CUPLOARE

Proprietati de baza ale cuploarelor directionale

Circuite cu patru porti

$(S_{ij} = S_{ji})$ Reciproc

$S_{ii} = 0$ Adaptare simultana la toate portile

$>$

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} & S_{14} \\ S_{12} & 0 & S_{23} & S_{24} \\ S_{13} & S_{23} & 0 & S_{34} \\ S_{14} & S_{24} & S_{34} & 0 \end{bmatrix}$$

+

$\sum_k S_{ik} S_{kj}^* = \delta_{ij}$ Fara pierderi

=

(11) $S_{14}^*\left(|S_{13}|^2 - |S_{24}|^2\right) = 0$

(13) $S_{23}\left(|S_{12}|^2 - |S_{34}|^2\right) = 0$

(14a) $|S_{12}|^2 + |S_{13}|^2 = 1$

(14b) $|S_{12}|^2 + |S_{24}|^2 = 1$

(14c) $|S_{13}|^2 + |S_{34}|^2 = 1$

(14d) $|S_{24}|^2 + |S_{34}|^2 = 1$

(15) $S_{12}^* S_{13} + S_{24}^* S_{34} = 0$

$<$ **10 ecuatii**

Cazul 1

(11) si (13) > $S_{14} = S_{23} = 0 \Rightarrow \quad [S] = \begin{bmatrix} 0 & S_{12} & S_{13} & 0 \\ S_{12} & 0 & 0 & S_{24} \\ S_{13} & 0 & 0 & S_{34} \\ 0 & S_{24} & S_{34} & 0 \end{bmatrix} \Leftrightarrow$ **Cuplor directional**

(14a) si (14b) > $|S_{13}| = |S_{24}|$

(14b) si (14d) > $|S_{12}| = |S_{34}|$

Alegem: $S_{12} = S_{34} = \alpha \qquad S_{13} = \beta e^{j\theta} \qquad S_{24} = \beta e^{j\phi}$

(15) > $\theta + \phi = \pi \pm 2n\pi$

Cuplor simetric $\theta = \phi = \pi/2$

$$[S] = \begin{bmatrix} 0 & \alpha & j\beta & 0 \\ \alpha & 0 & 0 & j\beta \\ j\beta & 0 & 0 & \alpha \\ 0 & j\beta & \alpha & 0 \end{bmatrix}$$

Cuplor antisimetric $\theta = 0,\ \phi = \pi$

$$[S] = \begin{bmatrix} 0 & \alpha & \beta & 0 \\ \alpha & 0 & 0 & -\beta \\ \beta & 0 & 0 & \alpha \\ 0 & -\beta & \alpha & 0 \end{bmatrix}$$

(14a) > $\alpha^2 + \beta^2 = 1$

Cazul 2

(11) si (13) > $\begin{cases} |S_{13}| = |S_{24}| \\ |S_{12}| = |S_{34}| \end{cases}$ Alegem: $S_{13} = S_{24} = \alpha$ $\quad S_{12} = S_{34} = j\beta$

(14a) > $\alpha^2 + \beta^2 = 1$

$$S_{13}^* S_{23} + S_{14}^* S_{24} = 0 \quad \Rightarrow \quad \alpha\left(S_{23} + S_{14}^*\right) = 0$$

$$S_{12}^* S_{23} + S_{14}^* S_{34} = 0 \quad \Rightarrow \quad \beta\left(S_{14}^* - S_{23}\right) = 0$$

→ $S_{14} = S_{23} = 0$ **Cuplor directional**

$$[S] = \begin{bmatrix} 0 & j\beta & \alpha & 0 \\ j\beta & 0 & 0 & \alpha \\ \alpha & 0 & 0 & j\beta \\ 0 & \alpha & j\beta & 0 \end{bmatrix}$$

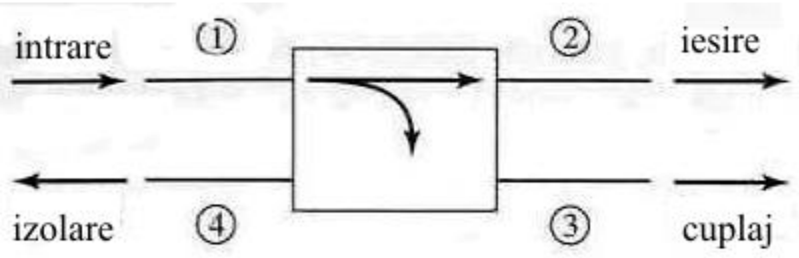
↓

$\alpha = \beta = 0$ **Caz banal**

CONCLUZIE

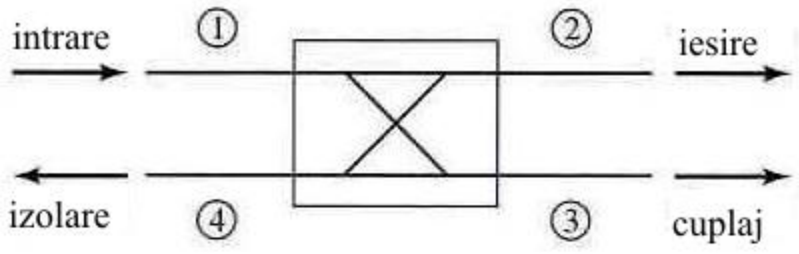
Orice circuit cu patru porti,
reciproc, fara pierderi si adaptat la toate portile
este un cuplor directional

Cuplor directional



$$\left|S_{12}\right|^2 = \alpha^2 = 1-\beta^2$$

$$\left|S_{13}\right|^2 = \beta^2$$



Cuplaj $= C = 10\log\frac{P_1}{P_3} = -20\log(\beta)\, dB$

Directivitate $= D = 10\log\frac{P_3}{P_4} = 20\log\left(\frac{\beta}{|S_{14}|}\right) dB$

Izolare $= I = 10\log\left(\frac{P_1}{P_4}\right) = -20\log|S_{14}|\, dB$

$$I = D + C \,,\ \ dB$$

Cuplor hibrid

Cuplorul hibrid este cuplorul directional de 3 dB

$$\alpha = \beta = 1/\sqrt{2}$$

Cuplor hibrid in cuadratura

$$\left(\theta = \phi = \pi/2\right)$$

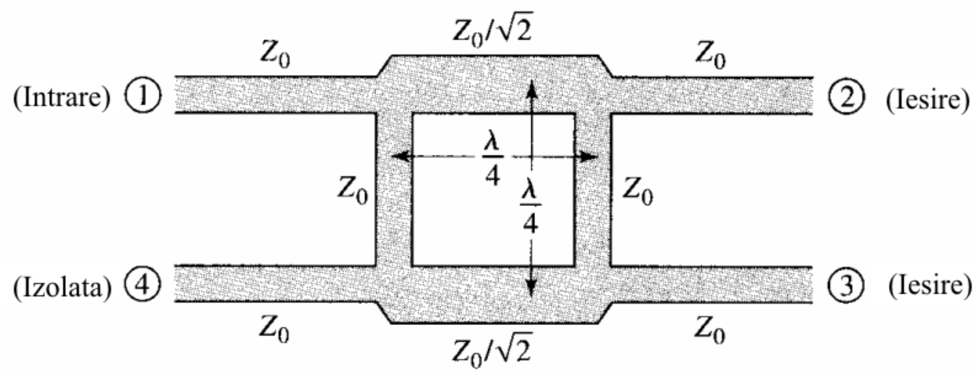
$$[S] = \frac{1}{\sqrt{2}}\begin{bmatrix} 0 & 1 & j & 0 \\ 1 & 0 & 0 & j \\ j & 0 & 0 & 1 \\ 0 & j & 1 & 0 \end{bmatrix}$$

Cuplor hibrid in inel

$$\left(\theta = 0\,, \phi = \pi\right)$$

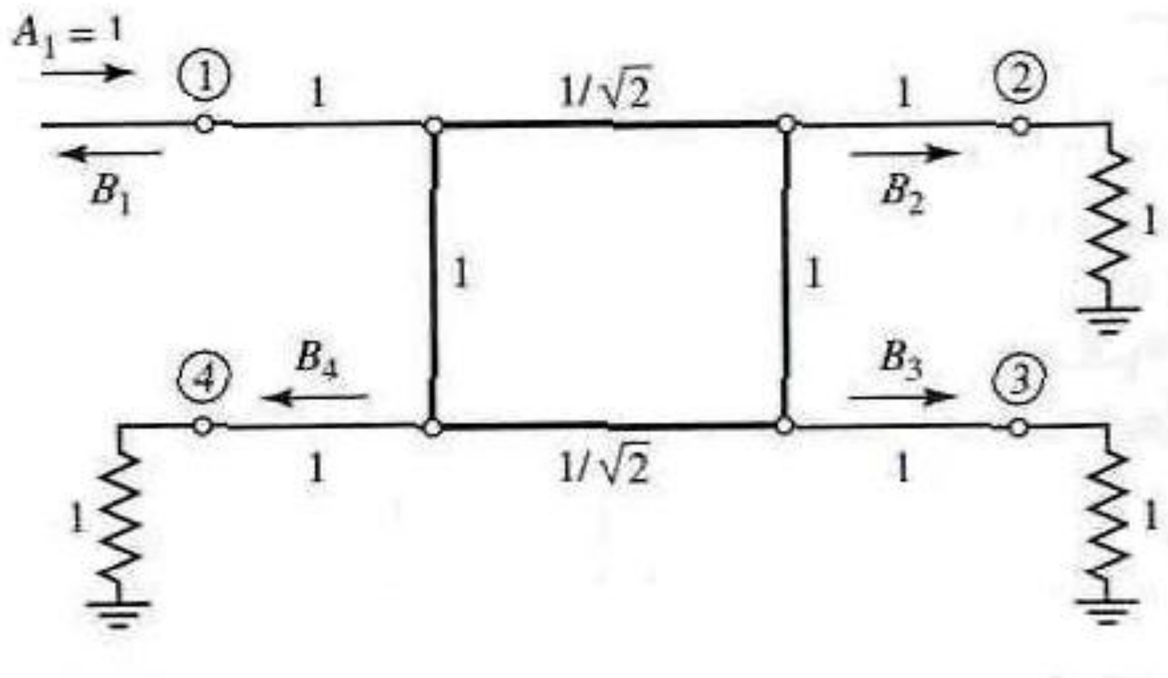
$$[S] = \frac{1}{\sqrt{2}}\begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & -1 \\ 1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \end{bmatrix}$$

