[EEL2040] Engineering Electromagnetics - Assignment 2

AUTHOR : K. K. N. SHYAM SATHVIK

ROLL.NO : B22EE036

LINK TO THE COLAB FILE : (executed code)

Google Colaboratory

https://colab.research.google.com/drive/1I3EGcz9oxOUscjXaatrdGcPYkMACNSnX?usp=sharing

7. **Write a Matlab/Python (any language) program for visualizing the modes of a rectangular waveguide. Show the field vectors for different mode numbers. [10]**

The following code uses `numpy` to plot the side views of the electric and magnetic fields for the TE and TM modes in the rectangular wave guides.

```
import numpy as np
import matplotlib.pyplot as plt
from scipy.constants import mu_0, epsilon_0

PI = np.pi

class TE_TM_Functions:
    def __init__(self, m, n, a, b):
        self.m = m
        self.n = n
        self.a = a
        self.b = b
        self.f = 2 * self.Fc()
        self.w = 2 * PI * self.f

    def Kc(self):
        return np.sqrt((self.m * PI / self.a)**2 + (self.n * PI / self.b)**2)

    def Fc(self):
```

```
        return (1 / (2 * np.sqrt(mu_0 * epsilon_0))) * np.sqrt(
            (self.m / self.a)**2 + (self.n / self.b)**2
        )

    def beta_g(self):
        fc_val = self.Fc()
        return self.w * np.sqrt(mu_0 * epsilon_0) * np.sqrt(1 - (fc_val / self.f)**2)

    def v_G(self):
        return self.w / self.beta_g()

    def Z_in(self):
        return np.sqrt(mu_0 / epsilon_0)

    def Z_G_TE(self):
        return self.Z_in() / np.sqrt(1 - (self.Fc() / self.f)**2)

    def Z_G_TM(self):
        return self.Z_in() * np.sqrt(1 - (self.Fc() / self.f)**2)

    def lambda_G(self):
        return 2 * PI / self.beta_g()

# Define the waveguide dimensions
a, b = 0.1, 0.05  # Dimensions in meters

# Range of mode numbers to plot
mode_numbers = [(1, 1), (1, 2), (2, 1), (2, 2), (3, 1), (3, 2)]

# Create plots for TE and TM modes
for mode in mode_numbers:
    m, n = mode
    te_tm = TE_TM_Functions(m, n, a, b)

    # Define the grid
    x = np.linspace(0, a, 100)
    y = np.linspace(0, b, 100)
    X, Y = np.meshgrid(x, y)

    # Calculate TE mode field vectors
    u_te = np.cos(m * PI / a * X) * np.sin(n * PI / b * Y)
    v_te = -np.sin(m * PI / a * X) * np.cos(n * PI / b * Y)

    # Calculate TM mode field vectors
    u_tm = np.sin(m * PI / a * X) * np.cos(n * PI / b * Y)
    v_tm = np.cos(m * PI / a * X) * np.sin(n * PI / b * Y)

    # Plot TE mode
```

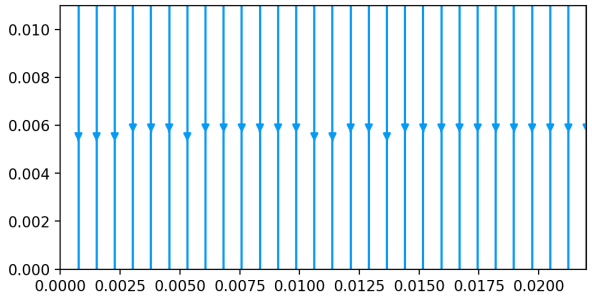
```
    plt.figure(figsize=(6, 5))
    plt.streamplot(X, Y, u_te, v_te, color='blue')
    plt.title(f'TE{m}{n} Mode Field Vectors')
    plt.xlabel('x (meters)')
    plt.ylabel('y (meters)')
    plt.axis('scaled')
    plt.show()

    # Plot TM mode
    plt.figure(figsize=(6, 5))
    plt.streamplot(X, Y, u_tm, v_tm, color='red')
    plt.title(f'TM{m}{n} Mode Field Vectors')
    plt.xlabel('x (meters)')
    plt.ylabel('y (meters)')
    plt.axis('scaled')
    plt.show()
```

