End-Semester Assignment

To - Dr Subasit Borah (Ph D)

By

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Chapter 1

Solutions

1.1 Q1.

Solution:

Given,
$Z_L = 100\Omega$
$Z_{in} = 50\Omega$
Also we know that for $\frac{\lambda}{4}$ transmission line characteristic impedance is given by,

$$Z_o = \sqrt{Z_L Z_{in}}$$
$$=> Z_o = \sqrt{100 * 50}$$
$$=> Z_o = 70.71\Omega$$

Now, The reflection coefficient is given by equation,

$$|\tau| = \left| \frac{Z_o - Zin}{Z_o + Zin} \right|$$

Where, Z_{in} is frequency dependent and is given by equation,

$$Z_{in}(z = -l) = Z_o \frac{Z_L + jZ_o tan(\beta l)}{Z_o + jZ_L tan(\beta l)}$$

Therefore, the equation for τ is also frequency dependent(f), since

$$\beta l = \pi/2 \frac{f}{f_o}$$

The plot for reflection coefficient (τ) Vs $\frac{f}{f_o}$ is shown in figure 1.4:

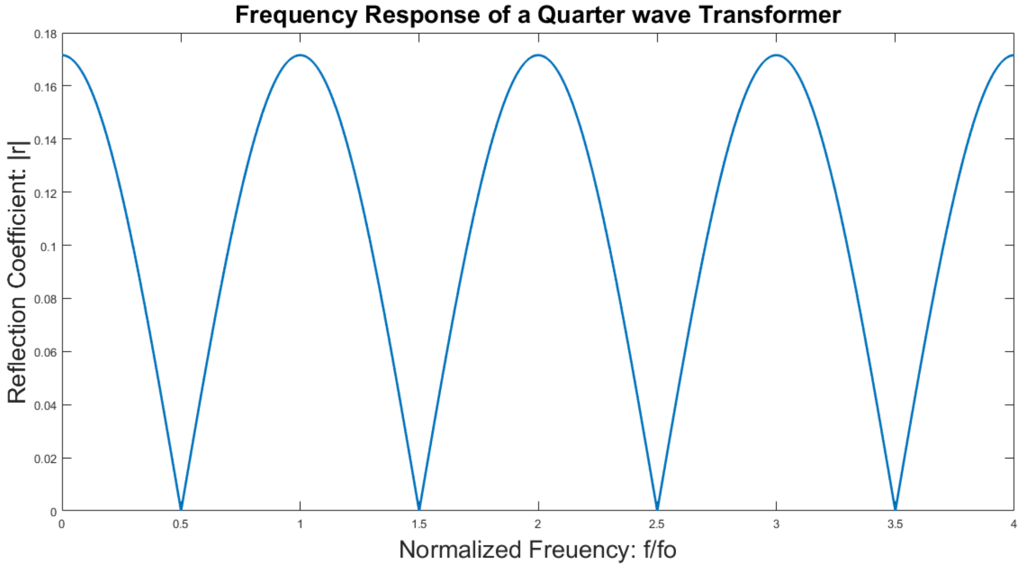

Figure 1.1: Reflection Coefficient Vs Normalized Frequency

Matlab Code

```
f_fo = 0:0.01:4; % f_fo represents normalised frequency f/fo
Bl = pi*f_fo/2; % Bl represents B*l
zo = 70.71; % Charecteristic Impedance
zl = 100; % Load Impedance
zin = abs(zo*(zl + 1i*zo*tan(Bl))./(zo + 1i*zl*tan(Bl))); %Input Impedance
tau = (zo - zin)./(zo + zin); % Reflection Coefficient
plot(f_fo, abs(tau), 'LineWidth',2)
title('Frequency Response of a Quarter wave Transformer', 'FontSize', 15)
xlabel('Normalized Freuency: f/fo', 'FontSize',12)
ylabel('Reflection Coefficient: |r|', 'FontSize',12)
```

1.2 Q2.

Solution:

Standing wave is superposition of incident wave and reflected wave [1]. Let incident wave be represented by V_i and reflected wave be represented by V_r.

$$V_i = Sin(x), \quad Assumption$$
$$So, V_r = \tau Sin(x + \pi)$$

V_r is a π angle phase shift of Vi multiplied by reflection coefficient τ. Phase shift by π is as per the reflection property of wave [2].

