Distortion in the Eye Diagrams of Synchronous Non-synchronous and 90° Bend Discontinuities

Eric Francisco Gutierrez Frias¹, Francisco Jimenez Hernandez¹, Edwin Christian Becerra Alvarez¹,
Marco Antonio Gurrola Navarro¹, Oscar Blanco Alonso², Ricardo Arturo Chavez Perez³,
Raul Rivera Rodriguez³, Jose Luis Medina Monroy³, Roberto Conte Galvan³,
Alejandro Dueñas Jiménez^{1,*}

¹ Department of Electronics and Computer Science, University Center of Exact Sciences and Engineering, University of Guadalajara, Mexico

² Department of Physics, University Center of Exact Sciences and Engineering, University of Guadalajara, Mexico

³ Center for Scientific Research and Higher Education of Ensenada, Baja California, Mexico

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Abstract A group of well-defined equations [1] are implemented on a simulation algorithm by using a 2-DFDTD method. The method allows find behaviors in the eye diagrams not encountered by simple physical measuring [2] [3].

Keywords Signal Integrity, Distortion, Delay, Phase Shift-effects, Cross Talk, Ringing, Eye Diagrams and Overshot

1. Introduction

The microwave circuit theory was sufficient to completely analyze structures such as microstrip with coupled load, microstrip with uncoupled load [4] [5] [6]. However, this is not the case for synchronous impedance transformers (Figure 1), non-synchronous impedance transformers (Figure 2) and the discontinuity at a right angle bend (Figure 3). This discontinuity is found in many practical applications and to analyze this type of circuit is necessary to use a combination of circuit theory of low frequency and a general network analysis.

Figure 1. Synchronous Impedance Transformer.

Figure 2. Non-Synchronous Impedance Transformer.

Figure 3. Right Angle Bend Discontinuity

2. Model for a Synchronous Impedance Transformer

In this section the structure of the synchronous impedance transformer with a load of 50 ohms is analyzed. This structure consists of three transformers of a quarter wavelength. The transformers were designed for each section had characteristic impedances of 50 ohms, 34.5 ohms and 25 ohms respectively. These characteristic impedances are obtained with a dielectric thickness of 0.07874 cm and a relative permittivity of 2.25 corresponding to polyethylene. In addition, microstrip widths for section one are 2.413mm, for section two are 4.064mm and for section three are 6.096mm. The center

frequency of 1.45GHz operation is taken from [1].

To calculate the length of each transformer quarter wave must meet the following condition:

$$\begin{aligned}\theta &= 90^\circ \\ \theta &= \beta l \\ 90^\circ &= \beta l = K_0 \sqrt{\epsilon_{eff}} l\end{aligned}\quad (1)$$

Therefore, by applying the equation (1), the length of each transformer quarter wave is calculated with the following equation.

$$l = \frac{\pi/2}{K_0 \sqrt{\epsilon_{eff}}} \quad (2)$$

As shown in Figure 1, the transformer structure is sectioned into different reference planes in which there are different input impedances. Therefore it will be necessary to make these calculations with the following equation impedance.

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)} \quad (3)$$

For Z_1 and Z_2 , the equation (3) is as follows:

$$Z_2 = Z_{03} \frac{Z_L + jZ_{03} \tan(\beta_3 l_3)}{Z_{03} + jZ_L \tan(\beta_3 l_3)} \quad (4)$$

$$Z_1 = Z_{02} \frac{Z_2 + jZ_{02} \tan(\beta_2 l_2)}{Z_{02} + jZ_2 \tan(\beta_2 l_2)} \quad (5)$$

Now, having the results of the input impedance for each section of the transformer, the calculus of the reflection coefficient and hence of the output signal and the eye diagrams are possible as show in the section of Results.

Figure 4. Circuitual representation of the right angle bend discontinuity

3. Model for Non-synchronous Impedance Transformer

In this section, the non-synchronous transformer the same as the synchronous transformer are simulated by using a 50 ohm load. This structure consists also of the three transformers of a quarter wavelength, but different of the synchronous transformer, on this the central part is composed of the microstrip with the major thickness. However, the array keeps the same widths. The algorithm to simulate the non-synchronous transformer is similar to the synchronous one, but the positions of the quarter wavelength are interchanged.

4. Model for a Right Angle Bend

The right angle bend is considered a two-port network as a microstrip structure. In such structure, each segment has a corresponding equivalent circuit. All together the circuitual representation of the discontinuity at a right angle bend microstrip is shown in Figure 4.

Where R1, L1, G1 and C1 correspond to the first segment of microstrip. LB1, LB2 and CB are the electric model of the right angle bend and finally C2, G2, L2 and R2 are the second segment of the microstrip.

