Power Dividers and Hybrid Couplers

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Slot: F1

Subject: Microwave Engineering

OBJECTIVE

For a given load of Z_L=28.3- j44.2,

1. For the given operating frequency and characteristic impedance, design power dividers and hybrid couplers with following design parameters.
2. Implement on standard substrate εr =4.4, H=1.6 mm, T=0.05 mm, Tanδ=0.001.
3. Compare the performance based on return loss, bandwidth, and quality factor for both solutions.
4. System Impedance (Ohm)= 30
5. Design Frequency (GHz)= 4.5
6. Parameters= K^2 =2/6
7. All parts should be matched: S_{ii} = 0 or < -40dB(practically)
8. Large isolation between output ports: P(2,3) => $S_{23}=S_{32}$
9. Reciprocal $S_{ij}=S_{ji}$ | where i is not equal to j
10. Loss-less condition: $|S_{11}|^2+|S_{21}|^2+|S_{31}|^2=1$
11. Power split: $K=0.577=P_3/P_2=(S_{31})^2/(S_{21})^2$

Procedure

Power Divider

1. Find the values of Z03,Z02,R,R2,R3.
2. Draw the schematic for the following circuit.
3. Run a frequency analysis for S parameters.
4. Tabulate the values.
5. Find the Bandwidth, Quality Factor and the return loss.

Hybrid Coupler

1. Find the values of Z_0 and $Z_0/(2)^{0.5.}$
2. Draw the schematic for the following circuit.
3. Run a frequency analysis for S parameters.
4. Tabulate the values.
5. Find the Bandwidth, Quality Factor and the return loss.

