.5</td>
<td>1.69</td>
</tr>
<tr>
<td>5.0</td>
<td>109.1</td>
<td>0.693</td>
<td>84.8</td>
<td>1.71</td>
</tr>
</tbody>
</table>
since \( \text{Power} \propto d^2 \Delta \), \( w = 5.0 \text{cm} \) absorbs 20% more power than \( w = 3.0 \text{cm} \). We also tried increasing both the pocket depth to 2 cm and pocket width to 4 cm, for this configuration we obtained

\[
\begin{array}{cccc}
Z_Z(n) & s(0.0) & Z_\Delta(n) & j(0.0) \\
119.1 & 0.659 & 93.6 & 1.67
\end{array}
\]

which gives a 26% or 1 dB improvement over the 1.25 x 3 cm geometry.

In summary, among the various 2-4 GHz designs we considered, the best for power absorption was the 2cm x 4cm geometry; however, none showed any significant dB gain.
**FIGURE 1**

PU GEOMETRY
FIGURE 2

1-2 GHz GEOMETRY
FIGURE 3

2-4 GHz GEOMETRY
since Power \propto d^2 \tilde{Z}_{\Delta}, \quad w = 5.0\,\text{cm} \\
absorbs 20\% more power than \quad w = 3.0\,\text{cm}. \quad \text{We also tried increasing} \\
both the pocket depth to 2\,\text{cm} \\
and pocket width to 4\,\text{cm}. \quad \text{For this} \\
configuration we obtained \\

\[
\begin{array}{c|c|c|c|c}
\tilde{Z}_{Z}(\lambda) & s(0,0) & \tilde{Z}_{\Delta}(\lambda) & d(0,0) \\
119.1 & 0.659 & 93.6 & 1.67 \\
\end{array}
\]

which gives a 26\% or 1\,\text{dB} improvement \\
over the 1.25 \times 3\,\text{cm geometry}.

In summary, among the various 
2-4\,\text{GHz} designs we considered, the 
best for power absorption was the 2cm \times 4cm 
geometry; however, none showed any significant 
\text{dB gain}.
References

1. For previous results, see A. Ruggiero, p. Note #148 and #199; D. Neuffer, p. Note #201; K. Sakagawa, p. Note #264; H. Unstattrer, unpublished (1982).