Since inductors LB1 and LB2 are equal, from now on they shall be designated only as LB in order to calculate

their values with the following equations [1]:

$$L_B = 100 \left(4 \sqrt{\frac{w}{h}} - 4.21 \right) h \quad (6)$$

$$C_B = \left(\frac{(14\epsilon_r + 12.5) \frac{w}{h} - (18.3\epsilon_r - 2.25)}{\sqrt{\frac{w}{h}}} + \frac{0.02\epsilon_r}{\frac{w}{h}} \right) w, \text{ para } \frac{w}{h} < 1 \quad (7)$$

$$C_B = \left((9.5\epsilon_r + 1.25) \frac{w}{h} + 5.2\epsilon_r + 7.0 \right) w, \text{ para } \frac{w}{h} \geq 1 \quad (8)$$

Thus, from the Figure 4, seeing the circuit from left to right the impedances can be calculated at the different points of reference with the following equations:

$$Z_a = X_{L2} + R_2 \quad (9)$$

$$Z_b = \frac{1}{Y_a + G_2 + B_{C2}} \quad (10)$$

$$Z_c = X_{LB} + Z_b \quad (11)$$

$$Z_d = \frac{1}{\frac{1}{Z_c} + \frac{1}{X_{CB}}} \quad (12)$$

$$Z_e = Z_b + X_{LB} \quad (13)$$

$$Z_f = \frac{1}{\frac{1}{Z_e} + B_{C1} + G1} \quad (14)$$

$$Z_{11} = Z_f + R_2 + X_{L1} \quad (15)$$

Now, seeing the structure as a cascaded connected array of two-port networks (Figure 5), the reflection coefficients of each section can be calculated.

Figure 5. Cascaded connected array of two-port networks

The right angle bend impedance can be calculated by means of the circuit model shown in the next figure:

Figure 6. Circuit model of the right angle bend impedance

Then, the equation to calculate these values are as follows:

$$Z_{Bend} = \frac{1}{\frac{1}{X_{LB}} + \frac{1}{X_{CB}}} + X_{LB} \quad (16)$$

$$\Gamma_1 = \frac{Z_e - Z_0}{Z_e + Z_0} \quad (17)$$

$$\Gamma_2 = \frac{Z_b - Z_{Bend}}{Z_b + Z_{Bend}} \quad (18)$$

$$\Gamma_3 = \frac{Z_L - Z_0}{Z_L + Z_0} \quad (19)$$

The last equations are implemented in a simulation algorithm which is presented in the next section.

5. Results

The results of the simulation code for the synchronous impedance transformer are as follows:

Figure 7. Signal of the eye diagram of the input signal of synchronous impedance transformer

Figure 8. Eye diagram of the input signal of synchronous impedance transformer

Figure 9. Signal of the eye diagram through the microstrip of synchronous impedance transformer

Figure 10. Eye diagram through the microstrip of synchronous impedance transformer

The results of the simulation code for non-synchronous impedance transformer are as follows:

Figure 11. Signal of the eye diagram of the input signal of non-synchronous impedance transformer

Figure 12. Eye diagram of the input signal of non-synchronous impedance transformer

Figure 13. Signal of the eye diagram through the microstrip of non-synchronous impedance transformer

Figure 14. Eye diagram through the microstrip of non-synchronous impedance transformer

The results of the simulation code for the bend discontinuities are as follows:

Figure 15. Signal of the eye diagram of the input signal of the bend discontinuities

Figure 16. Eye diagram of the input signal of the bend discontinuities

Figure 17. Signal of the eye diagram through the microstrip of the bend discontinuities

Figure 18. Eye diagram through the microstrip of the bend discontinuities

6. Conclusions

A group of well-defined equations has been implemented on a simulation algorithm by using a 2-DFDTD method. The method allows find behaviors in the eye diagrams not encountered by simple physical measuring.

Appendix A

The simulation codes for the synchronous impedance transformer are as follows:

```
%*****
% DIAGRAMA DE OJO DE UN TRANSFORMADOR
% DE IMPEDANCIA SÍNCRONO
%*****
```

```
%
%   Authors: ALEJANDRO DUEÑAS JIMÉNEZ
%            FRANCISCO JIMÉNEZ
%            HERNÁNDEZ
%
%            Departamento de Electrónica
%            Universidad de Guadalajara
%            Av. Revolución No. 1500
%            44110 Guadalajara, Jalisco, México
%            Tel. 52 33 1378 5900, Ext. 7726
%
%   Version 1.0: Enero 2014
%*****
%SINTAXIS DEL PROGRAMA
%TransSinc(f);
%
%EJEMPLO:
%TransSinc(5e9);
%
%Donde f=frecuencia a la que se desee simular la
%microcinta
%
%Entregaré dos diagramas de ojo:
%Diagrama de ojo 1: Señal original.
%Diagrama de ojo 2: Señal a través de la microcinta
```

