Microwave Review Quiz #4 solution 2016.12.20

1. As shown in Fig.1 (a), it is a _linear_ and _symmetric four-port network. One can then get its S-matrix by using the superposition of the S-matrixes of two-port even and odd networks as shown in Fig.1 (b) and Fig.1 (c). The input signal of Fig.1 (a) is a_1 at port 1.

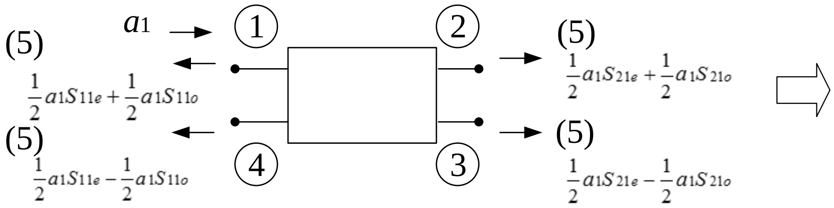


Fig.1 (a)

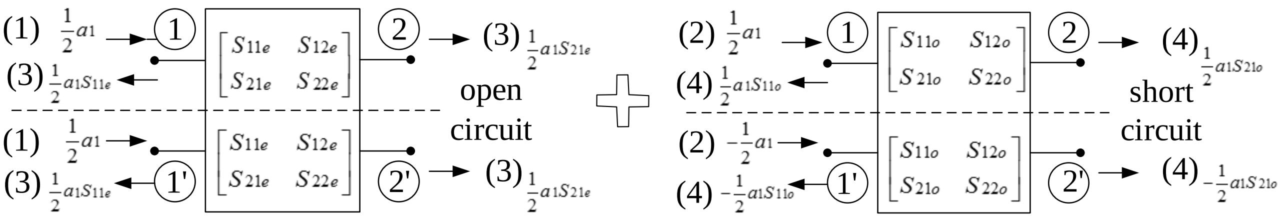


Fig.1 (b) Fig.1 (c)

(1) Give the excitation at ports 1 and 1' of an even-mode two-port network as $\underline{\frac{a_1}{2}}$ and $\underline{\frac{a_1}{2}}$.

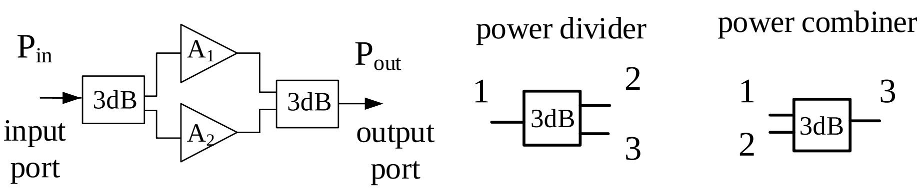
(2) Give the excitation at ports 1 and 1' of an odd-mode two-port network as $\underline{\frac{a_1}{2}}$ and $\underline{-\frac{a_1}{2}}$.

(3) Give the responses at ports 1, 1', 2, and 2' of an even-mode two-port network as $\underline{\frac{a_1}{2}S_{11e}}$, $\underline{\frac{a_1}{2}S_{11e}}$, $\underline{\frac{a_1}{2}S_{21e}}$, and $\underline{\frac{a_1}{2}S_{21e}}$.

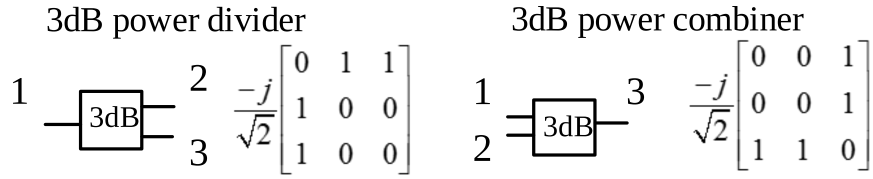
(4) Give the responses at ports 1, 1', 2, and 2' of an odd-mode two-port network as $\underline{\frac{a_1}{2}S_{11o}}$, $\underline{-\frac{a_1}{2}S_{11o}}$, $\underline{\frac{a_1}{2}S_{21o}}$, and $\underline{-\frac{a_1}{2}S_{21o}}$.

(5) Get the responses at ports 1, 2, 3, and 4 of the four-port network as $\underline{\frac{a_1}{2}(S_{11e}+S_{11o})}$, $\underline{\frac{a_1}{2}(S_{21e}+S_{21o})}$, $\underline{\frac{a_1}{2}(S_{21e}-S_{21o})}$, and $\underline{\frac{a_1}{2}(S_{11e}-S_{11o})}$.