Cuplorul hibrid în cuadratură (90°)

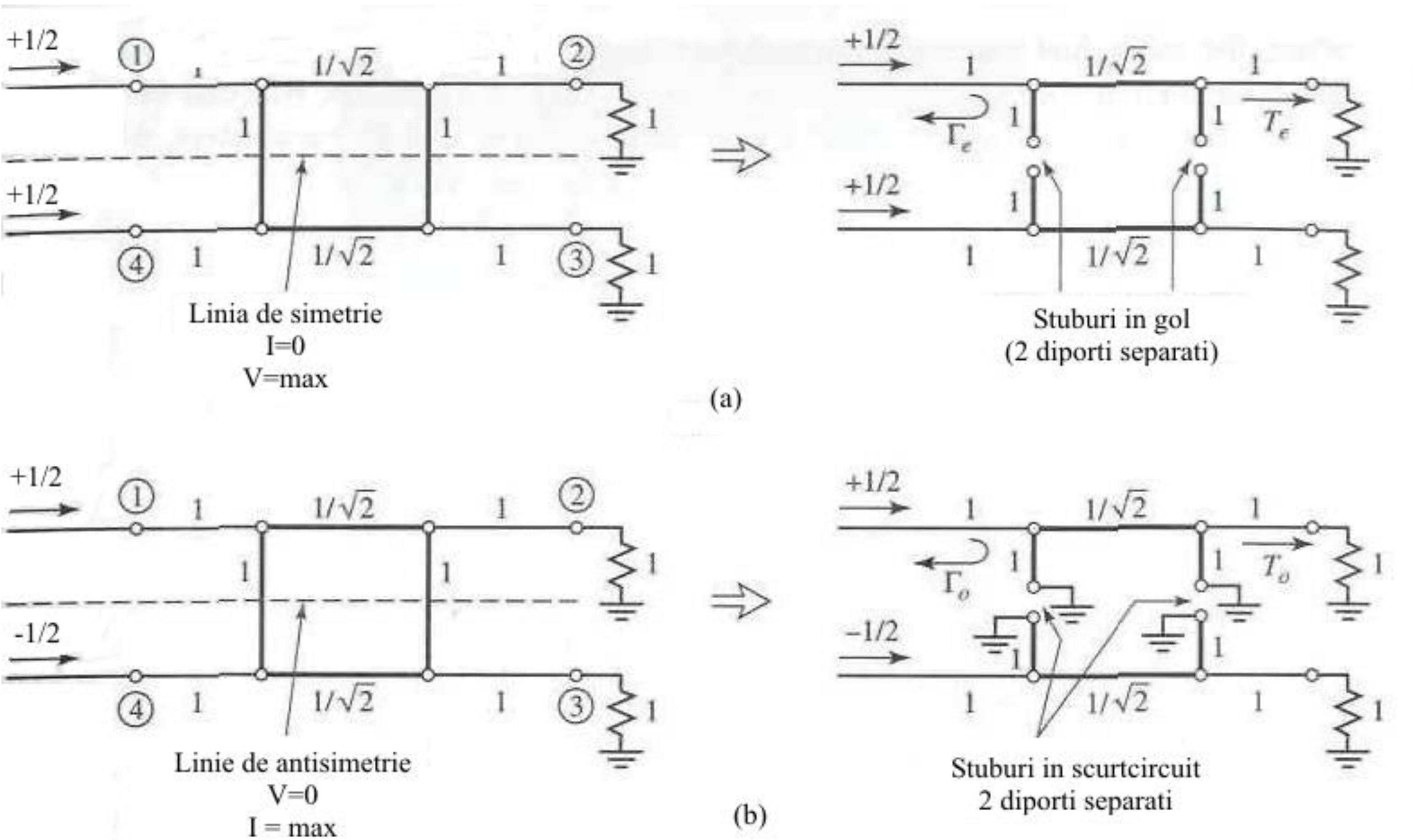


$$[S] = \frac{-1}{\sqrt{2}} \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix}$$

Analiza pe modul par-impar



Analiza pe modul par-impar

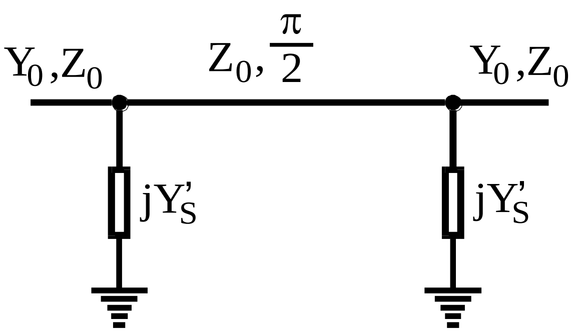


(a)
(b)

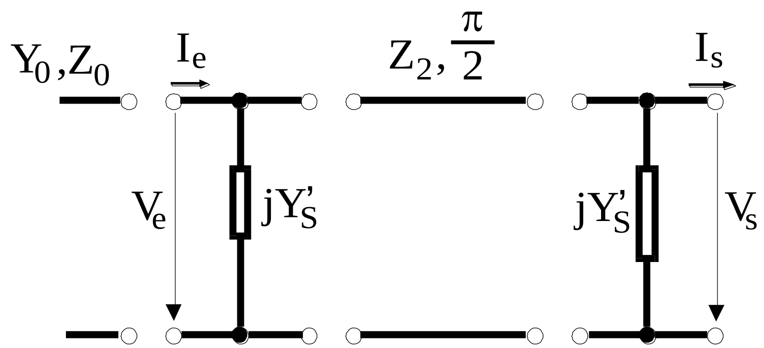
$$b_1 = \frac{1}{2}\Gamma_e + \frac{1}{2}\Gamma_o \qquad b_2 = \frac{1}{2}T_e - \frac{1}{2}T_o \qquad b_3 = \frac{1}{2}T_e - \frac{1}{2}T_o \qquad b_4 = \frac{1}{2}\Gamma_e - \frac{1}{2}\Gamma_o$$

Calculul cuploarelor cu două trepte

$$Y'_S = \begin{cases} Y_1 & \text{pentru modul par} \\ -Y_1 & \text{pentru modul impar} \end{cases}$$



a)



b)

$$\begin{bmatrix} V_e \\ I_e \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ jY'_S & 1 \end{bmatrix} \cdot \begin{bmatrix} 0 & jZ_2 \\ jY_2 & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ jY'_S & 1 \end{bmatrix} \cdot \begin{bmatrix} V_S \\ I_S \end{bmatrix}$$

$$\begin{bmatrix} V_e \\ I_e \end{bmatrix} = \begin{bmatrix} -Y'_S Z_2 & jZ_2 \\ -jY'^2_S Z_2 + jY_2 & -Y'_S Z_2 \end{bmatrix} \cdot \begin{bmatrix} V_S \\ I_S \end{bmatrix}$$

$$S_{11} = \frac{j\frac{Z_2}{Z_0} - Z_0\left(-jY'^2_S Z_2 + jY_2\right)}{-2Y'_S Z_2 + j\frac{Z_2}{Z_0} + Z_0\left(-jY'^2_S + jY_2\right)}$$

$$S_{12} = \frac{2\left[\left(-Y'_S Z_2\right)^2 - jZ_2\left(-jY'^2_S Z_2 + jY_2\right)\right]}{-2Y'_S Z_2 + j\frac{Z_2}{Z_0} + Z_0\left(-jY'^2_S Z_2 + jY_2\right)}$$

$$\Gamma = S_{11} = \frac{j\left(z_2 - y_2 + y'^2_S z_2\right)}{-2y'_S z_2 + j\left(z_2 + y_2 - y'^2_S z_2\right)} = S_{22}$$

$$S_{21} = \frac{2}{-2Y'_S Z_2 + j\frac{Z_2}{Z_0} + Z_0\left(-jY'^2_S Z_2 + jY_2\right)}$$

$$S_{22} = \frac{j\frac{Z_2}{Z_0} - Z_0\left(-jY'^2_S Z_2 + jY_2\right)}{-2Y'_S Z_2 + j\frac{Z_2}{Z_0} + Z_0\left(-jY'^2_S Z_2 + jY_2\right)}$$

$$T = S_{21} = \frac{2}{-2y'_S z_2 + j\left(z_2 + y_2 - y'^2_S z_2\right)} = S_{12}$$