%Se proponen los siguientes datos:

```
%N=100
%Br=1000bps
%Lp=6
%kb=10
```

%% FUNCIÓN PARA DIAGRAMA DE OJO DE MICROCINTA

```
function []= TransSinc(f)
clc
warning off
%% Datos
% x      : Secuencia de entrada binaria
% N      : Numero de datos binarios
% Br     : Bit rate (bps)
% kb     : Factor de sobremuestreo
% Lp     : Longitud del pulso (en periodos de símbolo)
% a      : Factor "roll-off" -> [0,1]
% sigma  : Desv.tip del ruido -> [0.01,0.5]
% fc     : Ancho de banda canal(Hz) Filtro paso-baja
```

```
a=1;
N=100;
Br=1000;
kb=10;
Lp=6;
```

%% SECUENCIA BINARIA Y CODIFICACION

```
x= randint(1,N);
cb=2*x(:)-1;
```

%% VARIABLES:

```
Nbits=length(x); % longitud de la secuencia binaria
Fs=Br*kb;         % frecuencia de muestreo
```

```

Tb=1/Br;          % periodo de símbolo
Ts=1/Fs;          % periodo de muestreo
Nss=(Tb/Ts);      % número de muestras por símbolo

%% TREN DE IMPULSOS x(t) Y CODIFICACIÓN
x=zeros(Nbits*Nss,1);
x(1:Nss:end)=cb;

%% FORMA DEL PULSO
NT=(Lp/2);
%recto=ones(Nss,1);
%sinco=rcosfir(0,NT,Nss,Tb,'normal');
rcoso=rcosfir(a,NT,Nss,Tb,'normal');

%% SEÑAL CONVOLUCIONADA
sgn1=conv(rcoso,x);

%% AGREGANDO CARACTERISTICAS DE LA MICROCINTA

%Tiempo y Periodo
T=1/f;
t=0:10*T/(length(sgn1)-1):10*T;
t=t';

%% MICROCINTA

[z01,gama1]=microstrip(f,2.413e-3);
[z02,gama2]=microstrip(f,4.064e-3);
[z03,gama3]=microstrip(f,6.096e-3);

%Coeficiente de reflexión e Impedancia de entrada.
ZL=50;
G3=(ZL-z03)/(ZL+z03);

Z2=z03*((ZL+(1i*z03*tan(1.5708)))/(z03+(1i*ZL*tan(1.5708))));
G2=(Z2-z02)/(Z2+z02);

Z1=z02*((Z2+(1i*z02*tan(1.5708)))/(z02+(1i*Z2*tan(1.5708))));
G1=(Z1-z01)/(Z1+z01);

%% SECCION 1 DE LA MICROCINTA
l1=0:3.75e-3/(length(sgn1)-1):3.75e-3;
l1=l1';

%Constante de atenuación y de fase
alfa1=real(gama1);
beta1=imag(gama1);

%Valores absoluto y Ángulo
V1=abs(sgn1);
theta1=angle(sgn1);

Vzt1=((V1).*(cos((2*pi*Fs*t)-(beta1.*l1)+(theta1))).*(exp(-alfa1.*l1)))+((G1).*(V1).*(cos((2*pi*Fs*t)+(beta1.*l1)+(theta1))).*(exp(alfa1.*l1)));

sgn2=Vzt1;
%% SECCION 2 DE LA MICROCINTA
l2=0:3.69e-3/(length(sgn2)-1):3.69e-3;
l2=l2';

%Constante de atenuación y de fase
alfa2=real(gama2);
beta2=imag(gama2);

%Valores absoluto y Ángulo
V2=abs(sgn2);
theta2=angle(sgn2);

Vzt2=((V2).*(cos((2*pi*Fs*t)-(beta2.*l2)+(theta2))).*(exp(-alfa2.*l2)))+((G2).*(V2).*(cos((2*pi*Fs*t)+(beta2.*l2)+(theta2))).*(exp(alfa2.*l2)));
sgn3=Vzt2;
%% SECCION 3 DE LA MICROCINTA
l3=0:3.64e-3/(length(sgn3)-1):3.64e-3;
l3=l3';

%Constante de atenuación y de fase
alfa3=real(gama3);
beta3=imag(gama3);

%Valores absoluto y Ángulo
V3=abs(sgn3);
theta3=angle(sgn3);

Vzt3=((V3).*(cos((2*pi*Fs*t)-(beta3.*l3)+(theta3))).*(exp(-alfa3.*l3)))+((G3).*(V3).*(cos((2*pi*Fs*t)+(beta3.*l3)+(theta3))).*(exp(alfa3.*l3)));

%% PLOTEO
figure(), plot(sgn1)
title('Signal of the Eye Diagram of the input signal');
xlabel('Binary Data');
ylabel('Amplitude (V)');

figure(), plot(Vzt3)
title('Signal of the Eye Diagram through the microstrip');
xlabel('Binary Data');
ylabel('Amplitude (V)');

%% DIAGRAMA DE OJO

%Diagrama de ojo de la funcion original
figure()
diaojos(sgn1(2*Nss+1:end),2*Nss,Fs,0);
title('Eye Diagram of the input signal');
xlabel('T(s)');
ylabel('Amplitude (V)');

%Diagrama de ojo de la señal a través de la microcinta
figure()
diaojos(Vzt3(2*Nss+1:end),2*Nss,Fs,0);
title('Eye diagram through the microstrip');
xlabel('T(s)');
ylabel('Amplitude (V)');