2. A power amplifier as shown in Fig.2 (a) with P_{in}=1W includes two 3dB power dividers, two 3dB power combiners and two amplifiers. Each 3dB coupler is a Wilkinson coupler. Two amplifiers A_1~A_2 are identical with 10dB power gain and -∞dB return loss for input port and output port.

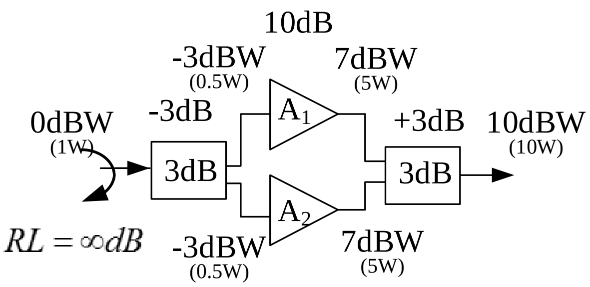


(1) Give the S-matrixes $\underline{\frac{-j}{\sqrt{2}}\begin{bmatrix}0 & 1 & 1\\ 1 & 0 & 0\\ 1 & 0 & 0\end{bmatrix}}$ and $\underline{\frac{-j}{\sqrt{2}}\begin{bmatrix}0 & 0 & 1\\ 0 & 0 & 1\\ 1 & 1 & 0\end{bmatrix}}$ as a 3dB power divider and a 3dB power combiner as shown in Fig.2 (b).



$$\frac{-j}{\sqrt{2}}\begin{bmatrix}0 & 1 & 1\\ 1 & 0 & 0\\ 1 & 0 & 0\end{bmatrix} \qquad \frac{-j}{\sqrt{2}}\begin{bmatrix}0 & 0 & 1\\ 0 & 0 & 1\\ 1 & 1 & 0\end{bmatrix}$$

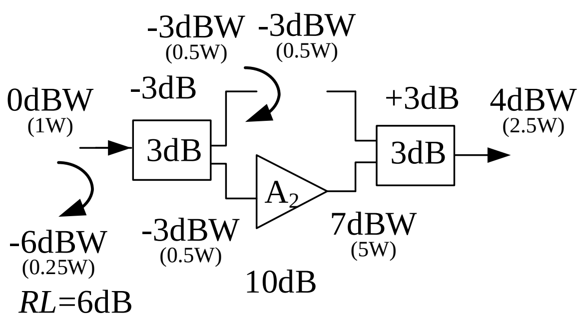
(2) Give the input RL, output power and power gain <u>∞dB</u>, <u>10dBW(10W)</u> and <u>10dB</u> of the power amplifier.



(3) Give the input RL, output power and power gain <u>6dB</u>, <u>4dBW(2.5W)</u> and <u>4dB</u> of the power amplifier as the amplifier A_1 fails as a short circuit.

Only the port 2 of the 3dB power divider gets an input signal at port 2 from a total reflection caused from a shorted amplifier A_1. The 3dB power divider then becomes as a power combiner. Its input signal is at port 1 to calculate the output signal to calculate the input RL (return loss).

$$\frac{-j}{\sqrt{2}}\begin{bmatrix}0 & 0 & 1\\ 0 & 0 & 1\\ 1 & 1 & 0\end{bmatrix}\begin{bmatrix}a\\ 0\\ 0\end{bmatrix} = \frac{-j}{\sqrt{2}}\begin{bmatrix}0\\ 0\\ a\end{bmatrix} \rightarrow \text{output power at port 3}: \frac{1}{2}\left|\frac{-j}{\sqrt{2}}a\right|^2 = \frac{1}{4}|a|^2 \quad \text{is a half of the input power.}$$



The input signal of the 3dB power combiner is only at port 2 to calculate the output signal.

$$\frac{-j}{\sqrt{2}}\begin{bmatrix}0 & 0 & 1\\ 0 & 0 & 1\\ 1 & 1 & 0\end{bmatrix}\begin{bmatrix}0\\ a\\ 0\end{bmatrix} = \frac{-j}{\sqrt{2}}\begin{bmatrix}0\\ 0\\ a\end{bmatrix} \rightarrow \text{output power at port 3}: \frac{1}{2}\left|\frac{-j}{\sqrt{2}}a\right|^2 = \frac{1}{4}|a|^2 \quad \text{is a half of the input power.}$$