Adaptarea cuplorului si coeficientul de cuplaj

$$\Gamma_e = \frac{j\left(z_2 - y_2 + y_1^2 z_2\right)}{-2y_1 z_2 + j\left(z_2 + y_2 - y_1^2 z_2\right)}$$

$$\Gamma_o = \frac{j\left(z_2 - y_2 + y_1^2 z_2\right)}{2y_1 z_2 + j\left(z_2 + y_2 - y_1^2 z_2\right)}$$

$$T_e = \frac{2}{-2y_1 z_2 + j\left(z_2 + y_2 - y_1^2 z_2\right)}$$

$$T_o = \frac{2}{2y_1 z_2 + j\left(z_2 + y_2 - y_1^2 z_2\right)}$$

$$b_1 = \frac{\Gamma_e + \Gamma_o}{2} = \frac{z_2^2 - \left(y_2 - y_1^2 z_2\right)^2}{\left(2y_1 z_2\right)^2 + \left(z_2 + y_2 - y_1^2 z_2\right)^2}$$

$$b_2 = \frac{T_e + T_o}{2} = \frac{-2j\left(z_2 + y_2 - y_1^2 z_2\right)}{\left(2y_1 z_2\right)^2 + \left(z_2 + y_2 - y_1^2 z_2\right)^2}$$

$$b_3 = \frac{T_e - T_o}{2} = \frac{-4y_1 z_2}{\left(2y_1 z_2\right)^2 + \left(z_2 + y_2 - y_1^2 z_2\right)^2}$$

$$b_4 = \frac{\Gamma_e - \Gamma_o}{2} = \frac{-2jy_1 z_2\left(z_2 - y_2 + y_1^2 z_2\right)}{\left(2y_1 z_2\right)^2 + \left(z_2 + y_2 - y_1^2 z_2\right)^2}$$

$$b_1 = 0 \Rightarrow z_2 - y_2 + y_1^2 z_2 = 0 \Rightarrow z_2^2 = \frac{1}{1 + y_1^2}$$

$$b_1 = 0 \quad b_4 = 0 \quad b_3 = -y_1 z_2 \quad b_2 = -jz_2$$

$$y_2^2 = 1 + y_1^2$$

$$b_3 = -\frac{\sqrt{y_2^2 - 1}}{y_2}, \quad b_2 = -\frac{j}{y_2}$$

$$C = 10\log\frac{P_1}{P_3} = -20\log\left|b_3\right|, dB$$

$$C = \frac{\sqrt{y_2^2 - 1}}{y_2}$$

$$b_3 = -C$$

$$b_2 = -j\sqrt{1 - C^2}$$

$$[S] = \begin{bmatrix} 0 & -j\sqrt{1-C^2} & -C & 0 \\ -j\sqrt{1-C^2} & 0 & 0 & -C \\ -C & 0 & 0 & -j\sqrt{1-C^2} \\ 0 & -C & -j\sqrt{1-C^2} & 0 \end{bmatrix}$$

Exemplu

Proiectaţi un cuplor în scară pe impedanţa caracteristică de 50 Ω, şi reprezentati mărimea parametrilor S între

$0.5 f_0$ şi $1.5 f_0$, unde f_0

este frecvenţa de proiectare la care liniile cuplorului sunt de lungime $\lambda/4$

.

Solutie

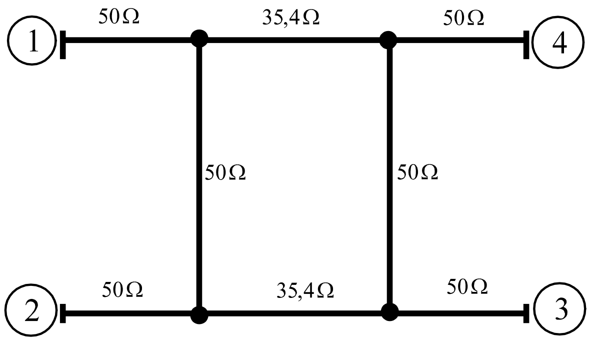
Un cuplor în scară cu C = 3dB, are $C = 1/\sqrt{2}$

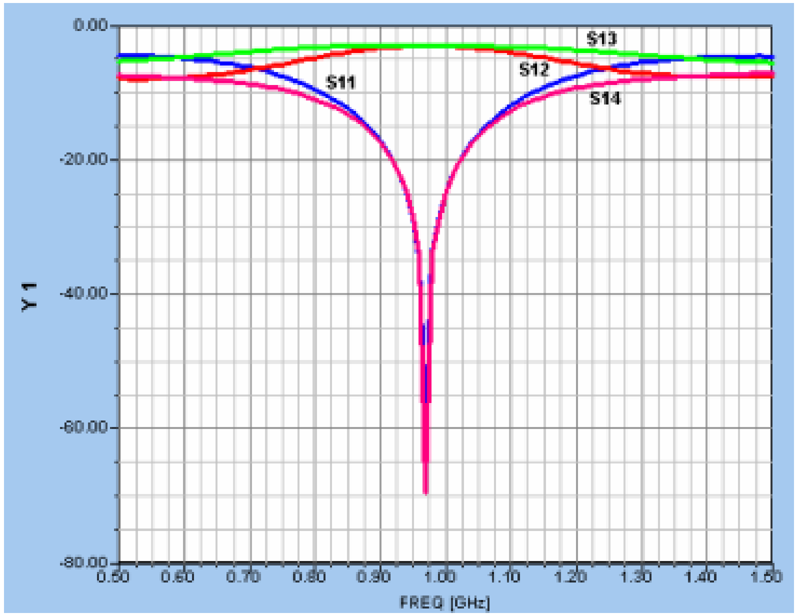
. Atunci $y_2 = \sqrt{2}$ şi $y_1 = 1$

. Astfel matricea S din relaţia (&.47) devine cea din relaţia (&.38). În plus, pentru $Z_0 = 50\Omega$

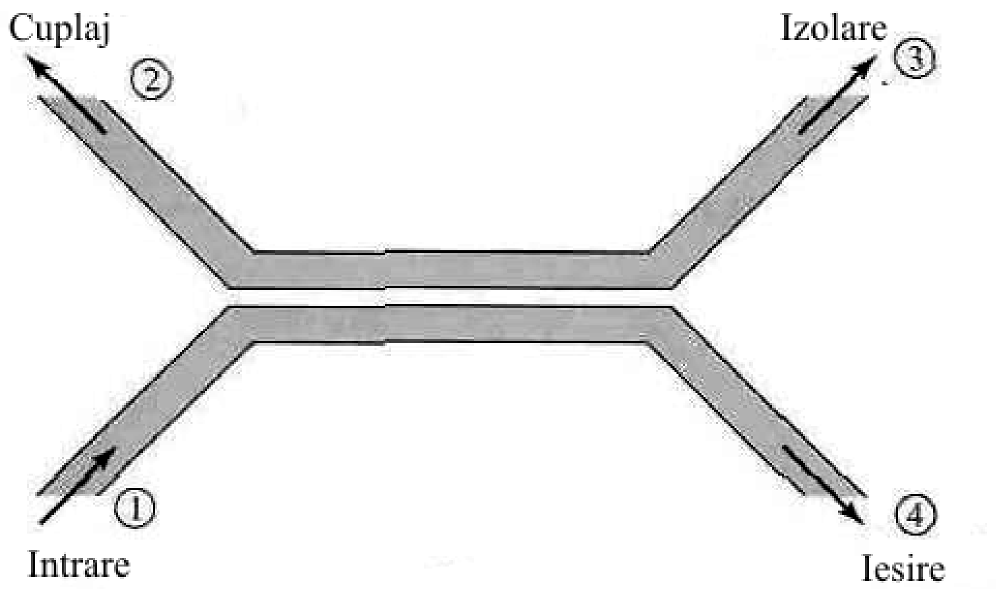
, impedanţele caracteristice ale liniilor cuplorului vor fi:

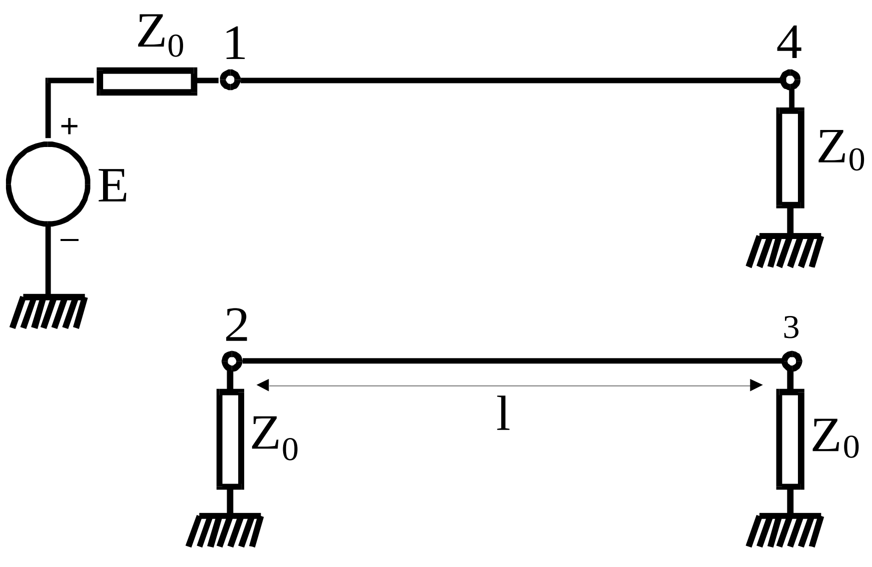
$$Z_1 = Z_0 = 50\Omega \qquad Z_2 = \frac{Z_0}{\sqrt{2}} = 35.4\Omega$$