```

```

end

%%% FUNCIÓN PARA GENERAR EL DIAGRAMA DE
OJO
function diaoj(y,Nss,Fs,Noff)

Nst=length(y); % Número de muestras de señal
xmax=max(y); % Amplitud máxima de señal
xmin=min(y); % Amplitud mínima de señal

%Trazamos Nss+1 muestras (una más del periodo)
tv=[0:Nss]/Fs;
n=Noff+1;

while((n+Nss+1)<=Nst)
    yy=y(n:n+Nss);
    plot(tv,yy);
    hold on
    n=n+Nss;
end

hold off
grid on
axis([min(tv) max(tv) xmin*1.1 xmax*1.1]);

end

%%% FUNCIÓN CON LOS PRINCIPALES
PARÁMETROS DE UNA MICROCINTA
function[Z0,gama]= microstrip(f,W)
%%% DATOS
% W Ancho de la cinta conductora
% h Grosor del dieléctrico
% l Longitud de la microcinta
% t Espesor de la microcinta
% er Constante dieléctrica del sustrato

%%% CONSTANTES
%e0= 8.854e-12; %Permitividad del espacio libre
er= 2.25; %Permitividad relativa o constante
dieléctrica del sustrato
mu0= 4*pi*1e-7; %Permeabilidad del espacio libre
%mur= 1; %Permeabilidad relativa del material
dieléctrico
%n0= 376.7; %Impedancia del espacio libre
p= 5.813e7; %Conductividad del cobre
%r= 1.71e-8; %Resistividad del cobre
c= 3e8; %Velocidad de la luz m/s
tand= 0.0004; %Tangente de pérdida

%%% VARIABLES DE PRUEBA
%W= 2.413e-3; para 50ohms de impedancia.
%W= 4.064e-3; para 34.5 ohms de impedancia.
%W= 6.096e-3; para 25 ohms de impedancia.
h= 0.7874e-3;
%t= 0.034e-3;

%%% IMPEDANCIA CARACTERISTICA

%Permitividad efectiva
eef=((er+1)/(2))+((er-1)/(2*(sqrt(1+(12*h/W)))));

%Impedancia caracteristica
if W/h<=1
    Z0=(60/sqrt(eef))*log(((8*h)/(W))+((W)/(h)));
else
    Z0=(120*pi)/([sqrt(eef)]*(W/h)+(1.39)+(0.667*log((W/h)
+(1.444)))));
end

%%% CONSTANTE DE PROPAGACIÓN
%gama1=sqrt((R+1i*2*pi*f*L)*(G+1i*2*pi*f*C));

k0= (2*pi*f)/(c);
b= k0*sqrt(eef);

ad=(k0*er*(eef-1)*tand)/(2*sqrt(eef)*(er-1));
Rs=sqrt((2*pi*f*mu0)/(2*p));
ac=(Rs)/(Z0*W);

at=ad+ac;
gama=at+1i*b;

%%% LONGITUD DEL TRANSFORMADOR DE
CUARTO DE ONDA
%l=(90*0.0174532925)/b;

%%% FRECUENCIA DE RESONANCIA DE LA
MICROCINTA
%fr=(c/(2*sqrt(er)))*(sqrt((1/l)^2+(0/W)^2));
End

The simulation codes for the non-synchronous impedance
transformer are as follows:
%*****
% DIAGRAMA DE OJO DE UN TRANSFORMADOR
DE IMPEDANCIA NO SÍNCRONO
%*****
% Authors: ALEJANDRO DUEÑAS JIMÉNEZ
% FRANCISCO JIMÉNEZ
% HERNÁNDEZ
% Departamento de Electrónica
% Universidad de Guadalajara
% Av. Revolución No. 1500
% 44110 Guadalajara, Jalisco, México
% Tel. 52 33 1378 5900, Ext. 7726
% Version 1.0: Enero 2014
%*****
%SINTAXIS DEL PROGRAMA
%TransSinc(f);
%
%EJEMPLO:
%TransSinc(5e9);
%
%Donde f=frecuencia a la que se desee simular la
microcinta
%
```



```

%Entregará dos diagramas de ojo:
%Diagrama de ojo 1: Señal original.
%Diagrama de ojo 2: Señal a través de la microcinta

%Se proponen los siguientes datos:
%N=100
%Br=1000bps
%Lp=6
%kb=10

%% FUNCIÓN PARA DIAGRAMA DE OJO DE MICROCINTA
function []= TransNOSinc(f)
clc
warning off
%% Datos
% x      : Secuencia de entrada binaria
% N      : Numero de datos binarios
% Br     : Bit rate (bps)
% kb     : Factor de sobremuestreo
% Lp     : Longitud del pulso (en periodos de símbolo)
% a      : Factor "roll-off"    -> [0,1]
% sigma  : Desv.tip del ruido   -> [0.01,0.5]
% fc     : Ancho de banda canal(Hz) Filtro paso-baja

a=1;
N=100;
Br=1000;
kb=10;
Lp=6;

%% SECUENCIA BINARIA Y CODIFICACION
x= randint(1,N);
cb=2*x(:)-1;

%% VARIABLES:
Nbits=length(x); % longitud de la secuencia binaria
Fs=Br*kb;        % frecuencia de muestreo
Tb=1/Br;         % periodo de símbolo
Ts=1/Fs;         % periodo de muestreo
Nss=(Tb/Ts);     % número de muestras por símbolo

%% TREN DE IMPULSOS x(t) Y CODIFICACIÓN
x=zeros(Nbits*Nss,1);
x(1:Nss:end)=cb;

%% FORMA DEL PULSO
NT=(Lp/2);
%recto=ones(Nss,1);
%sinco=rcosfir(0,NT,Nss,Tb,'normal');
rcoso=rcosfir(a,NT,Nss,Tb,'normal');

%% SEÑAL CONVOLUCIONADA
sgn1=conv(rcoso,x);

