Impedance Mismatch between the Microwave Generator and the Plasma Machine

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Plasma Machine

Argon gas is injected to the machine. The microwaves heat the Argon ions to initiate ionization and plasma is produced. A dielectric wall is used inside the rectangular waveguide to isolate the plasma machine and maintain vacuum.
A rectangular waveguide partially loaded with a dielectric has an impedance discontinuity that causes reflection. It is desirable to match the line in order to reduce reflection.
Teflon as Dielectric Isolator

A Teflon layer is used inside the rectangular waveguide to isolate the plasma machine and maintain vacuum, some absorption of microwaves will occur, causing reflection, reducing the efficiency of the power transfer.

Why Teflon?

Teflon resists temperatures as high as 300º C during long period of time without suffering any change or modification.
Problem

Power loss due to reflection may damage the generator in the long run. We intend to optimize the dielectric to minimize the reflection.

$1\text{Db} = 10^{-12}\text{W/m}^2$
Microwave Generator

- Power Output: 5kW continuous
  at 2.45 GHz

Power Meter

- Model: HP 432B
- Over Range Reading in 1-10mW and 10µW
- Waveform Sine Wave etc.
- Frequency 50/60Hz
Coupler

Incident and Reflected

Incident 46db

Reflected 55dB

03/03/2005
Dummy Load & Coupler

Description
- Dimension: 48”H x 7.5”W
- Weight: Approximately 60lbs
- Purpose: Only Test

Coupler

Dummy Load

32.0 mm
70.7 mm
Reflection Measurement

The term **reflection coefficient** is used in physics and electrical engineering when wave propagation in a medium containing discontinuities is considered.

In general, the reflection coefficient is the ratio of the reflected wave to the incident wave.

\[
\frac{P_{av,\text{reflected}}}{P_{av,\text{incident}}} = |\Gamma_L|^2 = .1
\]

\[
\Gamma_L = .316
\]
Finite-Difference Time Domain (FDTD) Solver

Rectangular Waveguide

dimensions:
- $a = 70.7\,\text{mm}$
- $b = 32\,\text{mm}$

Teflon:
- thickness: $L = 6.0\,\text{mm}$
- relative permittivity: $\varepsilon_r = 2.1$

Source:
- $f = 2.45\,\text{GHz}$
Analytical Formulas used in Matlab

\[ Z_{in} = Z_0 \ast \left( \frac{Z_{in_{load}} + jZ_0 \tan \beta_{in} l_{in}}{Z_0 + jZ_{in_{load}} \tan \beta_{in} l_{in}} \right) \]

\[ \Gamma = \left( \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \right) \]
Characteristic Impedance

The term *impedance* is a general expression which can be applied to any electrical entity which impedes the flow of current. In general, it is the ratio between voltage and current.

\[
Z_0 = \frac{-E_y}{H_x}
\]

![Graph showing characteristic impedance over frequency]
Free space characteristic impedance

(Free Space = 377)
Characteristic impedance of Teflon-filled Waveguide (Z0T)

\[ Z_{0r} = \frac{\left( K \times 377 \right)}{\sqrt{\varepsilon_r}} \frac{\beta}{\bar{z}_l} \]
Load Impedance

\[ Z_{in_{\text{load}}} = \text{Input Impedance with Teflon} \]

\[ Z_{in_{\text{load}}} = Z_{0r} \left( \frac{Z_{0} + jZ_{0} \tan \beta_{T}l_{T}}{Z_{0r} + jZ_{0} \tan \beta_{T}l_{T}} \right) \]
Input Impedance

\[ Z_{in} = Z_0 \times \left( \frac{Z_{in_{load}} + jZ_0 \tan \beta_{in} l_{in}}{Z_0 + jZ_{in_{load}} \tan \beta_{in} l_{in}} \right) \]
Reflection coefficient

Gamma (Γ)

\[ \Gamma = \left( \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \right) \]

Measurement
Future Work

- Change the thickness of the Teflon to know the maximum and minimum reflection ($\Gamma$).
- Change the material.

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>$\varepsilon_r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plexiglas</td>
<td>3.45</td>
</tr>
<tr>
<td>Quartz</td>
<td>3.8</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>2.56</td>
</tr>
<tr>
<td>Polyvinyl</td>
<td>3.0</td>
</tr>
<tr>
<td>Teflon</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Analytical

7.65cm vs. .1cm

Gamma en TE con l2=16cm

Frequency (GHz)

Gamma vs. Frequency (GHz)

X: 2.4
Y: 0.005278

X: 2.45
Y: 0.03415
Questions?
\[
\frac{z_{in} - z_0}{z_{in} + z_0} = \frac{e_{yf} - e_{yn}}{e_{yn}}
\]

\(X: 2.463\)
\(Y: 0.2556\)

\(Z_0\) (red, blue) and \(z_{in}\) cfdtd

\(X: 2.463\)
\(Y: 653.4\)
Gamma from TE and cfdtd

Frequency (GHz)

C:\CFDTD\RESEARCH\micGOOD\plot_imp_tog.m
Gamma en TE con l2=16cm

X: 2.446
Y: 0.2659
mic\GOOD\plot_imp_tog.m

![Graph showing frequency vs. impedance with annotations and markers at various points.](image-url)
TEₐ = 70.7 mm

- zin3
- z03
- zload

Frequency (GHz) vs. Zin8

- X: 2.45, Y: 753.9
- X: 2.45, Y: 600
- X: 2.45, Y: 583.4
\textbf{Gamma en TE con l2=16cm}

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>\textbf{Gamma3}</th>
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</thead>
<tbody>
<tr>
<td>2</td>
<td>0.38</td>
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<tr>
<td>2.5</td>
<td>0.36</td>
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<tr>
<td>3</td>
<td>0.34</td>
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<tr>
<td>3.5</td>
<td>0.32</td>
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<tr>
<td>4</td>
<td>0.30</td>
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<tr>
<td>4.5</td>
<td>0.28</td>
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<tr>
<td>5</td>
<td>0.26</td>
</tr>
</tbody>
</table>

\textbf{X: 2.45}
\textbf{Y: 0.2225}