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| Cairo University  Faculty of Engineering | Microwave Engineering (ELC3050)  EECE – 3rd Year  Assignment – Winter 2022 |



**Assignment ELC3050**

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| NAME | *Omar Amr Mahmoud Hafz* |  |  |  |
| GROUP | ***A*** |  |  |  |
| SEC | ***3*** |  |  |  |
| BENCH NUM. | ***3*** |  |  |  |
| STUDENT ID | ***9202967*** |  |  |  |
| EMAIL | ***eng.omar.amr@gmail.com*** |  |  |  |
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Supervised by: **Dr. Mohamed A. Nasr**

***ELC3050***

***Resonance frequency calculation:***

Adding walls to the guide forces boundary conditions in z direction:

,

*Hence, there’s a unique resonant frequency for each value of and for each resonant mode . The dominant resonant mode is always* ***.***there are four possibilities for the next resonance mode: , **,** ,**.**

***Which mode is the next mode?:***

We know that the given guide dimensions will be :

if

if *,*  *, now the next mode is either* *or* ***:***

*if then the next mode is* *(i.e,*

∴

Generally, if , the next mode is , otherwise the next mode is **.**

***Quality factor calculations:***

**∵** ,

at resonace :  *∴ ∴*

*to calculate the quality factor, we need to calculate the power loss ( , the stored energy () and the resonance frequency (calculated via the above-stated relation).*

***Given that:***

***For mode :***

generally:

Due to the two walls closing the resonator, the wave is reflected, it must satisfy the boundary conditions:

Diagram

Description automatically generated***For modes:***

Where , .

***Energy stored calculation:***

*∴*

***Power loss calculations:***

, where are for the lateral, top and front faces, respectively.

*Thus far we have derived a formula for calculating* for modes which includes the dominant mode and the next mode if it was (depending on the dimensions). Now we derive a general formula for mode to calculate the quality factor if the next mode was (the other possibility). We’ll basically go through the same steps.

***For mode :***

generally:

boundary conditions:

Diagram

Description automatically generated***For modes:***

Where , .

***Energy stored calculation:***

*∴*

***Power loss calculations:***

, where are for the lateral, top and front faces, respectively.

*The fractional bandwidth is given by:*

***Program code:*** (I used MATLAB R2021)

Run the “main” function via command window.

Start copying from here 😊

function main

clc;

clear;

close all;

format compact;

%cavity resonator dimensions in cm

global a;

global b;

global d;

%other cavity parameteers

global epsilon\_r;            %relative permitivity

global sigma;                %metal conductivity

global Q\_die;                %loss tangent at specific freq.

% epsilon\_r = 2.5;

% sigma = 5.8\*10^7;

% loss\_tanget = 0.00004;

% Q\_die = 1/loss\_tanget;

% a = 0.05;

% b = 0.04;

% d = 0.07;

%get inputs from user

a = input("a (in cm)= ")\*10^-2;

b = input("b (in cm)= ")\*10^-2;

d = input("d (in cm)= ")\*10^-2;

epsilon\_r = input("relative permeability ε\_r = ");

sigma = input("metal conductivity σ = ");

Q\_die = 1/input("loss\_tanget tan(δ) = ");

%constants

global c\_0;

global epsilon\_0;

global u\_0;

c\_0 = 3\*10^8;

epsilon\_0 = 8.8542\* 10^-12;

u\_0 = 4\*pi\*10^-7;

f\_res\_dominant =  resonance\_freq(1,0,1); %#ok<\*NOPRT,\*NASGU>

Q\_dominant = Q\_total\_10l(1,2\*pi\*f\_res\_dominant);

r = sqrt( (3\*(a^2)\*(b^2))/(a^2-b^2));

if d > r % next mode is TE102

   f\_res\_next = resonance\_freq(1,0,2);

   Q\_next = Q\_total\_10l(2,2\*pi\*f\_res\_next);

else

   f\_res\_next = resonance\_freq(0,1,1);