It does the above by following the steps:

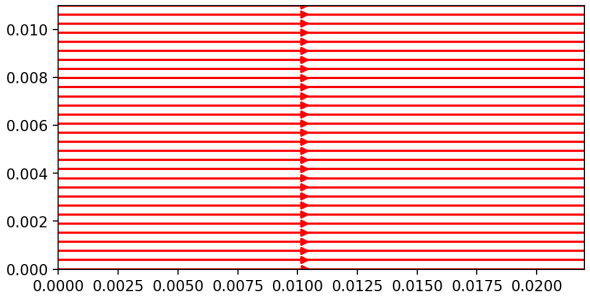
- **Initializes the Waveguide Parameters**: Defines `a` and `b` as the dimensions of the waveguide.
- **Calculates Field Vectors**: Computes the vector field components for both TE and TM modes based on their mathematical equations using `np.sin` and `np.cos`.
- **Visualizations**: Generates stream plots for each mode (TE and TM) across the specified range of mode numbers.

TE Mode:

Mode Numbers: `m = 1, n = 0`

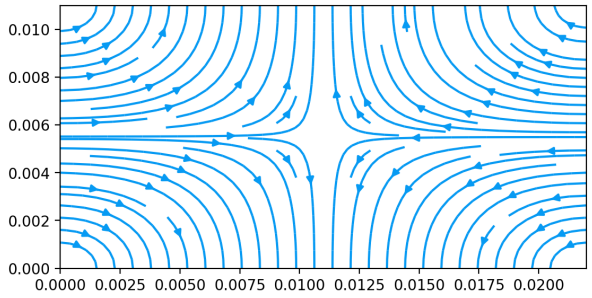