```

```

%% AGREGANDO CARACTERISTICAS DE LA MICROCINTA

%Tiempo y Periodo
T=1/f;
t=0:10*T/(length(sgn1)-1):10*T;
t=t';

%% MICROCINTA

[z01,gama1]=microstrip(f,2.413e-3);
[z02,gama2]=microstrip(f,6.096e-3);
[z03,gama3]=microstrip(f,4.064e-3);

%Coeficiente de reflexión e Impedancia de entrada.
ZL=50;
G3=(ZL-z03)/(ZL+z03);
Z2=z03*((ZL+(1i*z03*tan(1.5708)))/(z03+(1i*ZL*tan(1.5708))));
G2=(Z2-z02)/(Z2+z02);

Z1=z02*((Z2+(1i*z02*tan(1.5708)))/(z02+(1i*Z2*tan(1.5708))));
G1=(Z1-z01)/(Z1+z01);

%% SECCION 1 DE LA MICROCINTA
l1=0.3.75e-3/(length(sgn1)-1):3.75e-3;
l1=l1';

%Constante de atenuación y de fase
alfa1=real(gama1);
beta1=imag(gama1);

%Valores absoluto y Ángulo
V1=abs(sgn1);
theta1=angle(sgn1);

Vzt1=((V1).*(cos((2*pi*Fs*t)-(beta1.*l1)+(theta1)))).*(exp(-alfa1.*l1))+((G1).*(V1).*(cos((2*pi*Fs*t)+(beta1.*l1)+(theta1)))).*(exp(alfa1.*l1)));
sgn2=Vzt1;

%% SECCION 2 DE LA MICROCINTA
l2=0.3.64e-3/(length(sgn2)-1):3.64e-3;
l2=l2';

%Constante de atenuación y de fase
alfa2=real(gama2);
beta2=imag(gama2);

%Valores absoluto y Ángulo
V2=abs(sgn2);
theta2=angle(sgn2);

Vzt2=((V2).*(cos((2*pi*Fs*t)-(beta2.*l2)+(theta2)))).*(exp(-alfa2.*l2))+((G2).*(V2).*(cos((2*pi*Fs*t)+(beta2.*l2)+(theta2)))).*(exp(alfa2.*l2)));
sgn3=Vzt2;

%% SECCION 3 DE LA MICROCINTA
l3=0.3.69e-3/(length(sgn3)-1):3.69e-3;