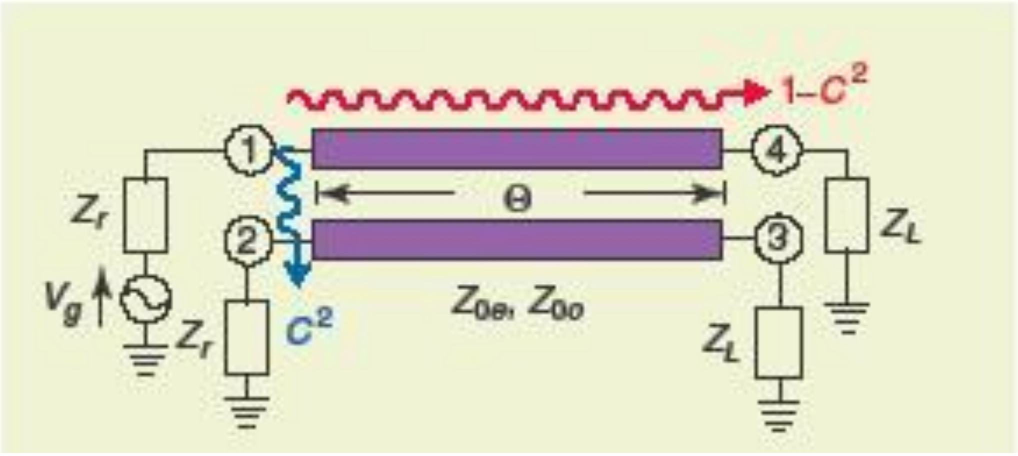


Cuplorul prin proximitate





Parametrii S



$$S_{11} = \frac{1}{2}\Gamma_e + \frac{1}{2}\Gamma_o$$

$$S_{21} = \frac{1}{2}\Gamma_e - \frac{1}{2}\Gamma_o$$

$$S_{31} = \frac{1}{2}T_e - \frac{1}{2}T_o$$

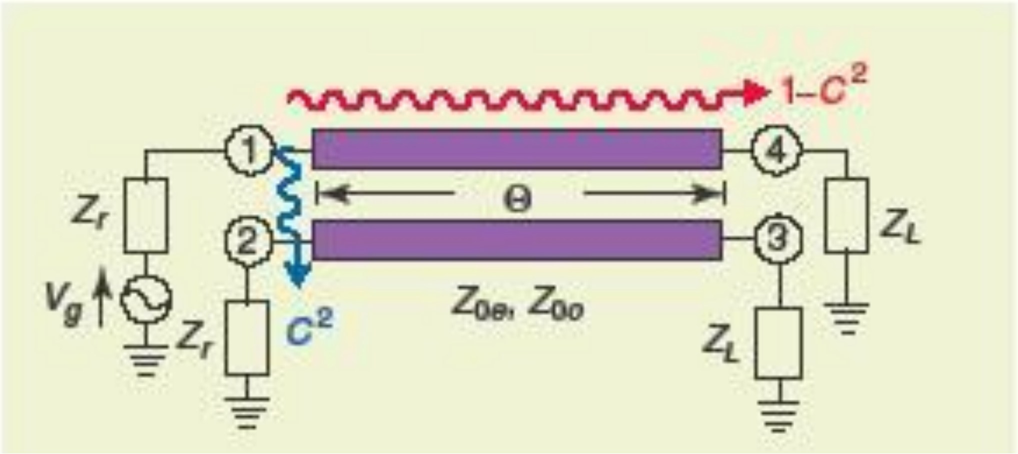
$$S_{41} = \frac{1}{2}T_e + \frac{1}{2}T_o$$

$$S_{11} = \frac{1}{2}\left(\Gamma_e + \Gamma_o\right) = \frac{\Re e\left(N\right) + j\Im m\left(N\right)}{D}$$

$$\Re e\left(N\right) = \left(Z_L^2 - Z_r^2\right)cos^2\theta - \left[\left(Z_{0e}Z_{0o} - \frac{1}{Z_{0e}Z_{0o}}\left(Z_L Z_r\right)^2\right)\right]sin^2\theta$$

$$\Im m\left(N\right) = \left[\left(Z_{0e} + Z_{0o}\right)Z_L - Z_L Z_r\left(\frac{1}{Z_{0e}} + \frac{1}{Z_{0o}}\right)Z_r\right]sin\theta\, cos\theta$$

Adaptarea cuplorului prin proximitate



$$\theta = 90°$$

$$Z_{0e} Z_{0o} = Z_L Z_r$$

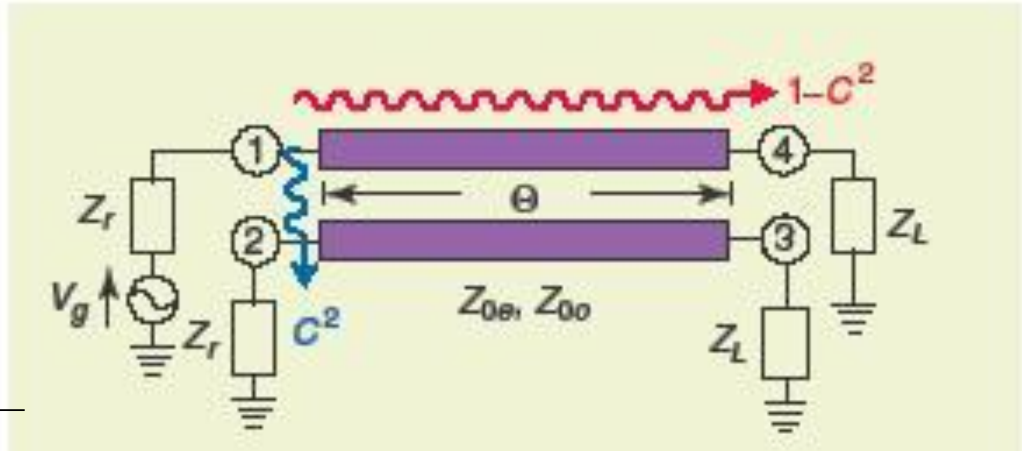
Directivitatea şi coeficientul de cuplaj ale cuplorului prin proximitate

$$S_{11}=\frac{(Z_L-Z_r)\cos\theta}{(Z_L+Z_r)\cos\theta+j(Z_{0e}+Z_{0o})\sin\theta}$$

$$S_{21}=\frac{j(Z_{0e}-Z_{0o})\sin\theta}{(Z_L+Z_r)\cos\theta+j(Z_{0e}+Z_{0o})\sin\theta}$$

$$S_{31}=0$$

$$S_{41}=\frac{2}{\left(\sqrt{\frac{Z_L}{Z_r}}+\sqrt{\frac{Z_r}{Z_L}}\right)\cos\theta+j\left(\sqrt{\frac{Z_{0e}}{Z_{0o}}}+\sqrt{\frac{Z_{0o}}{Z_{0e}}}\right)\sin\theta}$$



$$\theta=\pi/2$$

$$S_{11}=0 \qquad S_{31}=0$$

$$S_{21}=\frac{Z_{0e}-Z_{0o}}{Z_{0e}+Z_{0o}}=C$$

$$S_{41}=-j\frac{2\sqrt{Z_{0e}Z_{0o}}}{Z_{0e}+Z_{0o}}=-j\sqrt{1-C^2}$$

$$[S]=\begin{bmatrix}0 & C & 0 & -j\sqrt{1-C^2}\\ C & 0 & -j\sqrt{1-C^2} & 0\\ 0 & -j\sqrt{1-C^2} & 0 & C\\ -j\sqrt{1-C^2} & 0 & C & 0\end{bmatrix}$$

Exemplu

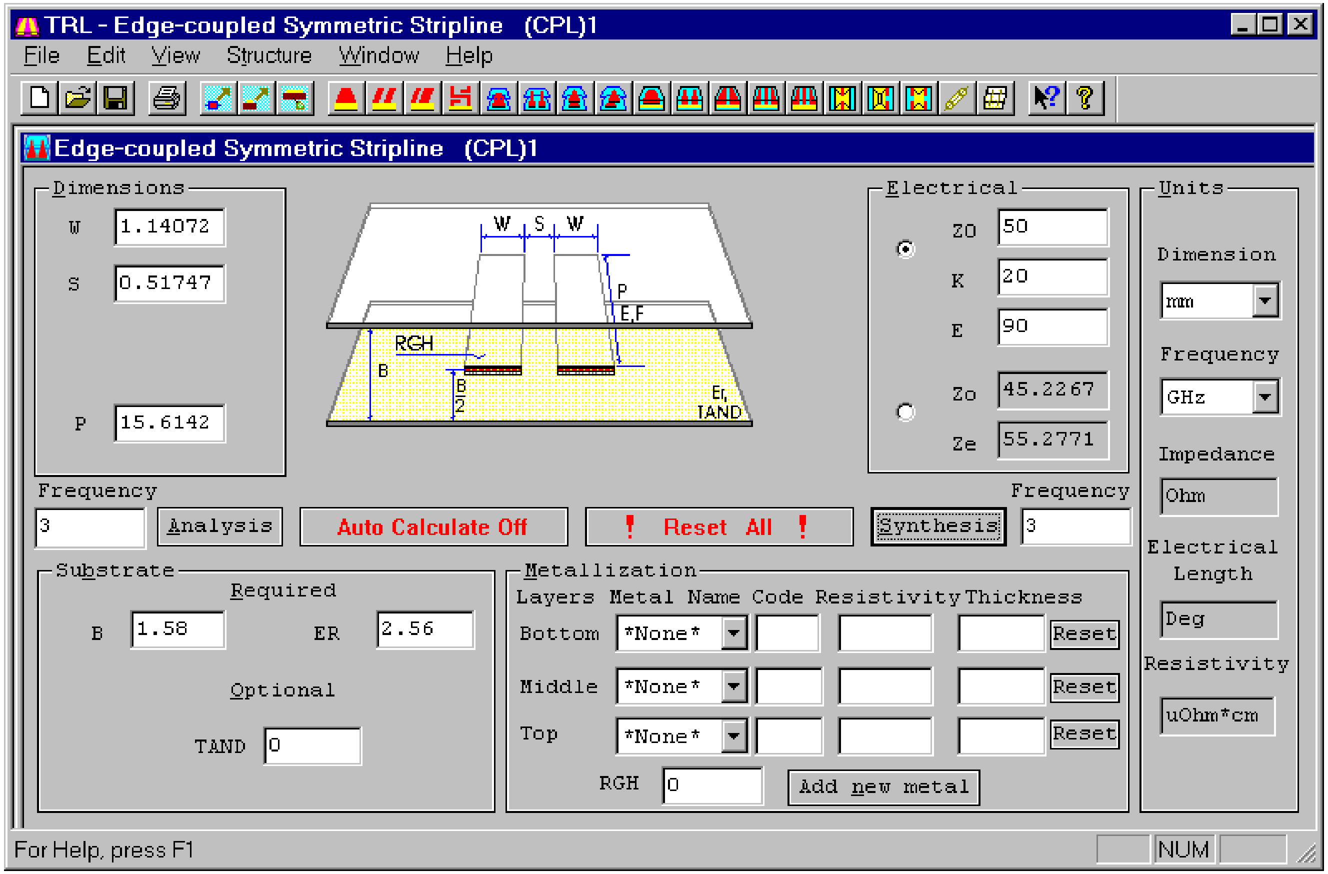
Proiectaţi un cuplor prin proximitate de 20 dB, în tehnologie stripline, folosind o distanta între planele de masă de 0.158 cm şi cu o permitivitate electrică relativa de 2.56, pe o impedanţa de 50 Ω, la frecvenţa de 3 GHz. Reprezentaţi cuplajul şi directivitatea între 1 si 5 GHz.

