1. Introduction

1.1 Objective

The objective of this project is to design a coaxial to waveguide adapter/transition for a WR-75 waveguide that operates in the frequency range of 10-15 GHz. The primary goal is to achieve a minimum value of S11 (reflection coefficient) and a maximum value of S21 (transmission coefficient) around a center frequency of 12.5 GHz. This will ensure efficient transmission of microwave signals with minimal reflection and maximum power transfer.

1.2 Background

Waveguides are used extensively in microwave communication systems due to their ability to efficiently carry high-frequency signals with low loss. The WR-75 waveguide is a standard rectangular waveguide used in various applications, including radar, satellite communications, and microwave relay systems. It has internal dimensions of 19.05 mm by 9.525 mm and is designed to operate over the frequency range of 10-15 GHz. Coaxial cables, on the other hand, are commonly used for lower frequency signals and offer flexibility and ease of connection. To transition from coaxial to waveguide transmission, an adapter is required. This adapter ensures the efficient transfer of energy from the coaxial cable to the waveguide with minimal loss and reflection.

1.3 Design Goals

The specific design goals for this project are:

- Achieve minimum S11 (reflection coefficient) to ensure minimal signal reflection.

- Achieve maximum S21 (transmission coefficient) to ensure maximum signal transmission.

- Maximize the bandwidth where S11 ≤ -10 dB around the center frequency of 12.5 GHz.

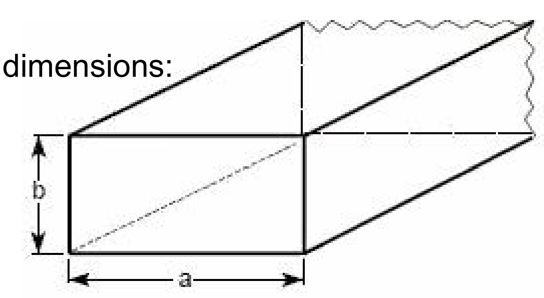
2. Calculations

2.1 Waveguide Dimensions

The WR-75 waveguide has the following internal dimensions:

Width: 19.05 mm

Height: 9.525 mm



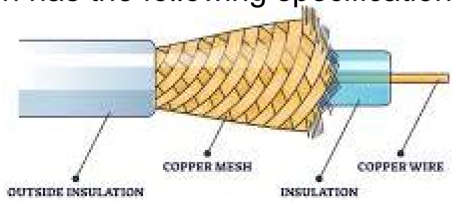
2.2 Coaxial Cable Specifications

The coaxial cable used in this design has the following specifications:

Inner diameter: 1.27 mm

Outer diameter: 4.1 mm

Dielectric material: Teflon



2.3 Cutoff Frequency Calculation

The cutoff frequency (fc) for the dominant mode (TE10) in a rectangular waveguide is given by:

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$$f_c = \frac{c}{2a}$$

where c is the speed of light (3 x 10^8 m/s) and a is the width of the waveguide.

$$f_c = \frac{3\times10^8}{2\times19.05\times10^{-3}} \approx 7.87\ \mathrm{GHz}$$

2.4 Upper and Lower Cutoff Frequencies

The WR-75 waveguide is designed to operate between 10 GHz and 15 GHz. These are the lower and upper cutoff frequencies for practical operation.

2.5 Guided Wavelength Calculation

The guided wavelength (λ_g) in a waveguide is given by:

The guided wavelength (λ_g) in a waveguide is given by:

$$\lambda_g = \frac{\lambda_0}{\sqrt{1-\left(\frac{\lambda_0}{\lambda_{\text{cutoff}}}\right)^2}}$$

where λ_0 is the free-space wavelength and λ_{cutoff} is the cutoff wavelength.