   Q\_next = Q\_total\_01l(1,2\*pi\*f\_res\_next);

end

print\_output(f\_res\_dominant,Q\_dominant,f\_res\_next,Q\_next,r);

end

function [f\_resonance] = resonance\_freq(m,n,l)

global a;

global b;

global d;

global epsilon\_r;

c\_0= 3\*10^8;

c = c\_0/sqrt(epsilon\_r);

kx = m\*pi/(a);

ky = n\*pi/(b);

beta = l\*pi/(d);

f\_resonance = (c/(2\*pi)) \* sqrt(kx^2 + ky^2 +beta^2);

end

%TE101 , TE102

function [Q\_10l] = Q\_total\_10l(l,w\_res)

global a;

global b;

global d;

global epsilon\_r;

global epsilon\_0;

global u\_0;

global sigma;

global Q\_die;

k\_c= pi/a;

R\_s = sqrt( (w\_res \* u\_0)/(2\*sigma));

Q\_num = w\_res \*(((epsilon\_r\*epsilon\_0\*a\*b\*d)/2) \* ((w\_res\*u\_0)/k\_c)^2);

Q\_den = R\_s \* (2\*(((a\*l)/d)^2)\*a\*b + 2\*d\*b + a\*d + (((a\*l)/d)^2)\*a\*d);

Q\_cond\_10l = Q\_num/Q\_den;

dummy = 1/Q\_cond\_10l + 1/Q\_die;

Q\_10l = 1/dummy;

end

%TE011

function [Q\_01l] = Q\_total\_01l(l,w\_res)

global a;

global b;

global d;

global epsilon\_r;

global epsilon\_0;

global u\_0;

global sigma;

global Q\_die;

R\_s=sqrt( (w\_res \* u\_0)/(2\*sigma));

k\_c=pi/b;

Q\_num = w\_res \*(((epsilon\_r\*epsilon\_0\*a\*b\*d)/2) \* ((w\_res\*u\_0)/k\_c)^2);

Q\_den = R\_s \* (2\*(((b\*l)/d)^2)\*a\*b + 2\*a\*d + b\*d + (((b\*l)/d)^2)\*b\*d);

Q\_cond\_01l = Q\_num/Q\_den;

dummy = 1/Q\_cond\_01l + 1/Q\_die;

Q\_01l = 1/dummy;

end

function print\_output(f\_res\_dominant,Q\_dominant,f\_res\_next,Q\_next,r)

global d;

if d >r

    next\_mode = "TE102";

else

    next\_mode = "TE011";

end

BW\_dominant = 1/Q\_dominant;

BW\_next = 1/Q\_next;

fprintf("\n==================================\n");

fprintf("The dominant mode: TE101\n");

fprintf("the 1st resonance frequency = %f GHz\n",f\_res\_dominant\*10^-9);

fprintf("the quality factor Q (TE101) = %f \n",Q\_dominant);

fprintf("the fractional bandwidth (TE101) = %e \n",BW\_dominant);

fprintf("==================================\n");

fprintf("The next mode: %s\n",next\_mode);

fprintf("the 2nd resonance frequency = %f GHz\n",f\_res\_next\*10^-9);

fprintf("the quality factor Q(%s) = %f \n",next\_mode,Q\_next);

fprintf("the fractional bandwidth (%s) = %e \n",next\_mode,BW\_next);

fprintf("==================================\n");

end

***Analytical Calculations:***

Let the dimensions be:

Let the other parameters be:

***MATLAB Verification:***

The dominant mode: TE101

the 1st resonance frequency = 2.055480 GHz

the quality factor Q (TE101) = 7056.113483

the fractional bandwidth (TE101) = 1.417211e-04

==================================

The next mode: TE102

the 2nd resonance frequency = 2.469818 GHz

the quality factor Q(TE102) = 8020.395946

the fractional bandwidth (TE102) = 1.246821e-04

A picture containing graphical user interface

Description automatically generated