Soluție

$$C = 10^{-20/20} = 0.1$$

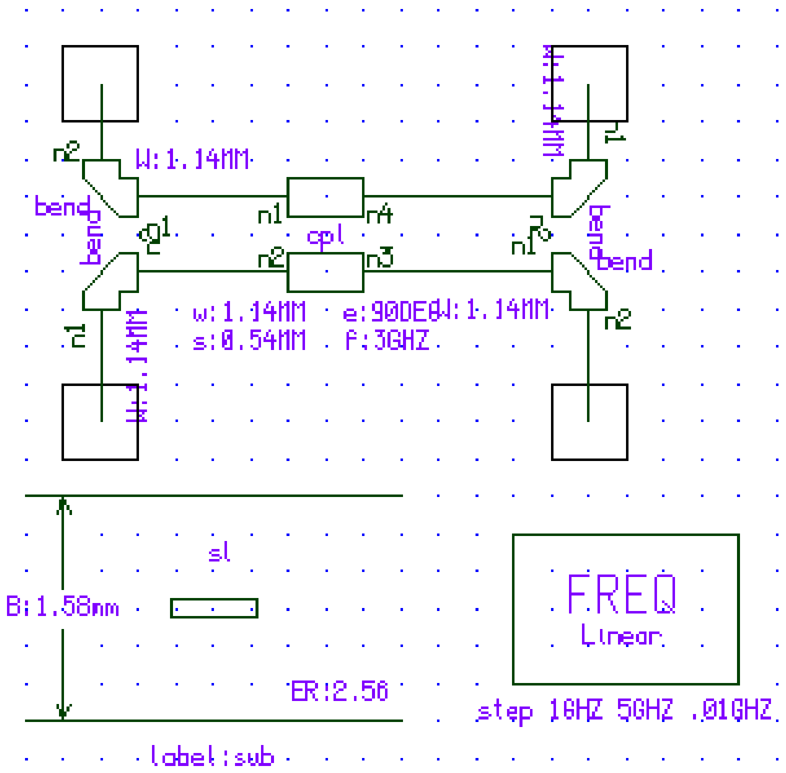
$$Z_{co} = 50\sqrt{\frac{0.9}{1.1}} = 45.23\Omega$$

$$Z_{ce} = 50\sqrt{\frac{1.1}{0.9}} = 55.28\Omega$$

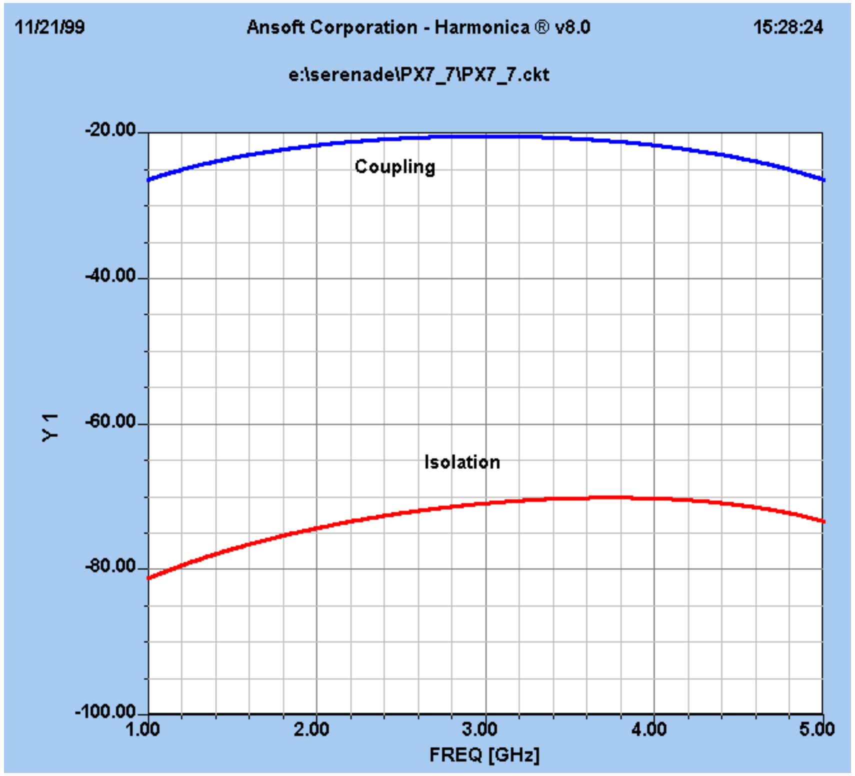


$$Z_{ce} = Z_0\sqrt{\frac{1+C}{1-C}}\,,\; Z_{co} = Z_0\sqrt{\frac{1-C}{1+C}}$$

Simulare



n2
W:1.14MM
bend
n1
n4
cpl
n2
n3
n1
bend
w:1.14MM
s:0.54MM
e:90DEG
f:3GHZ
W:1.14MM
n1
n2
sl
B:1.58mm
ER:2.56
label:sub
FREQ
Linear
step 1GHZ 5GHZ .01GHZ



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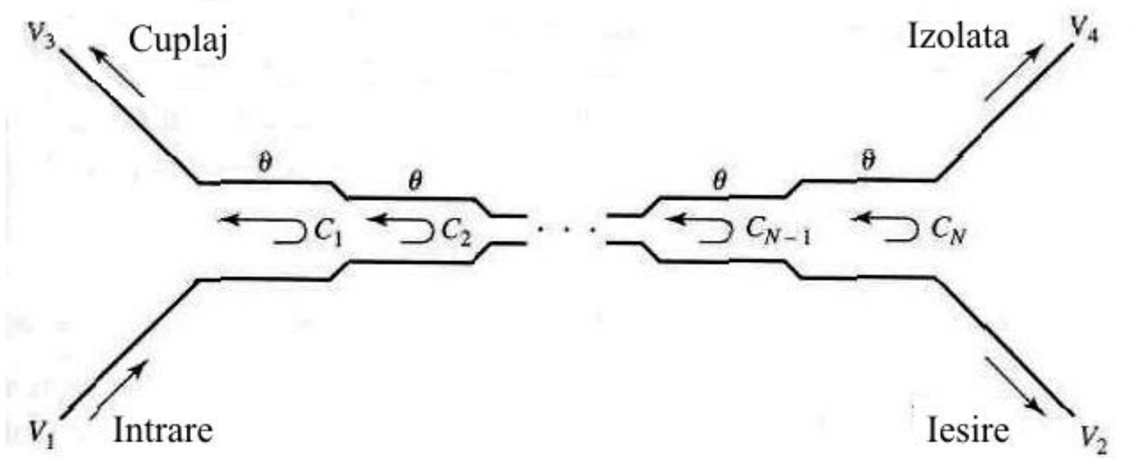
Coupling
Isolation
Y 1
-20.00
-40.00
-60.00
-80.00
-100.00
1.00
2.00
3.00
4.00
5.00
FREQ [GHz]

Cuplor prin proximitate cu mai multe secţiuni



C<<1

$$\frac{V_3}{V_1} = b_2 = \frac{jC\sin\theta}{\cos\theta\sqrt{1-C^2} + j\sin\theta} = \frac{jCtg\theta}{\sqrt{1-C^2} + jtg\theta} \approx \frac{jCtg\theta}{1+jtg\theta} = jC\sin\theta e^{-j\theta}$$

$$\frac{V_2}{V_1} = b_4 = \frac{\sqrt{1-C^2}}{\cos\theta\sqrt{1-C^2} + j\sin\theta} \approx \frac{1}{\cos\theta + j\sin} = e^{-j\theta}$$

$$C = \frac{V_3}{V_1} = 2j\sin\theta e^{-j\theta} e^{-j(N-1)\theta}\left[C_1\cos(N-1)\theta + C_2\cos(N-3)\theta + \ldots + \frac{1}{2}C_{\frac{N+1}{2}}\right]$$

Exemplu

Să se proiecteze un cuplor cu trei secţiuni, avînd un cuplaj de 20 dB, cu caracteristică binomiala (maxim plat), pe o impedanţă de 50 Ω, la frecvenţa centrală de 3 GHz. Să se reprezinte grafic cuplajul şi directivitatea între 1 şi 5 GHz.

