Virtual Lab 3 – Waveguide

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# EEL4436C Microwave Engineering

Section 0012

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**Rectangular Waveguide**

1. (10 pts) Plot the E field magnitude on the top surface of the waveguide for 6, 10, and 15 GHz. From the field plot, determine whether it is a propagating mode or evanescent mode at each frequency.

A blue rectangular object with a rainbow spectrum

Description automatically generated

Magnitude of Electricfield at 6 GHz

A rectangular object with a rainbow colored pattern

Description automatically generated with medium confidence

Magnitude of Electricfield at 10 GHz

A close-up of a rectangular object

Description automatically generated

Magnitude of Electricfield at 15 GHz

From the plot it can be seen that at 6 GHz the wave is in evanescent mode but for both 10 and 15 GHz modes the wave is in propagating mode.

1. (10 pts) Calculate the guided wavelength *λg* at 10 GHz using the equation in the book and compare with the guided wavelength read from the field plots.

The following MATLAB code was used to compute the guided wavelength,

e\_0 = 8.854187817e-12; % C²/(N \* m^1)

u = 4\*pi\*1e-7;

w = (10\*10^9)\*2\*pi;

k = w \* sqrt(u\*e\_0);

a = 22.86e-3;

b = 10e-3;

m = 1;

n = 0;

kc = sqrt( (m\*pi/a)^2 - (n\*pi/b)^2 );

beta = sqrt(k^2 - kc^2);

guided\_wavelength = 2\*pi/beta; % meters

The computed guided wavelength is 39.7 mm.

The measured guided wavelength in HFSS is 40mm. The simulated value is exactly the same as the computed value, the reason for minor differences is due to the low resolution of the measuring position tool in HFSS.

A screen shot of a computer screen

Description automatically generated

Measured Guided Wavelength

1. (10 pts) Calculate how many modes can exist at 18 GHz and identify the name of each mode.

Five modes can exist at 18 GHz and the following is the name of each mode.

|  |  |  |  |
| --- | --- | --- | --- |
| MODE | n | m | Cut off (GHz) |
| TE | 0 | 1 | 6.56 |
| TE | 0 | 2 | 13.12 |
| TE | 1 | 0 | 15.00 |
| TE/TM | 1 | 1 | 16.37 |

1. (10 pts) Plot the vector E and H fields of each mode and provide the name of the mode in the plot.

A 3d model of a rectangular object with many colored lines

Description automatically generated

EL TE01

A rectangular object with many arrows

Description automatically generated

EL TE10

A 3d model of a rectangular object with colorful pins

Description automatically generated

EL TE11

A 3d model of a rectangular object with many colored arrows

Description automatically generated

EL TE20

A 3d model of a rectangular object

Description automatically generated

EL TM11

A 3d model of a rectangular object

Description automatically generated

ME TE01

A green rectangular object with colorful lines

Description automatically generated

ME TE10

A drawing of a rectangular object with colored lines

Description automatically generated

ME TE11

A green rectangular object with colorful lines

Description automatically generated

ME TE20

A 3d model of a rectangular object

Description automatically generated

ME TM11

1. (10 pts) Plot the vector electric current on the top surface and one side wall for TE10 mode at 10 GHz. What is the relationship between the current and the magnetic field for this mode? If you want to plot the fields for the higher-order mode, go to “HFSS”🡪 “Fields”🡪 “Edit Sources” and change the amplitude of the higher-order mode to be 1 and set the amplitude of other modes to be 0.

A 3d model of a rectangular object

Description automatically generated

1. A screenshot of a computer

   Description automatically generatedA screenshot of a computer

   Description automatically generatedA screenshot of a computer

   Description automatically generated(10 pts) There is no unique definition of impedance for a waveguide which does not support TEM mode. To figure out which impedance is used in HFSS simulation, first read the port 1 impedance at 8, 10 and 12 GHz and then identify the formula for the impedance calculations in HFSS.

The closest impedance equation to match port impedance is the .

**Coaxial Line:**

1. (10 pts) What is the cutoff frequency of the first higher-order mode? Which mode is it?

The first higher mode for a coaxial line is TE11 and to compute the higher order mode cut-off frequency of a coaxial line we use the following equations from the Pozar book,

The cut off frequency for this waveguide is 11.78 GHz, the following is the MATLAB code used to compute the cutoff frequency.

%% coaxial cut off frequency

c = 299792458;

a = 1.27e-3; % meter (original is 50mil)

b = 4.318e-3; % meter (original is 170mil)

k\_c = 2 / (a + b);

e\_r = 2.1; % teflon

% cut off frequency for TE11

f\_c = (c\*k\_c)/(2\*pi\*sqrt(e\_r));

f\_c = f\_c/1e9;

1. (10 pts) Plot the vector E and H field distribution of the TEM and the first higher order mode.

A green cylinder with blue dots

Description automatically generated

TEM Mode

A graphic of a cylinder

Description automatically generated

TE11 Mode

**Circular Waveguide**

1. (10 pts) What is the cutoff frequency of the lowest and 1st higher-order modes? Which modes are they?

The cutoff frequency of the lowest mode (TE11) is 17.57 GHz, and the cutoff frequency of the next higher order mode is 22.95 GHz (TM01).

|  |  |  |  |
| --- | --- | --- | --- |
| MODE | n | m | Cut off (GHz) |
| TE | 0 | **1** | **36.58** |
| TE | 1 | **1** | **17.57** |
| TE | 2 | **1** | **29.14** |
| TE | 0 | **2** | **66.95** |
| TE | 1 | **2** | **50.87** |
| TE | 2 | **2** | **64.00** |
| TE | 0 | **3** | **97.08** |
| TE | 1 | **3** | **81.46** |
| TE | 2 | **3** | **95.14** |
| TM | 0 | **1** | **22.95** |
| TM | 1 | **1** | **36.57** |
| TM | 2 | **1** | **49.00** |
| TM | 0 | **2** | **52.68** |
| TM | 1 | **2** | **66.95** |
| TM | 2 | **2** | **80.32** |
| TM | 0 | **3** | **82.58** |
| TM | 1 | **3** | **97.09** |
| TM | 2 | **3** | **110.89** |

1. (10 pts) Plot the vector E and H field distribution of the two modes.

A 3d model of a cylinder

Description automatically generated

Electric field TE11

A green cylinder with a black line

Description automatically generated with medium confidence

Magnetic field TE11

A colorful object with lines

Description automatically generated with medium confidence

Electric field TM01

A green cylinder with colorful dots

Description automatically generated

Magnetic field TM01