Calculations

Wilkinson Power divider

Design

Given: $\varepsilon_R = 4.4$

$H = 1.6mm$

$T = 0.05mm$

$\tan\delta = 0.001$

$f_0 = 4.5GHz$

$K^2 = 2/6$ or $1/3$

Thus Power split ratio: $P_3/P_2 = K^2 = 1/3$, ($\Rightarrow K = 0.57$

Calculations

$Z_0(\text{given}) = 30\Omega$

$Z_{03} = Z_0\left(\sqrt{(1+K^2)/K^3}\right) = 79.021\Omega$

$Z_{02} = Z_{03}K^2 = 26.341\Omega$

$R = Z_0(K + 1/K) = 69.303\Omega$

$R_2 = Z_0 K = 17.310\Omega$

$R_3 = Z_0/K = 51.993\Omega$

Frequency range $\rightarrow$ $f_0/2$ to $1.5f_0$

2.25GHz to 6.75GHz

w and l for port 1: $w = 6.60607$ mm

$L = 8.69264$ mm

port 2: $w = 7.88122$ mm

$L = 8.56113$ mm

port 3: $w = 1.22905$ mm

$L = 9.39905$ mm

Hybrid Coupler

Design

$Z_0 = 30\Omega$

$Z_0/\sqrt{2} = 30/\sqrt{2} = 21.216\Omega$

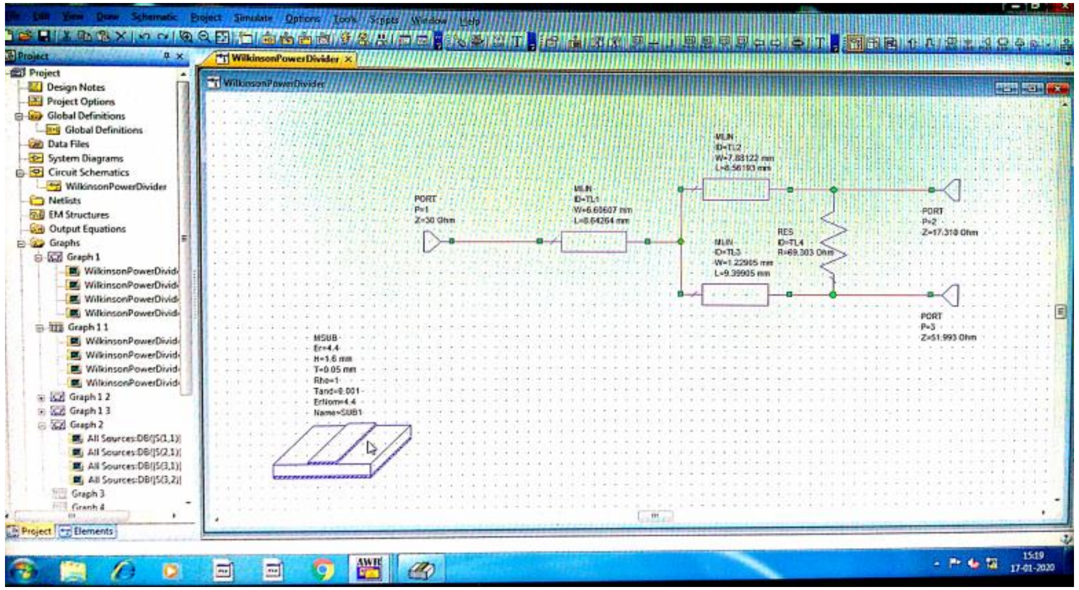
$Z_0 \Rightarrow w = 6.60578$

$L = 8.64268$

$Z_0/\sqrt{2} \Rightarrow w = 10.4416$

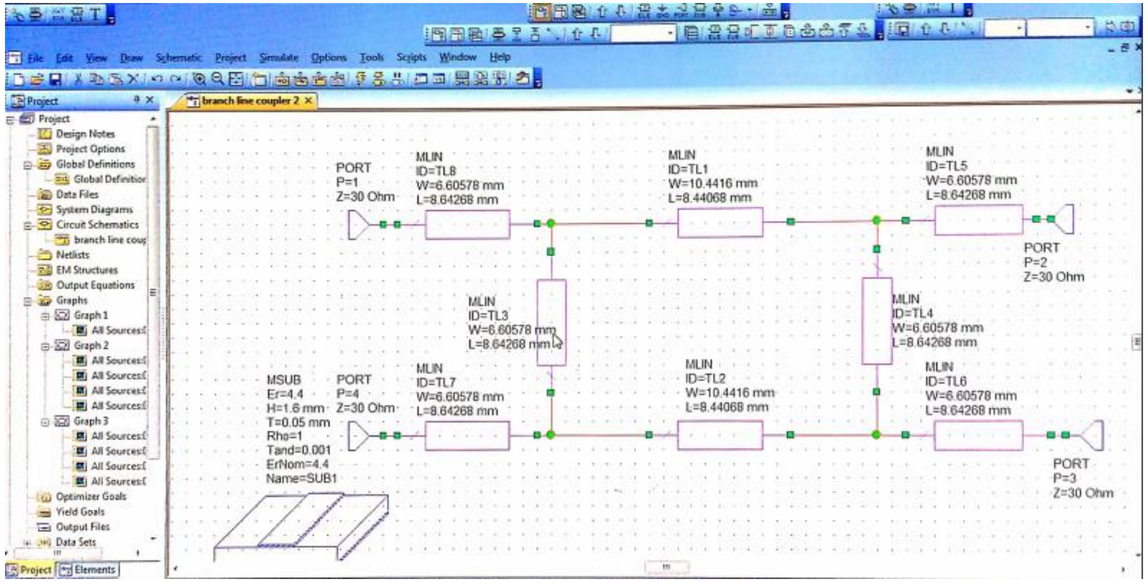
$L = 8.44068$

Design



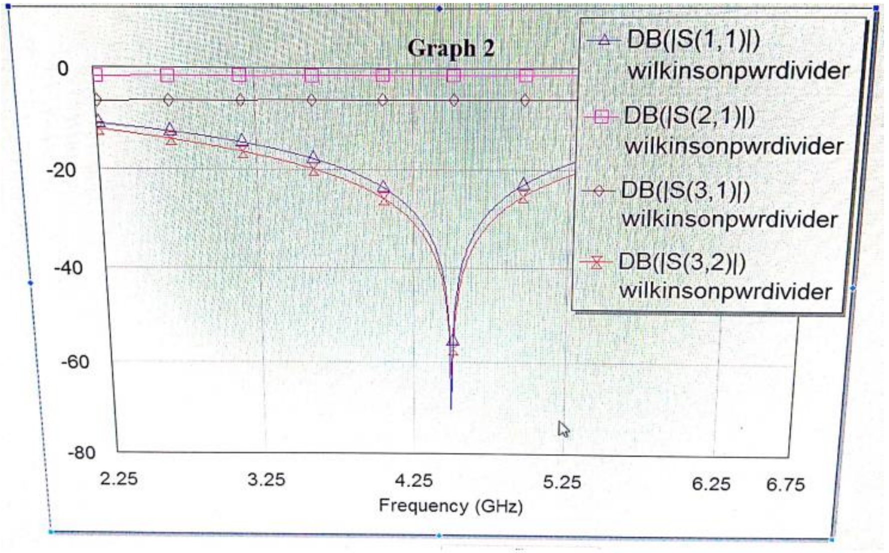
Wilkinson Power divider

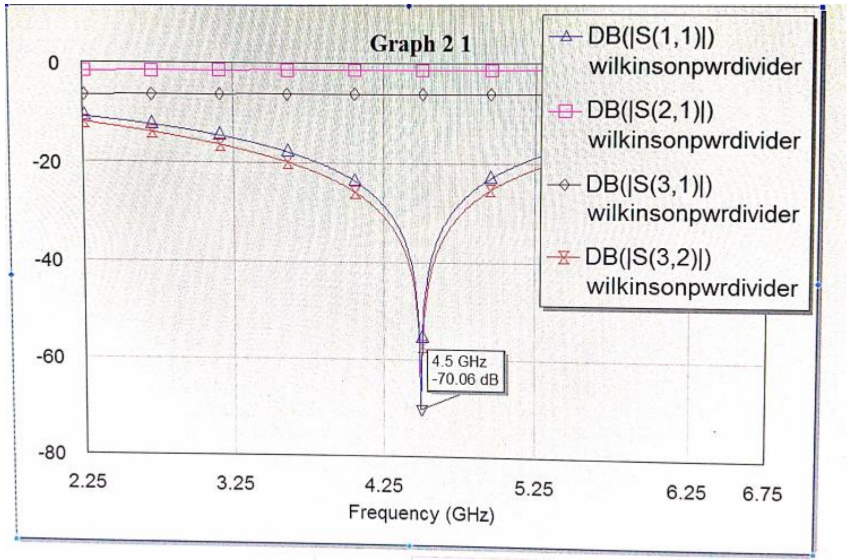
Hybrid Coupler



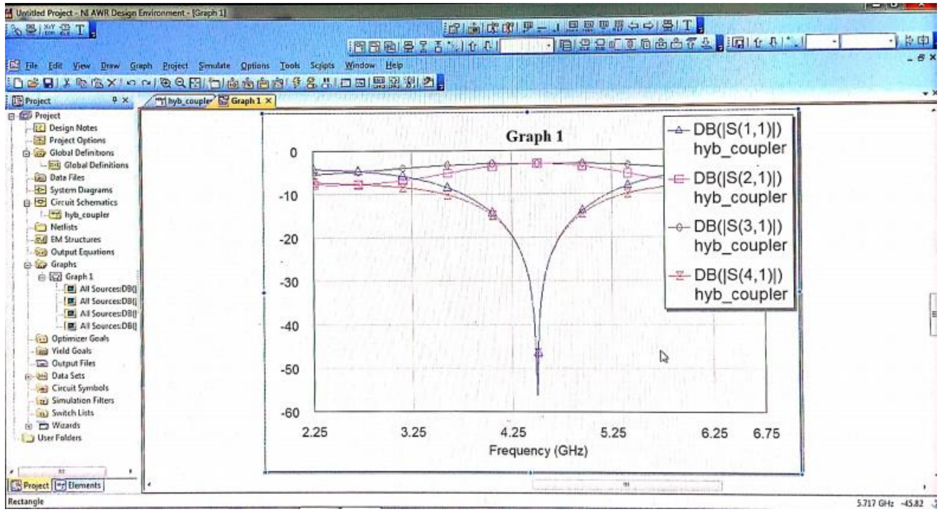
Graph

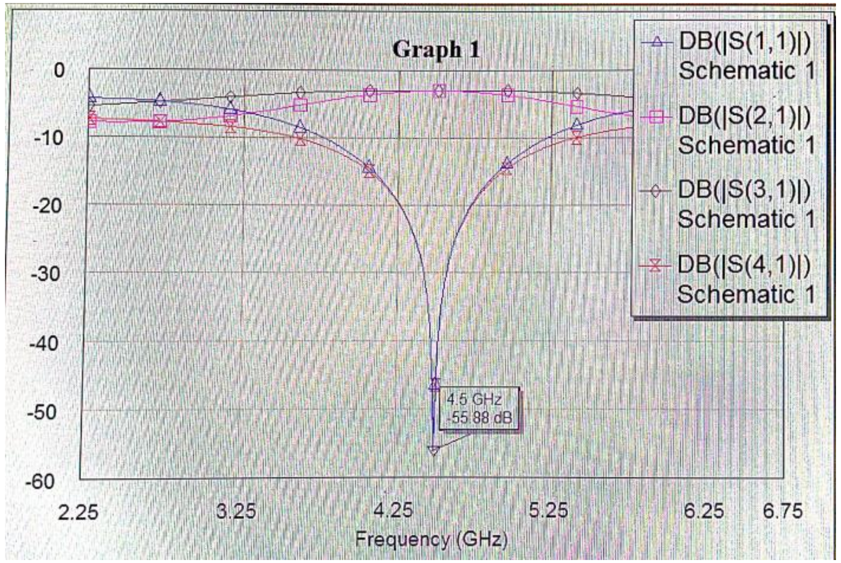
Wilkinson Power divider





Hybrid Coupler





Tabular Readings

Wilkinson Power divider

Frequency (GHz)	DB(|S(1,1)|) wilkinsonpwrdivid	DB(|S(2,1)|) wilkinsonpwrdivid	DB(|S(3,1)|) wilkinsonpwrdivid	DB(|S(3,2)|) wilkinsonpwrdivid