Electric Field

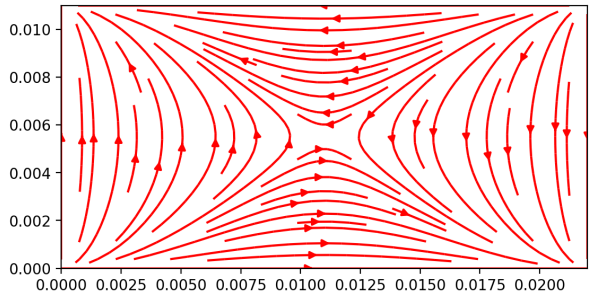


Magnetic Field

Mode Numbers: `m = 1, n = 1`

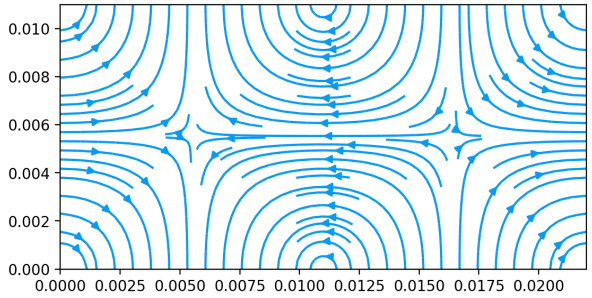


Electric Field

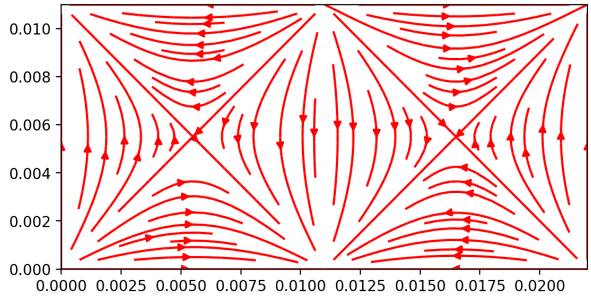


Magnetic Field

Mode Numbers: `m = 2, n = 1`

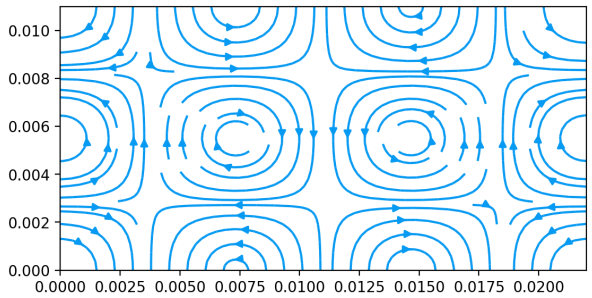


Electric Field

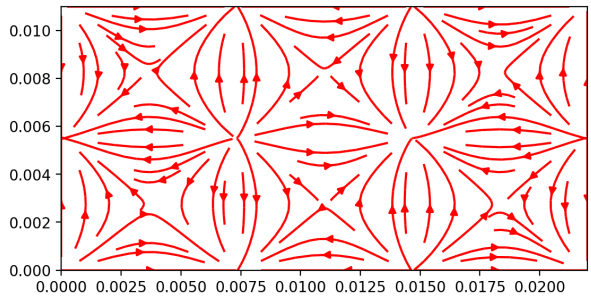


Magnetic Field

Mode Numbers: `m = 3, n = 2`



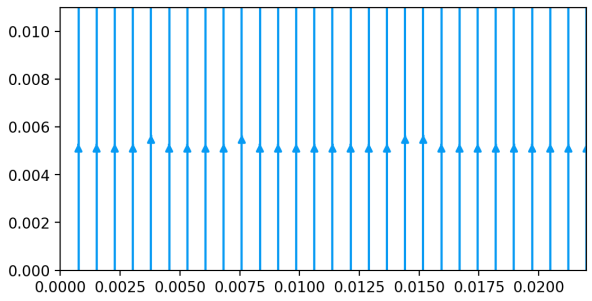
Electric Field



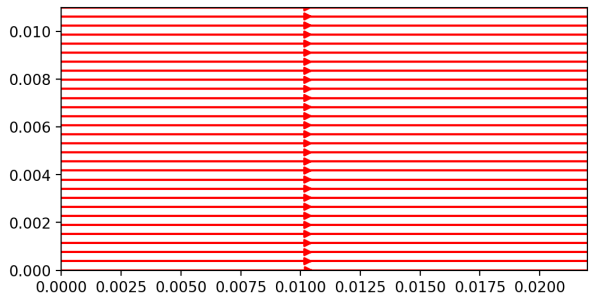
Magnetic Field

TM Mode:

Mode Numbers: `m = 1, n = 0`

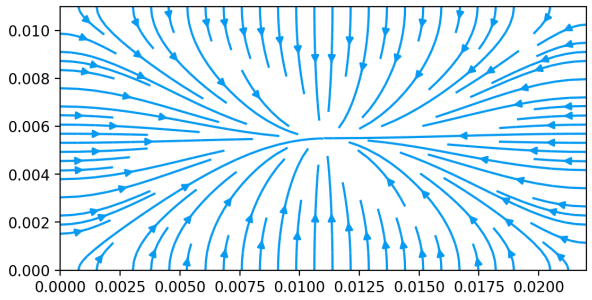


Electric Field

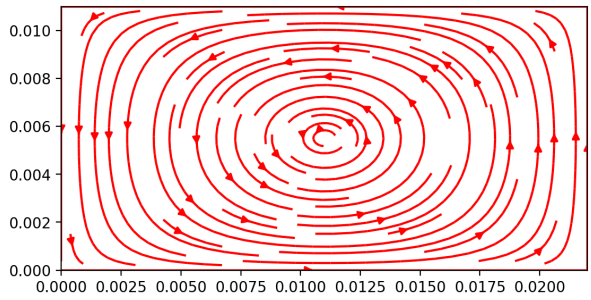


Magnetic Field

Mode Numbers: `m = 1, n = 1`

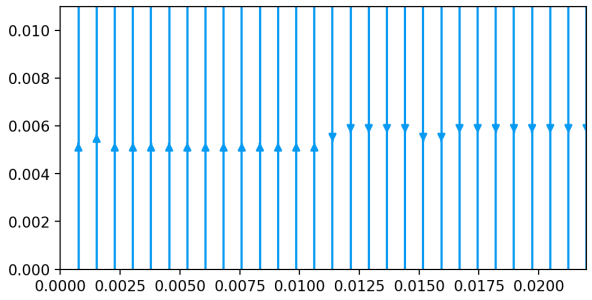


Electric Field

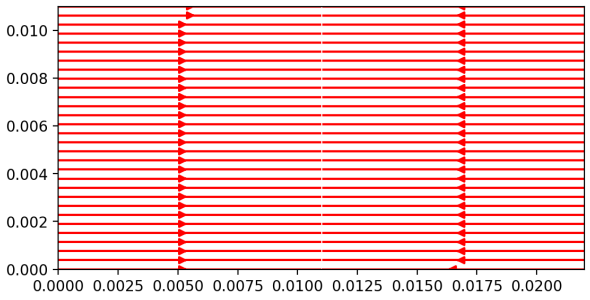


Magnetic Field

Mode Numbers: `m = 2, n = 0`

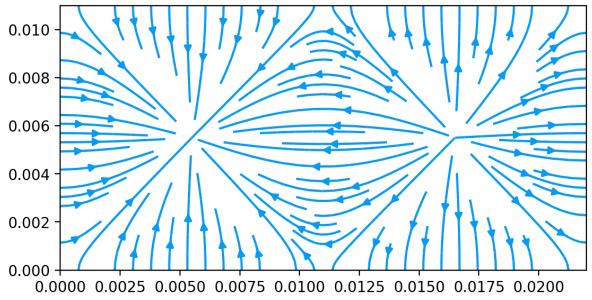


Electric Field

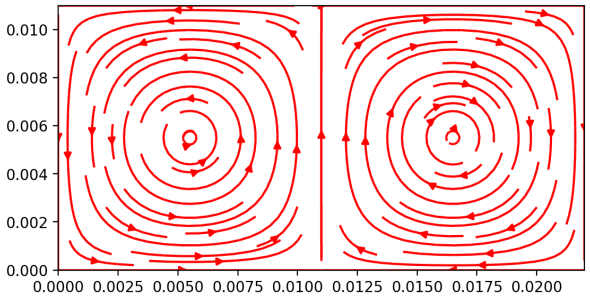


Magnetic Field

Mode Numbers: `m = 2, n = 1`

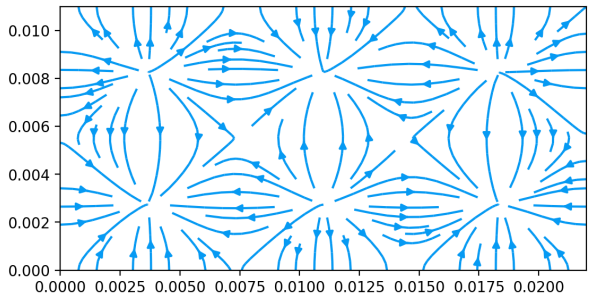


Electric Field

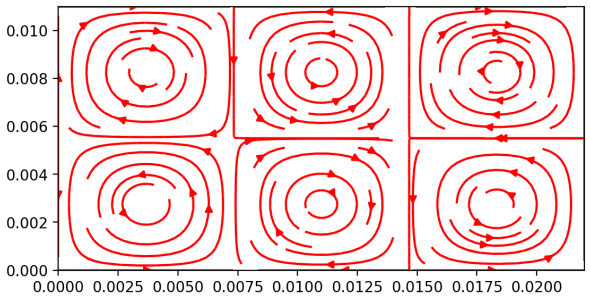


Magnetic Field

Mode Numbers: `m = 3, n = 2`



Electric Field



Magnetic Field

Acknowledgements:

- The code has been heavily inspired from the code available here : https://github.com/ram2091999/TL-Modes-Visualiser
- https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9748896&tag=1