Solutie

$$\left(N=3\right) \qquad C_0 = 20\ dB \qquad \theta = \pi/2$$

$$\left.\frac{d^n}{d\theta^n} C(\theta)\right|_{\theta=\pi/2} = 0,\ n = 1{,}2$$

$$C = \left|\frac{V_3}{V_1}\right| = 2\sin\theta\left[C_1\cos 2\theta + \frac{1}{2}C_2\right] = C_1\left(\sin 3\theta - \sin\theta\right) + C_2\sin\theta$$

$$\frac{dC}{d\theta} = \left[3C_1\cos 3\theta + \left(C_2 - C_1\right)\cos\theta\right]\Big|_{\theta=\pi/2} = 0$$

$$\frac{d^2C}{d\theta^2} = \left[-9C_1\sin 3\theta - \left(C_2 - C_1\right)\sin\theta\right]\Big|_{\theta=\pi/2} = 10C_1 - C_2 = 0$$

$$\begin{cases} C_2 - 2C_1 = 0.1 \\ 10C_1 - C_2 = 0 \end{cases}$$

$$\begin{cases} C_1 = C_3 = 0.0125 \\ C_2 = 0.125 \end{cases}$$

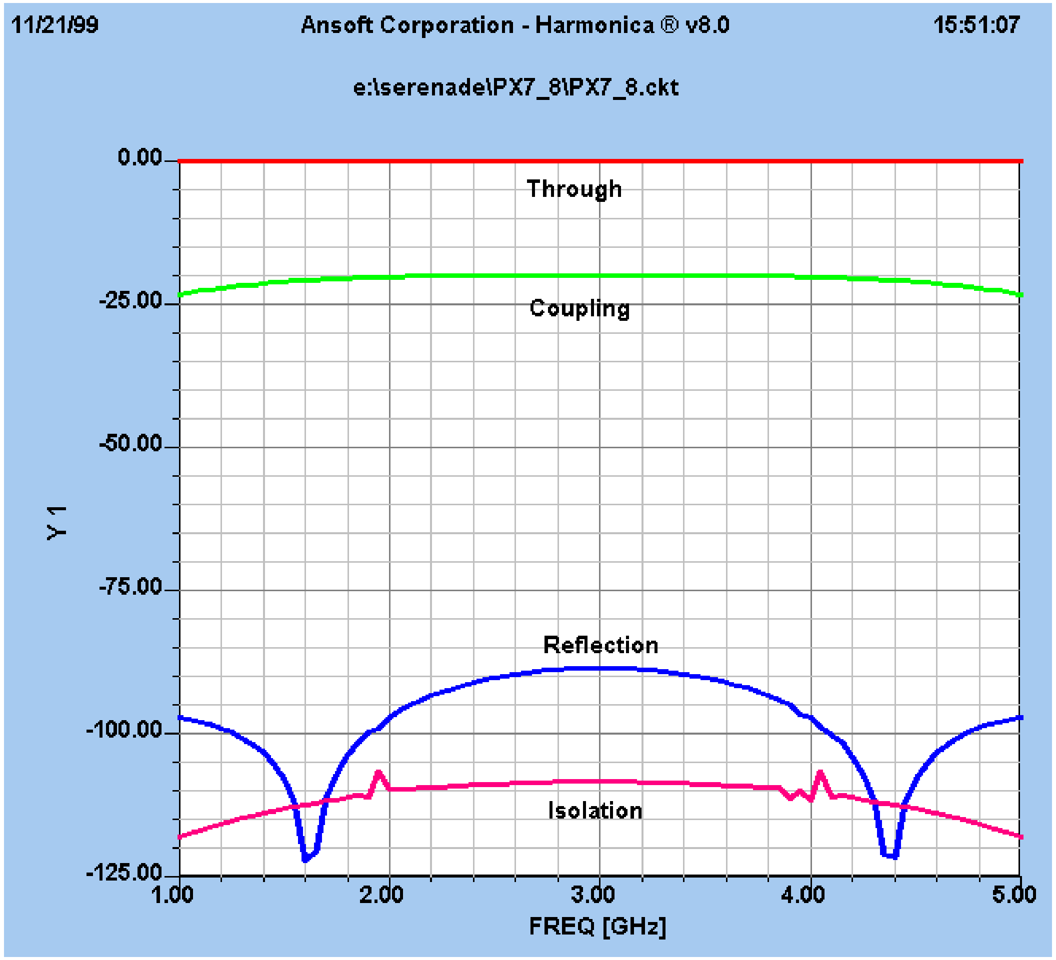
$$Z_{0e}^1 = Z_{0e}^3 = 50\sqrt{\frac{1.0125}{0.9875}} = 50.63\,\Omega$$

$$Z_{0o}^1 = Z_{0o}^3 = 50\sqrt{\frac{0.9875}{1.0125}} = 49.38\,\Omega$$

$$Z_{0e}^2 = 50\sqrt{\frac{1.125}{0.875}} = 56.69\,\Omega$$

$$Z_{0o}^2 = 50\sqrt{\frac{0.875}{1.125}} = 44.10\,\Omega$$

Simulare



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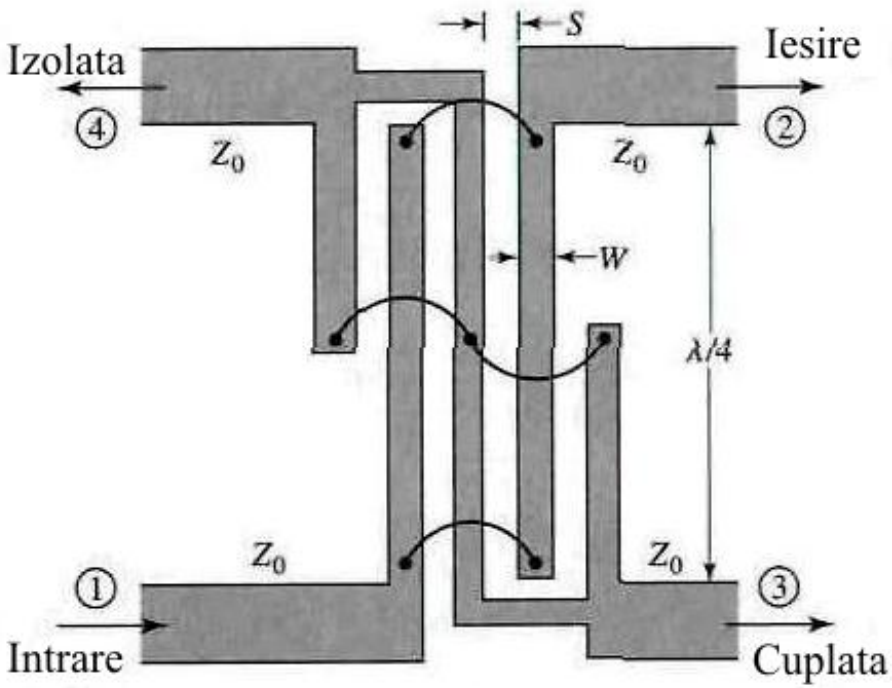
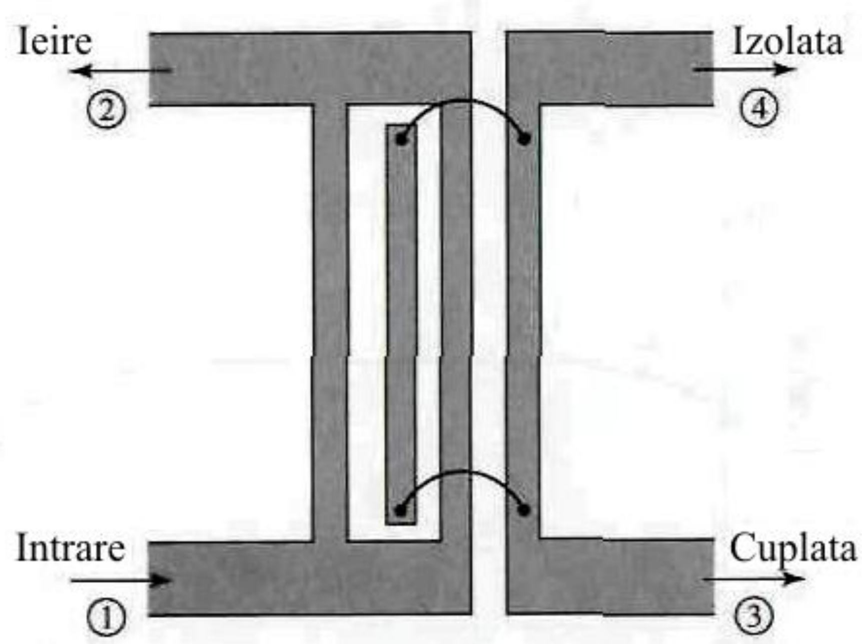
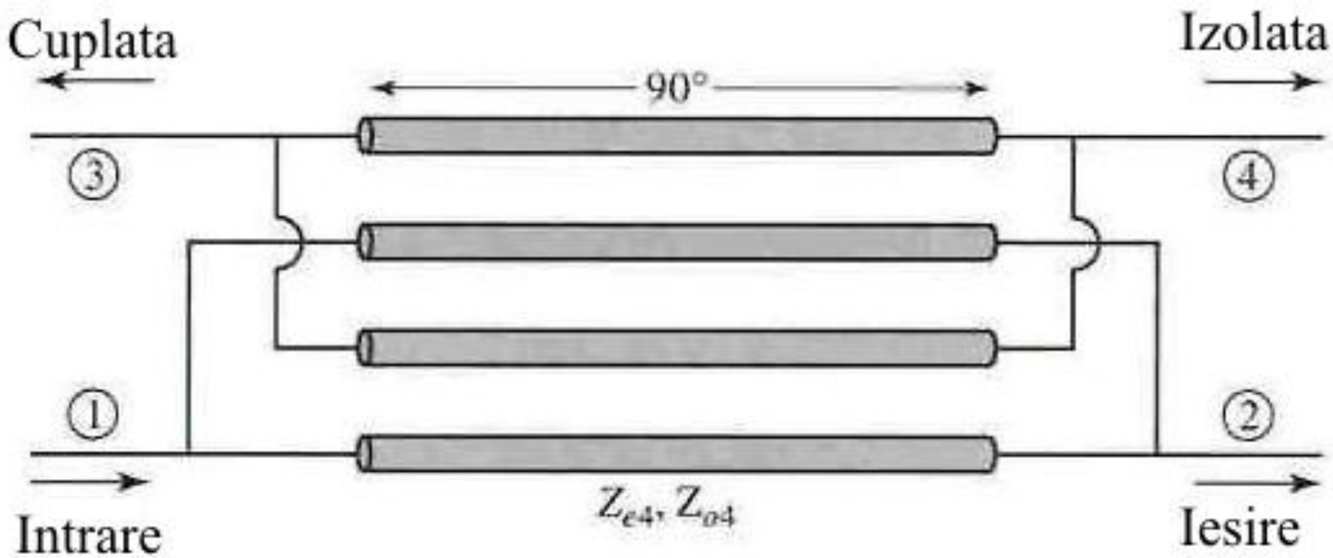
Through
Coupling
Reflection
Isolation
Y 1
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
1.00
2.00
3.00
4.00
5.00
FREQ [GHz]