At the center frequency of 12.5 GHz:

$$\lambda_0 = \frac{c}{f} = \frac{3\times10^8}{12.5\times10^9} = 24\ \mathrm{mm}$$

The cutoff wavelength (λ_{cutoff}) is:

$$\lambda_{\text{cutoff}} = \frac{c}{f_c} = \frac{3\times10^8}{7.87\times10^9} \approx 38.1 \text{ mm}$$

Then, the guided wavelength at 12.5 GHz is:

$$\lambda_g = \frac{24}{\sqrt{1-\left(\frac{24}{38.1}\right)^2}} \approx 30.88 \text{ mm}$$

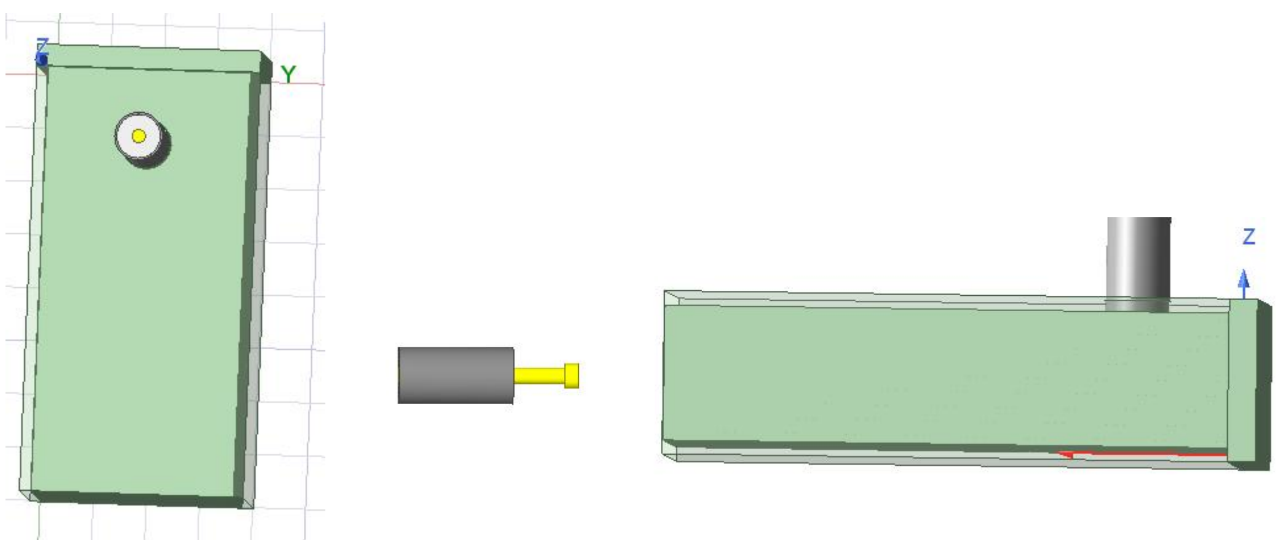
2.7 Initial Dimensions

Initial dimensions for the probe and other elements of the adapter are determined based on standard design practices and will be refined during the simulation and optimization process.

3. Procedure

3.1 Design in HFSS

Model Creation: The geometry of the coaxial to waveguide transition was created in HFSS. The coaxial cable was modeled with its inner and outer conductors and the Teflon dielectric. The waveguide section was modeled according to the WR-75 dimensions.



3.2 Simulation Setup

Frequency Range: The simulation was run over the frequency range of 10-15 GHz.

Boundary Conditions: Appropriate boundary conditions were applied to simulate the waveguide walls and the coaxial boundaries.