Standing wave pattern for $\tau = 0.1$ and $\tau = 1$ are:

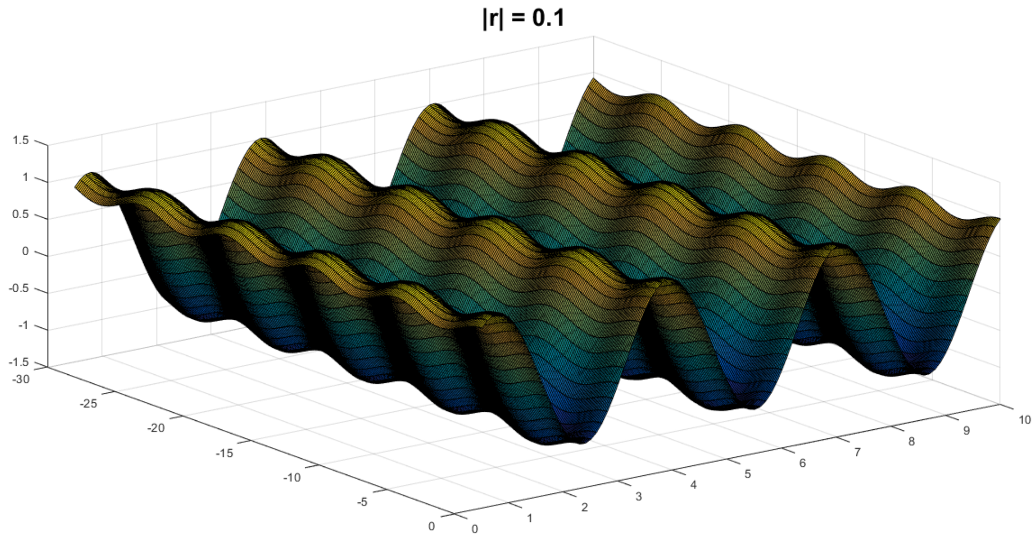

Figure 1.2: Standing wave pattern for $\tau = 0.1$

Matlab Code

```
tau = 0.1; % Reflection Coefficient
[X,Y] = meshgrid(0:0.1:30, 0.5:0.1:10); % Axix range
Z = sin(2*Y) - tau*sin(1*X); % Standing Wave (Superposition)
surf(-X, Y, Z) % 3D Plot Function
title('|r| = 1', 'FontSize', 20)
```