```

```

l3=l3';

%Constante de atenuación y de fase
alfa3=real(gama3);
beta3=imag(gama3);

%Valores absoluto y Ángulo
V3=abs(sgn3);
theta3=angle(sgn3);

Vzt3=((V3).*(cos((2*pi*Fs*t)-(beta3.*l3)+(theta3))).*(exp(-alfa3.*l3)))+(G3).*(V3).*(cos((2*pi*Fs*t)+(beta3.*l3)+(theta3))).*(exp(alfa3.*l3)));

%% PLOTEO
figure(), plot(sgn1)
title('Signal of the Eye Diagram of the input signal');
xlabel('Binary Data');
ylabel('Amplitude (V)');

figure(), plot(Vzt3)
title('Signal of the Eye Diagram through the microstrip');
xlabel('Binary Data');
ylabel('Amplitude (V)');
%% DIAGRAMA DE OJO

%Diagrama de ojo de la funcion original
figure()
diaojosgn1(2*Nss+1:end),2*Nss,Fs,0);
title('Eye Diagram of the input signal');
xlabel('T(s)');
ylabel('Amplitude (V)');

%Diagrama de ojo de la señal a través de la microcinta
figure()
diaojosgn1(Vzt3(2*Nss+1:end),2*Nss,Fs,0);
title('Eye diagram through the microstrip');
xlabel('T(s)');
ylabel('Amplitude (V)');

end

%% FUNCIÓN PARA GENERAR EL DIAGRAMA DE OJO
function diaojosgn1(y,Nss,Fs,Noff)

Nst=length(y); % Número de muestras de señal
xmax=max(y); % Amplitud máxima de señal
xmin=min(y); % Amplitud mínima de señal

%Trazamos Nss+1 muestras (una más del periodo)
tv=[0:Nss]/Fs;
n=Noff+1;

while((n+Nss+1)<=Nst)
    yy=y(n:n+Nss);
    plot(tv,yy);
    hold on
    n=n+Nss;
end

hold off
grid on
axis([min(tv) max(tv) xmin*1.1 xmax*1.1]);

end

%% FUNCIÓN CON LOS PRINCIPALES PARÁMETROS DE UNA MICROCINTA
function[Z0,gama]= microstrip(f,W)
%% DATOS
% W Ancho de la cinta conductora
% h Grosor del dieléctrico
% l Longitud de la microcinta
% t Espesor de la microcinta
% er Constante dieléctrica del sustrato

%% CONSTANTES
%e0= 8.854e-12; %Permitividad del espacio libre
er= 2.25; %Permitividad relativa o constante dieléctrica del sustrato
mu0= 4*pi*1e-7; %Permeabilidad del espacio libre
%mur= 1; %Permeabilidad relativa del material dieléctrico
%no= 376.7; %Impedancia del espacio libre
p= 5.813e7; %Conductividad del cobre
%r= 1.71e-8; %Resistividad del cobre
c= 3e8; %Velocidad de la luz m/s
tand= 0.0004; %Tangente de pérdida

%% VARIABLES DE PRUEBA
%W= 2.413e-3; para 50ohms de impedancia.
%W= 4.064e-3; para 34.5 ohms de impedancia.
%W= 6.096e-3; para 25 ohms de impedancia.
h= 0.7874e-3;
%t= 0.034e-3;

%% IMPEDANCIA CARACTERISTICA
%Permitividad efectiva
eef=((er+1)/(2))+((er-1)/(2*(sqrt(1+(12*h/W)))));

%Impedancia caracteristica
if W/h<=1
    Z0=(60/sqrt(eef))*log(((8*h)/(W))+((W)/(h)));
else
    Z0=(120*pi)/([sqrt(eef)]*[(W/h)+(1.39)+(0.667*log((W/h)+(1.444)))]);
end

%% CONSTANTE DE PROPAGACIÓN
%gama1=sqrt((R+1i*2*pi*f*L)*(G+1i*2*pi*f*C));

k0= (2*pi*f)/(c);
b= k0*sqrt(eef);

ad=(k0*er*(eef-1)*tand)/(2*sqrt(eef)*(er-1));
Rs=sqrt((2*pi*f*mu0)/(2*p));

```

```
ac=(Rs)/(Z0*W);
```

```
at=ad+ac;
```

```
gama=at+1i*b;
```

```
%%% LONGITUD DEL TRANSFORMADOR DE  
CUARTO DE ONDA
```

```
%l=(90*0.0174532925)/b;
```

```
%%% FRECUENCIA DE RESONANCIA DE LA  
MICROCINTA
```

```
%fr=(c/(2*sqrt(er)))*(sqrt((1/l)^2+(0/W)^2));  
end
```