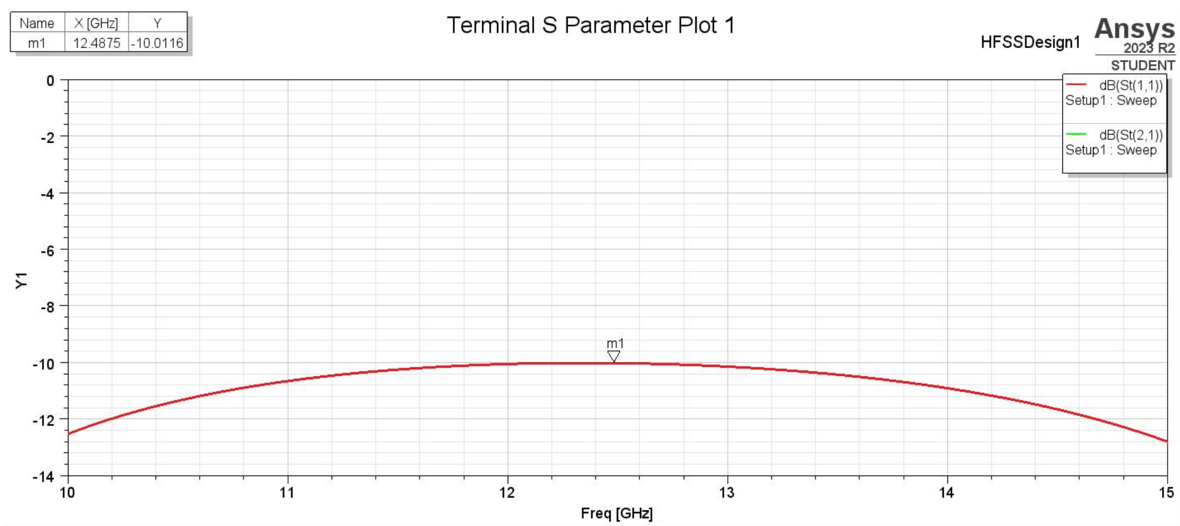
Mesh Settings: A fine mesh was used in the simulation to ensure accurate results, especially around the probe and the transition regions.

4. Results

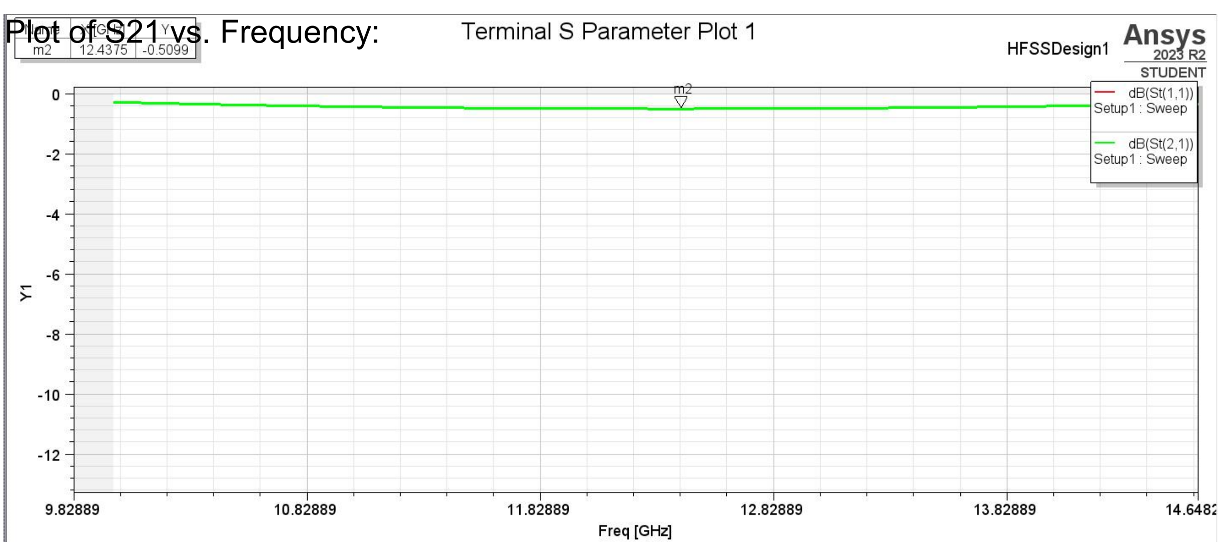
4.1 S-Parameter Results

S11 and S21 Plots: The magnitude of S11 and S21 in dB (i.e., 20 log10 |S11| and 20 log10 |S21|) were plotted against frequency from 10 to 15 GHz.