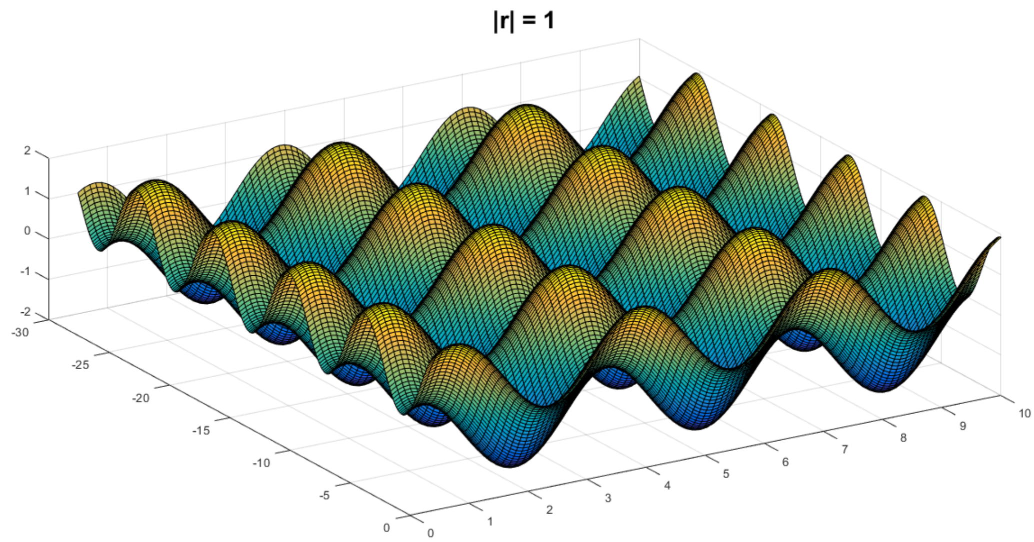

Figure 1.3: Standing wave pattern for $\tau = 1$

Matlab Code

```
tau = 1; % Reflection Coefficient
[X,Y] = meshgrid(0:0.1:30, 0.5:0.1:10); % Axis range
Z = sin(2*Y) - tau*sin(1*X); % Standing Wave (Superposition)
surf(-X, Y, Z) % 3D Plot Function
title('|r| = 1', 'FontSize', 20)
```

1.3 Q3.

Solution:

Input impedance of a transmission line is given by equation:

$$Z_{in}(z=-l) = Z_o \frac{Z_L + jZ_o tan(\beta l)}{Z_o + jZ_L tan(\beta l)}$$

For a transmission line that is terminated in a short circuit, the equation decomposes to:

$$Z_{in}(z=-l) = jZ_o tan(\beta l)$$

Matlab Code to compute input impedance when $2\beta l$ is passed as input.

```
two_Bl = input('Enter value for 2Bl: ');
Bl = two_Bl/2;
zo = 1; % Charecteristic Impedance
zl = 0; % Load Impedance
zin = 1i*zo*tan(Bl); %Input Impedance
display('Input Impedance is:')
display(zin)
```

OUTPUT

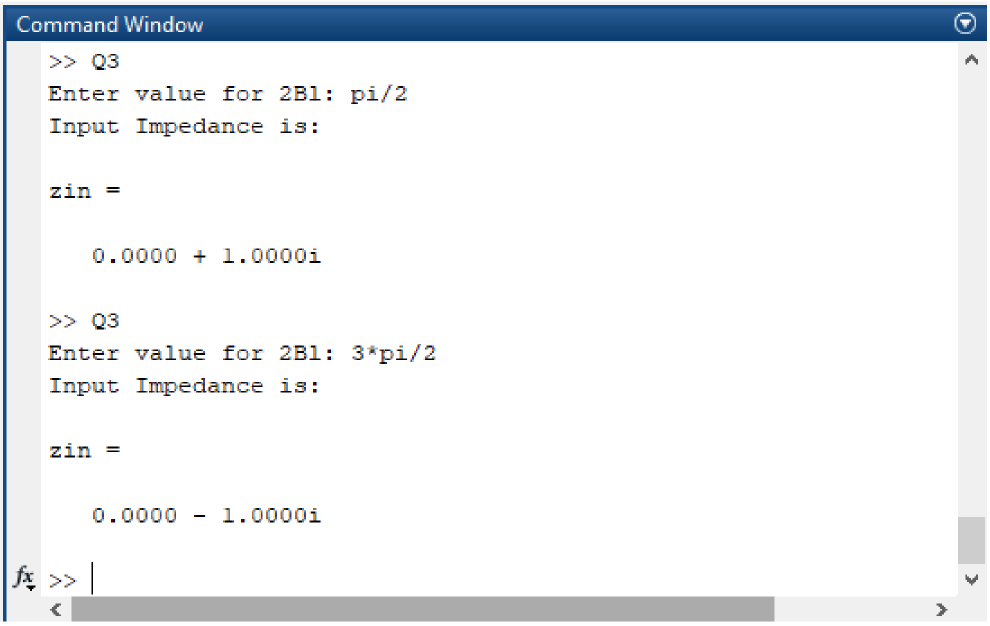

Figure 1.4: Input Impedance for $2\beta l = \{90', 270'\}$

1.4 Q4.

1.4.1 a

Solution:

The coupler shown in figure 1.5, 1.6, 1.7 is designed in HFSS software. Design parameters assumed in the designing the coupler are as per the question description. Apart from that other assumptions are:

- Substrate: ”Rogers Ultralam 2000 (tm)”
- Shape and size of the coupler [3].

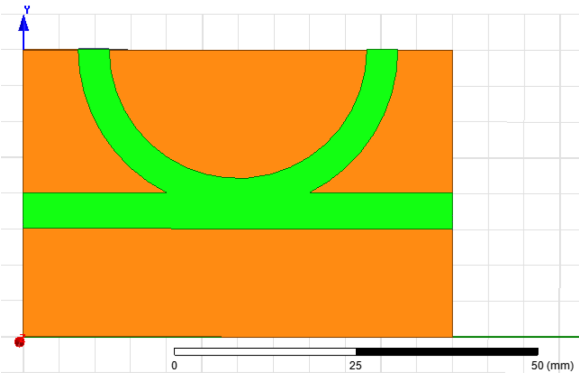

Figure 1.5: Front view of coupler

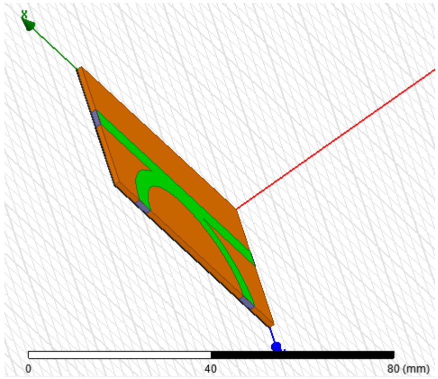

Figure 1.6: Cross Sectional View of coupler

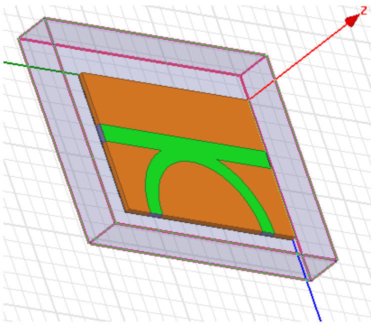

Figure 1.7: Coupler with radiation box

S-Matrix is shown in table 1.1 at frequency = 3GHz when port 1 i s excited.

$$\begin{vmatrix} S11 & S12 & S13 & S14 \\ S21 & S22 & S23 & S24 \\ S31 & S32 & S33 & S34 \\ S41 & S42 & S43 & S44 \end{vmatrix} = \begin{vmatrix} -11.33074065 & -3.01406265 & -12.07898315 & -10.31970471 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{vmatrix}$$

Table 1.1: S-Matrix

Similarly, the values for other S_{mn} are calculated by exciting other ports.

Matlab Code to plot the S-Parameter,

```
filename = 'coupler.csv'; % S-Parameter values are extracted from HFSS
    into coupler.csv
M = csvread(filename, 1, 0);
t = 1:5:601;
plot(M(t, 1), M(t, 2), 'b-+', 'LineWidth', 1) % Plot for S11
hold on
plot(M(t, 1), M(t, 3), 'g-', 'LineWidth', 1) % Plot for S12
hold on
plot(M(t, 1), M(t, 4), 'm-o', 'LineWidth', 1) % Plot for S13
hold on
plot(M(t, 1), M(t, 5), 'r-*', 'LineWidth', 1) % Plot for S14
legend('S11:Input', 'S12:Through', 'S13:Coupled', 'S14:Isolation')
axis([0 6 -50 0])
grid on;
text(2.5, -11.3, '3 GHz, -12 db', 'Color', 'black','FontSize',10)
title('Scattering Matrix Plot', 'FontSize', 20)
xlabel('Freuency (GHz)', 'FontSize', 20)
ylabel('S Parameter', 'FontSize', 20)
```