4.47	-46.936	-1.2743	-6.0468	-48.86
4.48	-50.529	-1.2743	-6.0467	-52.145
4.49	-56.715	-1.2743	-6.0467	-57.107
4.5	-70.256	-1.2744	-6.0467	-62.7
4.51	-55.602	-1.2744	-6.0467	-57.265
4.52	-49.95	-1.2745	-6.0467	-52.24
4.53	-46.538	-1.2747	-6.0467	-48.922
4.54	-44.091	-1.2748	-6.0468	-46.493
4.55	-42.182	-1.2749	-6.0468	-44.585
4.56	-40.616	-1.2751	-6.0469	-43.017
4.57	-39.289	-1.2753	-6.0471	-41.686
4.58	-38.138	-1.2755	-6.0472	-40.531
4.59	-37.121	-1.2758	-6.0474	-39.51
4.6	-36.21	-1.276	-6.0476	-38.596
4.61	-35.385	-1.2763	-6.0478	-37.769
4.62	-34.632	-1.2766	-6.048	-37.013
4.63	-33.938	-1.2769	-6.0482	-36.318
4.64	-33.296	-1.2773	-6.0485	-35.673
4.65	-32.697	-1.2776	-6.0488	-35.073
4.66	-32.137	-1.278	-6.0491	-34.512
4.67	-31.611	-1.2784	-6.0495	-33.984
4.68	-31.114	-1.2788	-6.0498	-33.487
4.69	-30.645	-1.2793	-6.0502	-33.016
4.7	-30.199	-1.2797	-6.0506	-32.569
4.71	-29.775	-1.2802	-6.051	-32.145

Hybrid Coupler

Frequency (GHz)	DB(|S(1,1)|) hyb_coupler	DB(|S(2,1)|) hyb_coupler	DB(|S(3,1)|) hyb_coupler	DB(|S(4,1)|) hyb_coupler
4.35	-23.829	-3.1327	-3.0611	-23.919
4.36	-24.43	-3.1236	-3.061	-24.511
4.37	-25.076	-3.1152	-3.0609	-25.148
4.38	-25.774	-3.1074	-3.0609	-25.837
4.39	-26.532	-3.1002	-3.0608	-26.587
4.4	-27.362	-3.0936	-3.0608	-27.41
4.41	-28.279	-3.0877	-3.0608	-28.321
4.42	-29.305	-3.0824	-3.0608	-29.339