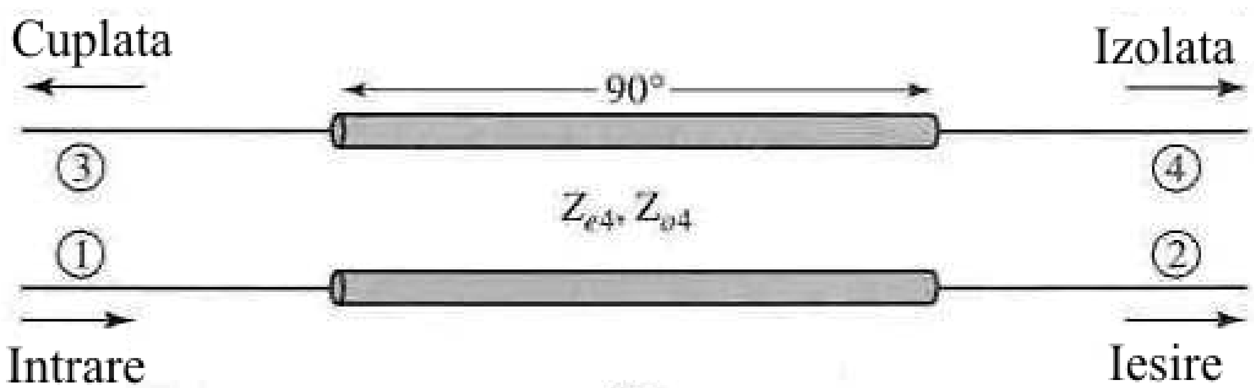
Cuplorul Lange



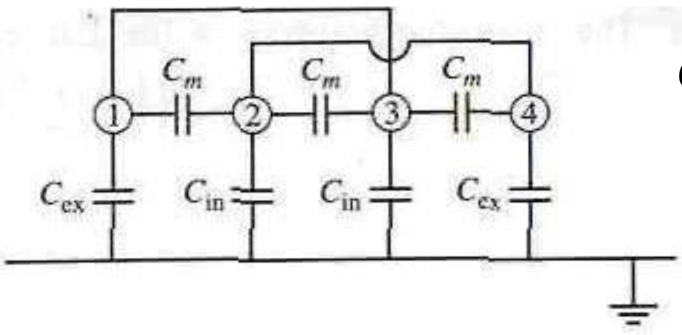


Cuplor Lange





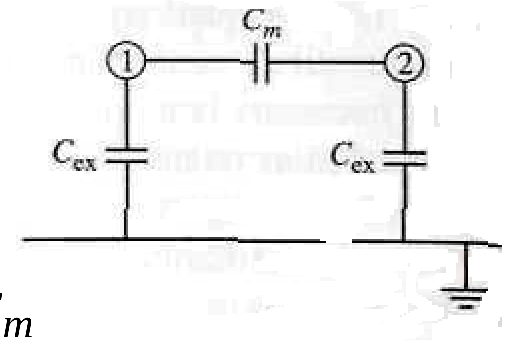
Modelul de circuit



$$C_{in} = C_{ex} - \frac{C_{ex} C_m}{C_{ex} + C_m}$$

$$C_{e4} = C_{ex} + C_{in}$$

$$C_{o4} = C_{ex} + C_{in} + 6C_m$$



$$C_e = C_{ex}$$

$$C_o = C_{ex} + 2C_m$$

$$Z_{e4} = \frac{1}{vC_{e4}}$$

$$Z_{o4} = \frac{1}{vC_{o4}}$$

$$C_{e4} = \frac{C_e(3C_e + C_o)}{C_e + C_o}$$

$$C_{o4} = \frac{C_o(3C_o + C_e)}{C_e + C_o}$$

$$Z_{e4} = Z_{0e}\frac{Z_{0e} + Z_{0o}}{3Z_{0o} + Z_{0e}}$$

$$Z_{o4} = Z_{0o}\frac{Z_{0e} + Z_{0o}}{3Z_{0e} + Z_{0o}}$$

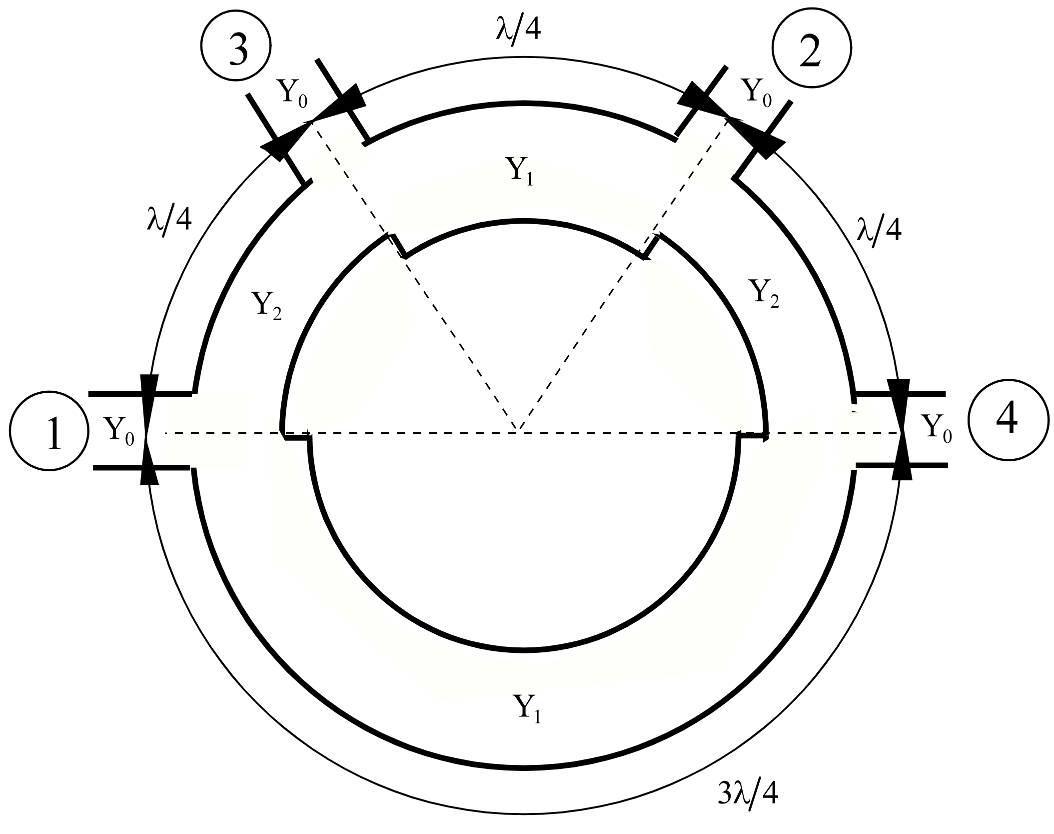
$$Z_0 = \sqrt{Z_{e4} Z_{o4}} = \sqrt{\frac{Z_{0e} Z_{0o} (Z_{0o} + Z_{0e})^2}{(3Z_{0o} + Z_{0e})(3Z_{0e} + Z_{0o})}}$$

$$C = \frac{Z_{e4} - Z_{o4}}{Z_{e4} + Z_{o4}} = \frac{3(Z_{0e}^2 - Z_{0o}^2)}{3(Z_{0e}^2 + Z_{0o}^2) + 2Z_{0e} Z_{0o}}$$