OUTPUT

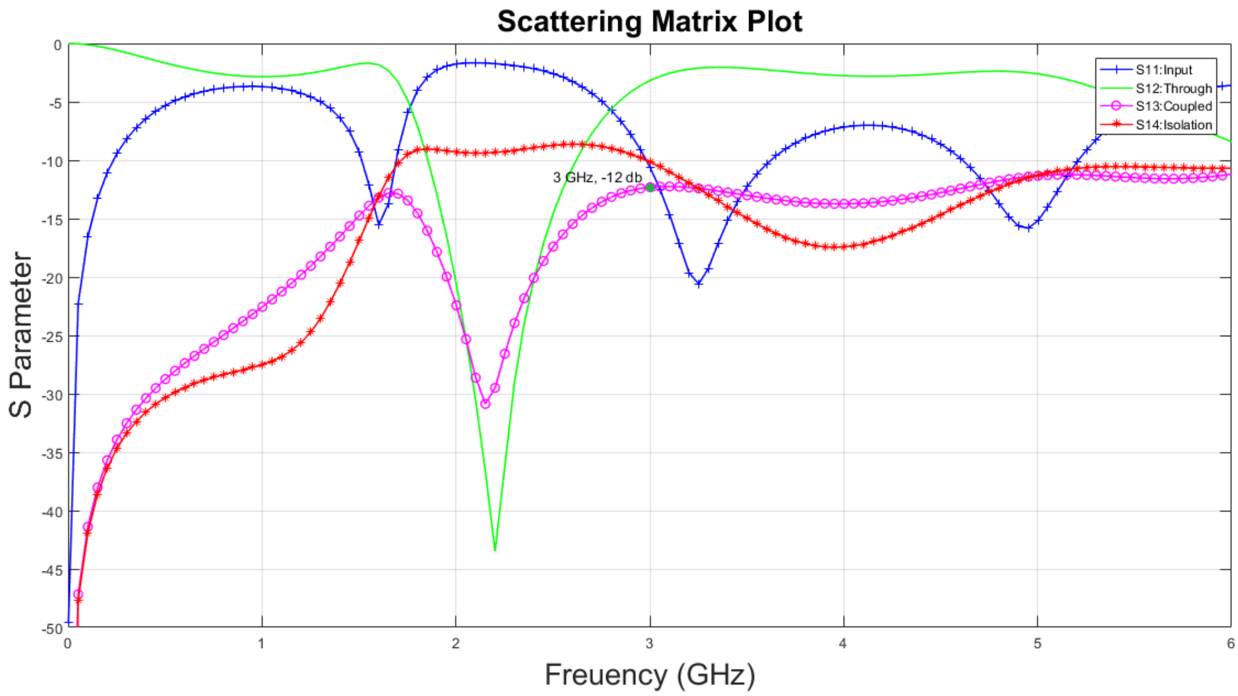

Figure 1.8: S-Parameter plot

Matlab Code to plot the $|S|^2$-Parameter,

```
filename = 'coupler.csv'; % S-Parameter values are extracted from HFSS
    into coupler.csv
M = csvread(filename, 1, 0);
t = 1:5:601;
plot(M(t, 1), 10*log10((10.^(M(t, 2)./10)).^2), 'b-+', 'LineWidth', 1) %
    Plot for |S11|^2
hold on
plot(M(t, 1), 10*log10((10.^(M(t, 3)./10)).^2), 'g-', 'LineWidth', 1) %
    Plot for |S12|^2
hold on
plot(M(t, 1), 10*log10((10.^(M(t, 4)./10)).^2), 'm-o', 'LineWidth', 1) %
    Plot for |S13|^2
hold on