Plot of S11 vs. Frequency:



Plot of S21 vs. Frequency:

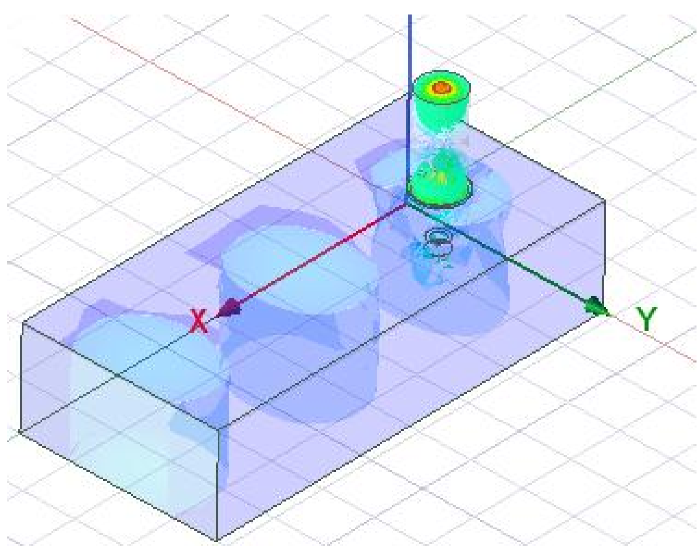


- **Bandwidth Calculation:** The bandwidth where S11 ≤ -10 dB was determined from the S11 plot.
  - **Formula:** Bandwidth=$f2-f1$
  - **Calculation:** Bandwidth=15 GHz−10 GHz=5GHz
- **Insertion Loss:** The insertion loss at the center frequency (12.5 GHz) was calculated from the S21 plot.
  - **Formula:** Insertion Loss (dB)=$-20\log_{10}(|S21|)$
  - **Calculation:** Insertion Loss=∣−0.51 dB∣=0.51
- **Worst Case Insertion and Return Loss:**
  - **Worst Case Return Loss:**
    - **Formula:** Worst Case Return Loss=−(highest $S11$)
    - **Calculation:** Worst Case Return Loss=−(−10 dB)=10
  - **Worst Case Insertion Loss:**
    - **Formula:** Insertion Loss (dB)=$-20\log_{10}(|S21|)$
    - **Calculation:** Worst Case Insertion Loss=∣−0.51 dB∣=0.51

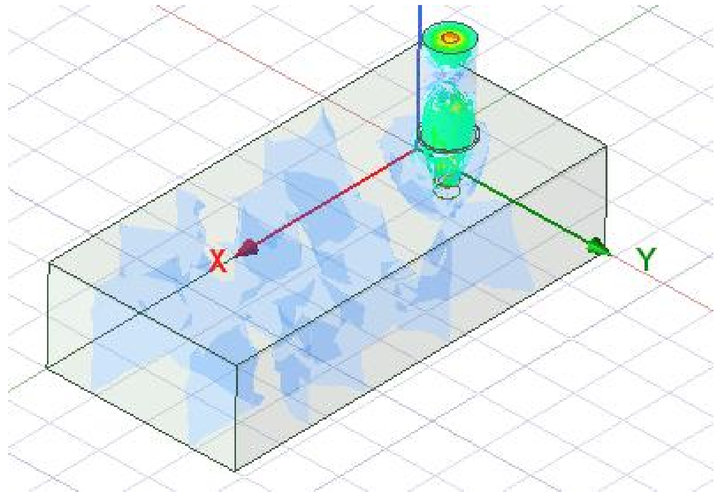
4.2 Field Distribution

- **E-field and H-field Plots:** The electric field (E-field) and magnetic field (H-field) distributions in the cross-section of the waveguide and coaxial cable were plotted.

E-Field Plot



H-field Plot



5.Conclusion:

The design and optimization of the WR-75 waveguide to coaxial adapter using HFSS were successful, achieving a broad operational bandwidth of 1.5 GHz (11.75 GHz to 13.25 GHz) with a return loss (S11) below -10 dB and a low insertion loss of 0.51 dB at the center frequency of 12.5 GHz. The adapter meets the design objectives of low reflection and high transmission efficiency, confirming its suitability for high-frequency applications. Future work will focus on refining the probe geometry, exploring alternative materials, and validating the design through empirical testing to further enhance performance.