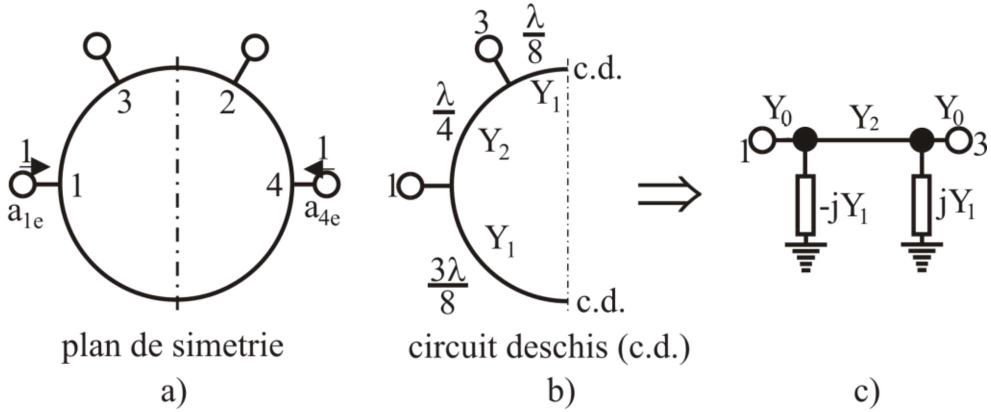
$$Z_{0e} = \frac{4C - 3 + \sqrt{9 - 8C^2}}{2C\sqrt{(1-C)/(1+C)}} Z_0$$

$$Z_{0o} = \frac{4C + 3 - \sqrt{9 - 8C^2}}{2C\sqrt{(1+C)/(1-C)}} Z_0$$

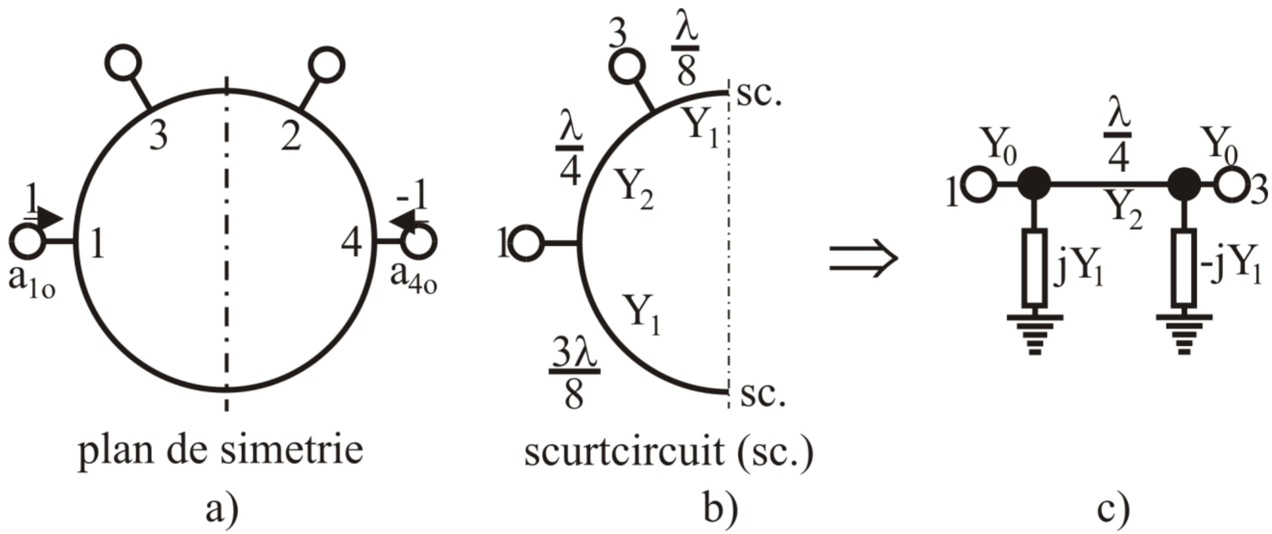
Cuplorul in inel



Analiza cuplorului in inel



Modul par

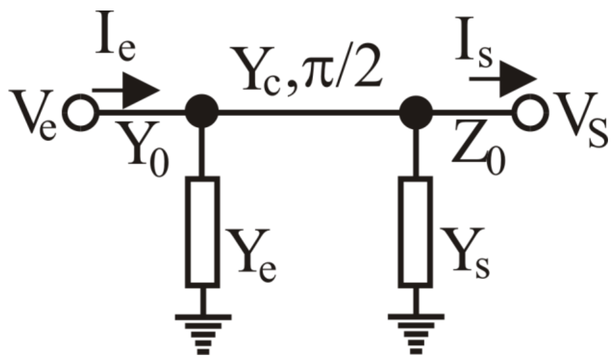


Modul impar

Analiza cuplorului in inel

$$S_{11}=\frac{jz_2y_s+jz_2-j\left(y_2+y_ey_sz_2\right)-jy_ez_2}{jz_2y_s+jz_2+j\left(y_2+y_ey_sz_2\right)+jy_ez_2}$$

$$S_{12}=\frac{2}{jz_2y_s+jz_2+j\left(y_2+y_ey_sz_2\right)+jy_ez_2}$$



$$S_{21}=\frac{2}{jz_2y_s+jz_2+j\left(y_2+y_ey_sz_2\right)+jy_ez_2}$$

$$S_{22}=\frac{-jz_2y_s+jz_2-j\left(y_2+y_ey_sz_2\right)+jy_ez_2}{jz_2y_s+jz_2+j\left(y_2+y_ey_sz_2\right)+jy_ez_2}$$

Pentru modul par:

$$y_e=-jy_1$$
$$y_s=jy_1$$

$$S_{11e}=\frac{z_2-y_2-y_1^2z_2+2jz_2y_1}{z_2+y_2+y_1^2z_2}$$

$$S_{12e}=S_{21e}=\frac{-2j}{z_2+y_2+y_1^2z_2}$$

$$S_{22e}=\frac{z_2-y_2-y_1^2z_2-2jz_2y_1}{z_2+y_2+y_1^2z_2}$$

Conditia de adaptare

$$y_1^2+y_2^2=1$$

$$[S]=\begin{bmatrix}0 & 0 & -jy_2 & jy_1\\ 0 & 0 & -jy_1 & -jy_2\\ -jy_2 & -jy_1 & 0 & 0\\ jy_1 & -jy_2 & 0 & 0\end{bmatrix}$$

Pe modul impar:

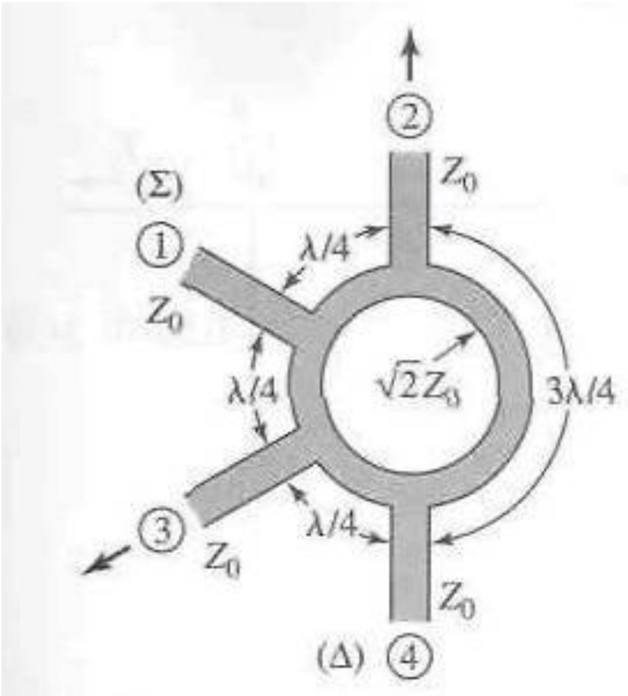
$$y_e=jy_1$$
$$y_s=-jy_1$$

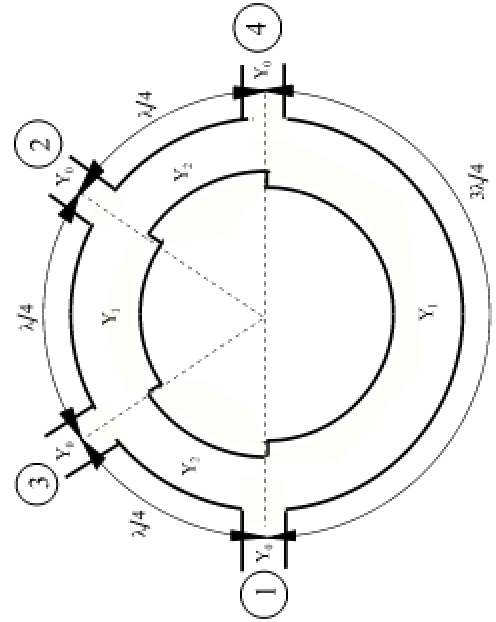
$$S_{11o}=\frac{z_2-y_2-y_1^2z_2-2jz_2y_1}{z_2+y_2+y_1^2z_2}$$

$$S_{12o}=S_{21o}=\frac{-2j}{z_2+y_2+y_1^2z_2}$$

$$S_{22o}=\frac{z_2-y_2-y_1^2z_2+2jz_2y_1}{z_2+y_2+y_1^2z_2}$$

Cuplorul in inel





$$[S]=\begin{bmatrix}0 & -jy_2 & -jy_1 & 0\\ -jy_2 & 0 & 0 & jy_1\\ -jy_1 & 0 & 0 & -jy_2\\ 0 & jy_1 & -jy_2 & 0\end{bmatrix}=-j\begin{bmatrix}0 & \alpha & \beta & 0\\ \alpha & 0 & 0 & -\beta\\ \beta & 0 & 0 & \alpha\\ 0 & -\beta & \alpha & 0\end{bmatrix}$$

$$C(dB)=-20\log(\beta)=-20\log(y_1)$$

Proiectarea şi performanţa unui cuplor în inel

Proiectaţi un cuplor în inel de 3dB şi reprezentati mărimea parametrilor S între 0.5 si 1.5 din frecventa centrala.

$$\sqrt{2}Z_0 = 70.7\Omega$$