plot(M(t, 1), 10*log10((10.^(M(t, 5)./10)).^2), 'r-*', 'LineWidth', 1) %
    Plot for |S14|^2
legend('S11:Input', 'S12:Through', 'S13:Coupled', 'S14:Isolation')
axis([0 6 -50 0])
grid on;
text(2.5, -11.3, '3 GHz, -12 db', 'Color', 'black','FontSize',10)
title('Scattering Matrix Plot', 'FontSize', 20)
xlabel('Freuency (GHz)', 'FontSize', 20)
ylabel('S Parameter', 'FontSize', 20)
```

OUTPUT

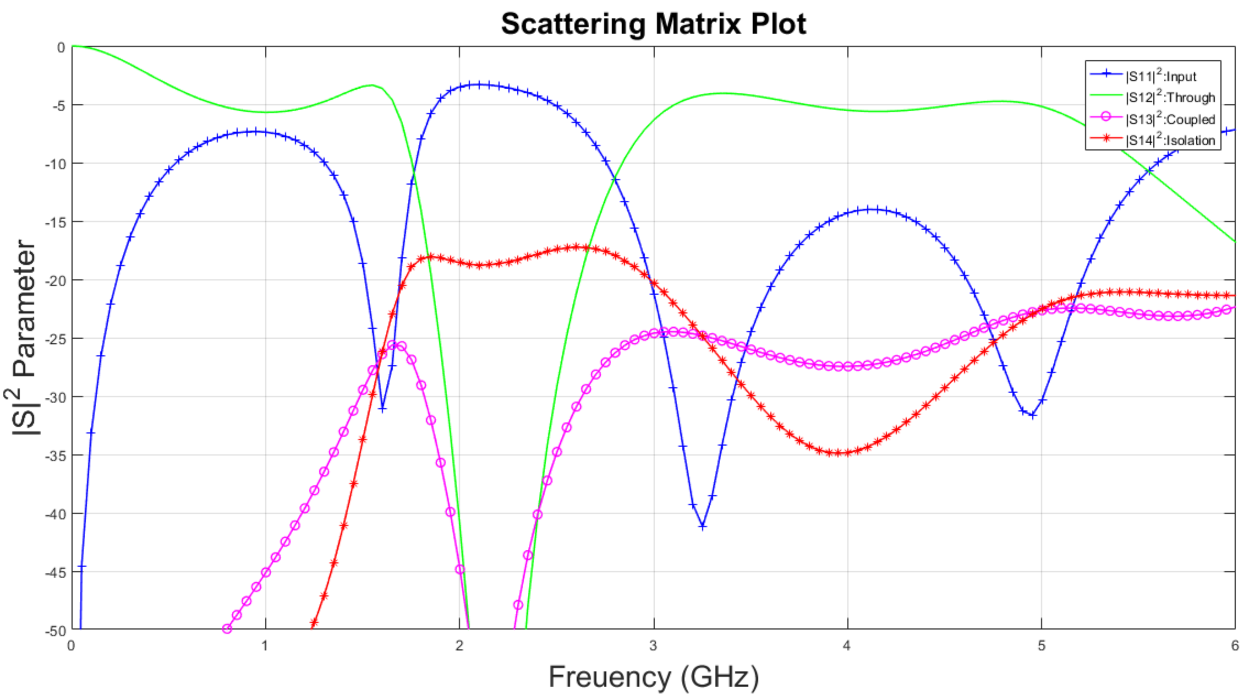

Figure 1.9: $|S|^2$-Parameter plot

1.4.2 b

Solution:
Step by step procedure to plot signal flow graph [4] is shown in figure 1.10, 1.11 and 1.12.