The results of the simulation code for the bend discontinuities are as follows:

```
% DIAGRAMA DE OJO DE UNA MICROCINTA CON  
DESCONTINUIDADES A 90°
```

```
%*****
```

```
%      Authors: ALEJANDRO DUEÑAS JIMÉNEZ
```

```
%      FRANCISCO JIMÉNEZ
```

```
HERNÁNDEZ
```

```
%      Departamento de Electrónica
```

```
%      Universidad de Guadalajara
```

```
%      Av. Revolución No. 1500
```

```
%      44110 Guadalajara, Jalisco, México
```

```
%      Tel. 52 33 1378 5900, Ext. 7726
```

```
%      Version 1.0: Enero 2014
```

```
%*****
```

```
%SINTAXIS DEL PROGRAMA
```

```
%RightABend(f);
```

```
%
```

```
%EJEMPLO:
```

```
%RightABend(5e9);
```

```
%
```

```
%Donde f=frecuencia a la que se desee simular la  
microcinta
```

```
%
```

```
%Entregará dos diagramas de ojo:
```

```
%Diagrama de ojo 1: Señal original.
```

```
%Diagrama de ojo 2: Señal a través de la microcinta
```

```
%Se proponen los siguientes datos:
```

```
%N=100
```

```
%Br=1000bps
```

```
%Lp=6
```

```
%kb=10
```

```
%%% FUNCIÓN PARA DIAGRAMA DE OJO DE  
MICROCINTA
```

```
function []= RightABend(f)
```

```
clc
```

```
warning off
```

```
%%% Datos
```

```
% x      : Secuencia de entrada binaria
```

```
% N      : Numero de datos binarios
```

```
% Br      : Bit rate (bps)
```

```
% kb      : Factor de sobremuestreo
```

```
% Lp      : Longitud del pulso (en periodos de símbolo)
```

```
% a      : Factor "roll-off" -> [0,1]
```

```
% sigma   : Desv.tip del ruido -> [0.01,0.5]
```

```
% fc      : Ancho de banda canal(Hz) Filtro paso-baja
```

```
a=1;
```

```
N=100;
```

```
Br=1000;
```

```
kb=10;
```

```
Lp=6;
```

```
%%% SECUENCIA BINARIA Y CODIFICACION
```

```
x= randint(1,N);
```

```
cb=2*x(:)-1;
```

```
%%% VARIABLES:
```

```
Nbits=length(x); % longitud de la secuencia binaria
```

```
Fs=Br*kb; % frecuencia de muestreo
```

```
Tb=1/Br; % periodo de símbolo
```

```
Ts=1/Fs; % periodo de muestreo
```

```
Nss=(Tb/Ts); % número de muestras por símbolo
```

```
%%% TREN DE IMPULSOS x(t) Y CODIFICACIÓN
```

```
x=zeros(Nbits*Nss,1);
```

```
x(1:Nss:end)=cb;
```

```
%%% FORMA DEL PULSO
```

```
NT=(Lp/2);
```

```
%recto=ones(Nss,1);
```

```
%sinco=rcosfir(0,NT,Nss,Tb,'normal');
```

```
rcoso=rcosfir(a,NT,Nss,Tb,'normal');
```

```
%%% SEÑAL CONVOLUCIONADA
```

```
%sgn=conv(recto,x);
```

```
%sgn=conv(sinco,x);
```

```
sgn1=conv(rcoso,x);
```

```
%%% AGREGANDO CARACTERISTICAS DE LA  
MICROCINTA
```

```
%Sección de microcinta
```

```
[LB,CB,R,L,C,G,z0,gama]=MS(f);
```

```
XLB=2*pi*f*LB;
```

```
XCB=1/(2*pi*f*CB);
```

```
%Cálculo de las Reactancias y las Susceptancias.
```

```
XL1=2*pi*f*L;
```

```
XL2=XL1;
```

```
XC1=1/(2*pi*f*C);
```

```
XC2=XC1;
```

```
BC1=1/XC1;
```

```
BC2=1/XC2;
```

```
%Impedancias de las secciones
```

```

ZA=R+XL2;
YA=1/ZA;
ZB=1/(YA+G+BC2);
ZC=XLB+ZB;
ZD=1/((1/ZC)+(1/XCB));
ZE=ZD+XLB;
%ZF=1/((1/ZE)+(BC1)+(G));
%Z11=ZF+R+XL1;

ZBend=(1/((1/XLB)+(1/XCB)))+(XLB);

%Coeficiente de reflexión.
ZL=50;
GAMA3=(ZL-z0)/(ZL+z0);
GAMA2=(ZB-ZBend)/(ZB+ZBend);
GAMA1=(ZE-z0)/(ZE+z0);

%Constante de atenuación y de fase
alfa=real(gama);
beta=imag(gama);

%Longitud de la microcinta
l1=0.5e-3/(length(sgn1)-1):5e-3;
l1=l1';

l2=l1;

%Tiempo y Periodo
T=1/f;
t=0:10*T/(length(sgn1)-1):10*T;
t=t';

%Valores absoluto y Ángulo
V1=abs(sgn1);
theta1=angle(sgn1);

%Función primera parte.
Vzt1=((V1).*(cos((2*pi*Fs*t)-(beta.*l1)+(theta1))).*(exp(-
alfa.*l1)))+(GAMA3).*(V1).*(cos((2*pi*Fs*t)+(beta.*l1)
+(theta1))).*(exp(alfa.*l1)));
sgn2=Vzt1;

V2=abs(sgn2);
theta2=angle(sgn2);

%Función segunda parte.
Vzt2=((V2).*(cos((2*pi*Fs*t)-(beta.*l2)+(theta2))).*(exp(-
alfa.*l2)))+(GAMA2).*(V2).*(cos((2*pi*Fs*t)+(beta.*l2)
+(theta2))).*(exp(alfa.*l2)));
sgn3=Vzt2;

V3=abs(sgn3);
theta3=angle(sgn3);

%Función tercera parte.
Vzt3=((V3).*(cos((2*pi*Fs*t)-(beta.*l1)+(theta3))).*(exp(-
alfa.*l1)))+(GAMA1).*(V3).*(cos((2*pi*Fs*t)+(beta.*l1)
+(theta3))).*(exp(alfa.*l1)));

figure(), plot(sgn1)
figure(), plot(Vzt3)

%% DIAGRAMA DE OJO

%Diagrama de ojo de la funcion original
figure()
diaojoo(sgn1(2*Nss+1:end),2*Nss,Fs,0);
title('Diagrama de ojo de la señal');
xlabel('T(s)');
ylabel('Amplitud (V)');

%Diagrama de ojo de la señal a través de la microcinta
figure()
diaojoo(Vzt3(2*Nss+1:end),2*Nss,Fs,0);
title('Diagrama de ojo de la señal a través de la microcinta');
xlabel('T(s)');
ylabel('Amplitud (V)');

end

%% FUNCIÓN PARA GENERAR EL DIAGRAMA DE
OJO
function diaojoo(y,Nss,Fs,Noff)

Nst=length(y); % Número de muestras de señal
xmax=max(y); % Amplitud máxima de señal
xmin=min(y); % Amplitud mínima de señal

%Trazamos Nss+1 muestras (una más del periodo)
tv=[0:Nss]/Fs;
n=Noff+1;

while((n+Nss+1)<=Nst)
    yy=y(n:n+Nss);
    plot(tv,yy);
    hold on
    n=n+Nss;
end

hold off
grid on
axis([min(tv) max(tv) xmin*1.1 xmax*1.1]);

end

%% FUNCIÓN CON LOS PRINCIPALES
PARÁMETROS DE UNA MICROCINTA
function[LB,CB,R,L,C,G,Z0,gama]= MS(f)
%% DATOS

% W Ancho de la cinta conductora
% h Grosor del dieléctrico
% l Longitud de la microcinta
% t Espesor de la microcinta
% er Constante dieléctrica del sustrato

%% CONSTANTES