4.43	-30.467	-3.0778	-3.0608	-30.495
4.44	-31.809	-3.0738	-3.0608	-31.83
4.45	-33.395	-3.0704	-3.0608	-33.409
4.46	-35.335	-3.0677	-3.0608	-35.34
4.47	-37.83	-3.0656	-3.0609	-37.82
4.48	-41.321	-3.0641	-3.0609	-41.282
4.49	-47.073	-3.0633	-3.0609	-46.92
4.5	-56.237	-3.0631	-3.061	-55.421
4.51	-46.56	-3.0636	-3.061	-46.55
4.52	-41.037	-3.0647	-3.0611	-41.073
4.53	-37.633	-3.0665	-3.0611	-37.675
4.54	-35.182	-3.0689	-3.0611	-35.226
4.55	-33.268	-3.072	-3.0612	-33.314
4.56	-31.699	-3.0757	-3.0612	-31.747
4.57	-30.368	-3.08	-3.0613	-30.42
4.58	-29.214	-3.085	-3.0614	-29.27
4.59	-28.194	-3.0907	-3.0615	-28.255
4.6	-27.28	-3.0969	-3.0616	-27.347
4.61	-26.453	-3.1039	-3.0617	-26.526

Results

- Bandwidth= 4.5
- Quality factor= 70.06/4.5=15.70
- Return loss= 70.256 dB

Wilkinson Power divider

- Bandwidth= 4.5
- Quality factor=55.88/4.5=12.41
- Return loss= 56.237dB

Hybrid Coupler

Inferences

The Circuit diagram has been created for dividing input power in the ratio of 2:6 by designing a power divider and a hybrid coupler.

The graphs have been constructed and the output values such as return loss, bandwidth and quality factor has been recorded.

References

- Microwave Engineering- David M. Pozar
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- https://www.microwaves101.com/encyclopedias/waveguide-mathematics
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