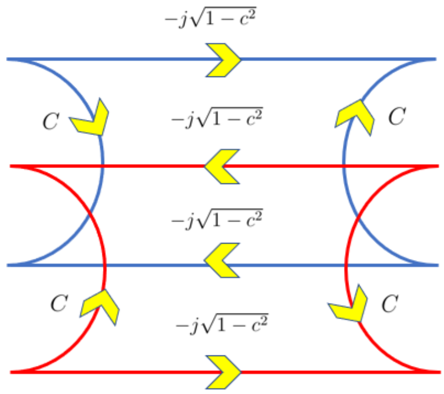

Figure 1.10: Step-1

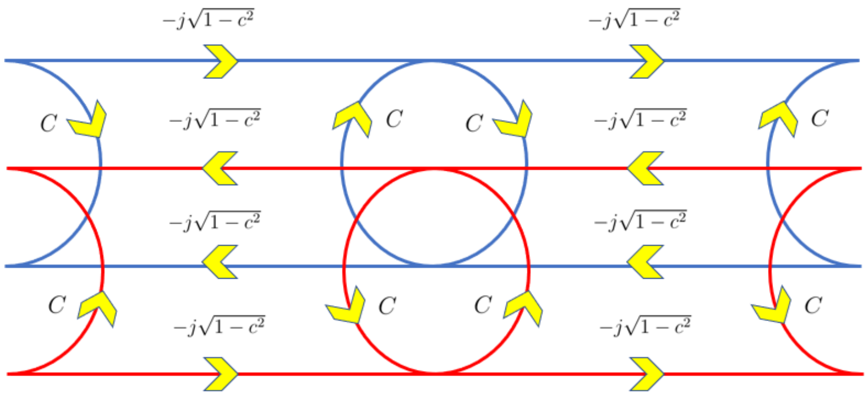

Figure 1.11: Step-2

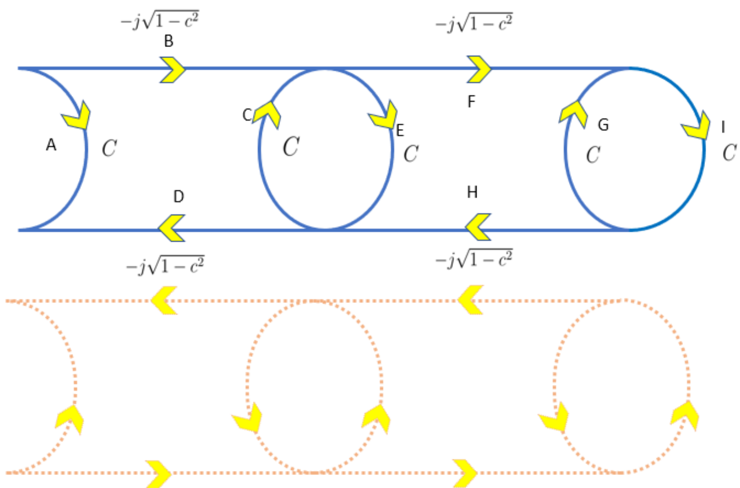

Figure 1.12: Step-3

Signal Flow Path = A, BED, BFIHD .....

Bibliography

[1] T. Lines, "Standing Waves on Transmission Line and Impedance Transformation," https://nptel.ac.in/courses/117101057/downloads/lec5.pdf, [Online; accessed 10-Apr-2019].

[2] Wiki, "Reflection phase change," https://en.wikipedia.org/wiki/Reflection_phase_change, [Online; accessed 10-Apr-2019].

[3] A. M. Abbosh and M. E. Bialkowski, "Design of compact directional couplers for uwb applications," *IEEE Transactions on Microwave Theory and Techniques*, vol. 55, no. 2, pp. 189–194, Feb 2007.

[4] jstiles, "Signal Flow Graph," http://www.ittc.ku.edu/~jstiles/723/handouts/section_4_5_Signal_Flow_Graphs_package.pdf, [Online; accessed 21-Apr-2019].