```

```

%e0= 8.854e-12; %Permitividad del espacio libre
er= 2.25; %Permitividad relativa o constante
dieléctrica del sustrato
mu0= 4*pi*1e-7; %Permeabilidad del espacio libre
%mur= 1; %Permeabilidad relativa del material
dieléctrico
%n0= 376.7; %Impedancia del espacio libre
%p= 5.813e7; %Conductividad del cobre
r= 1.71e-8; %Resistividad del cobre
c= 3e8; %Velocidad de la luz m/s
tand= 0.0004; %Tangente de pérdida

%% VARIABLES DE PRUEBA
w= 3.8497e-3;
h= 1.256e-3;
l= 50e-3;
%t= 0.034e-3;

%% IMPEDANCIA CARACTERISTICA
%Permitividad efectiva
eef=((er+1)/(2))+((er-1)/(2*(sqrt(1+(12*h/w)))));

%Impedancia característica
if w/h<=1
    Z0=(60/sqrt(eef))*log(((8*h)/(w))+((w)/(h)));
else
    Z0=(120*pi)/([sqrt(eef)]*[(w/h)+(1.39)+(0.667*log((w/h)+(1.444)))]);
end

%% VALORES DEL BEND
LB=100*(4*sqrt(w/h)-4.21)*h;

if w/h<1
    CB((((14*er+12.5)*w/h-(18.3*er-2.25))/(sqrt(w/h)))+(0.02*er/(w/h)))*w;
else if w/h>=1;
    CB=((9.5*er+1.25)*w/h+5.2*er+7.0)*w;
end
end

%% FRECUENCIA DE RESONANCIA DE LA MICROCINTA
%fr=(c/(2*sqrt(er)))*(sqrt((1/l)^2+(0/w)^2));

%% PARAMETROS RLCG
R= 1*(sqrt(pi*mu0*r*f))/(w);
L= 1*((Z0)/c)*(sqrt(eef));
C= 1*(sqrt(eef))/(c*Z0);

```

```

G= l*tand*2*pi*f*C;

%% CONSTANTE DE PROPAGACIÓN
gama=sqrt((R+1i*2*pi*f*L)*(G+1i*2*pi*f*C));

% k0= (2*pi*f)/(c);
% b= k0*sqrt(eef);
%
% ad=(k0*er*(eef-1)*tand)/(2*sqrt(eef)*(er-1));
% Rs=sqrt((2*pi*f*mu0)/(2*p));
% ac=(Rs)/(Z0*W);
%
% at=ad+ac;
%gama=at+j*b

end

```

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