Einführung in die Hochfrequenztechnik - Vorlesung 8

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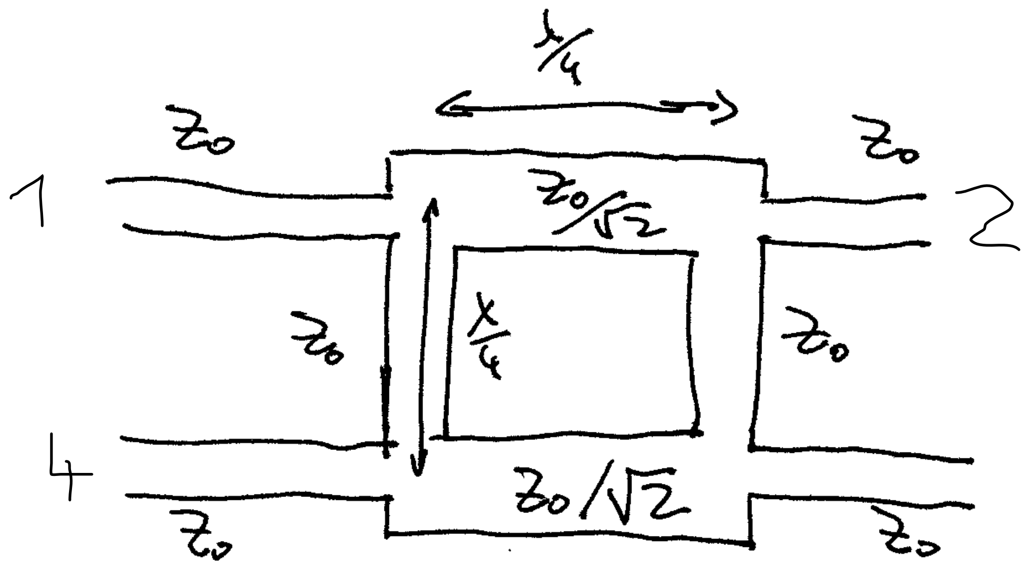
Branch-Line-Koppler



S-Matrix des Branch-Line Kopplers

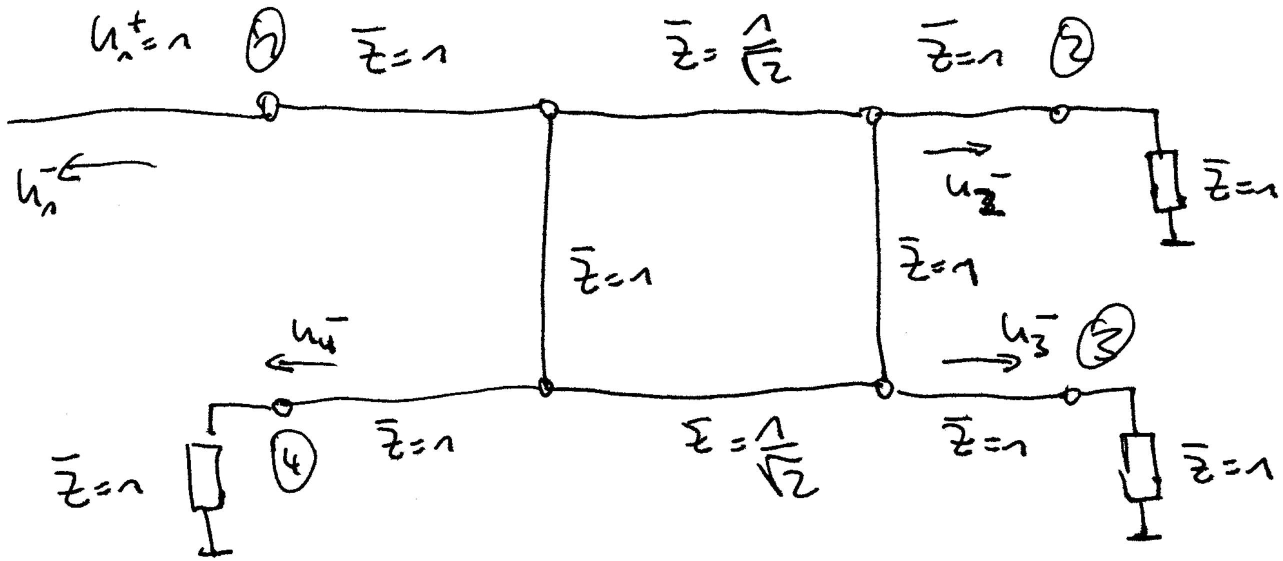
- $[S] = \frac{-1}{\sqrt{2}} \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix}$

- symmetrischer Koppler, alle Tore können als Eingang verwendet werden

- reziprok

- angepasst, verlustlos

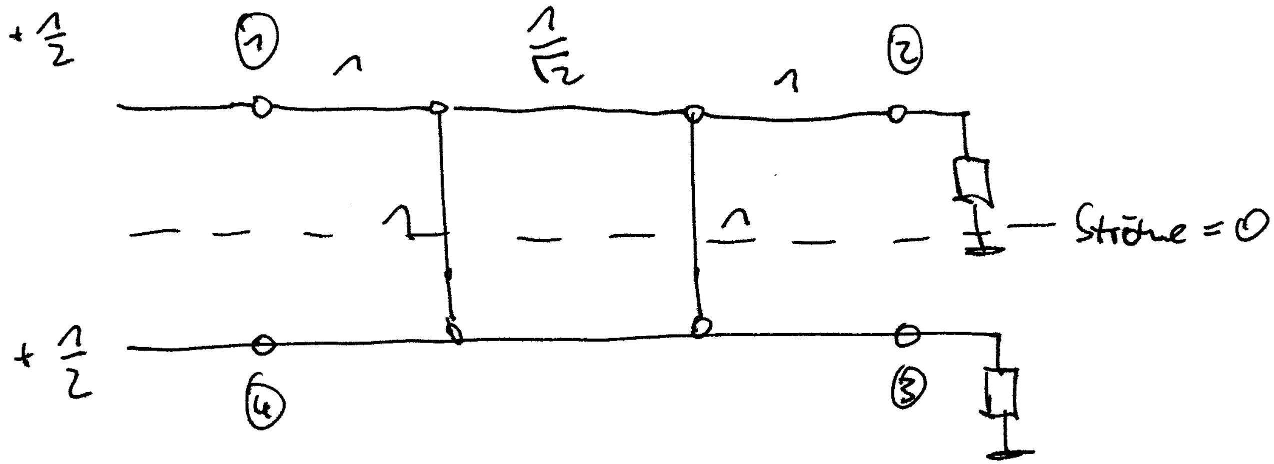
Normiertes ESB des Branch-Line Kopplers



Even / Odd Mode Analyse

- Anregung der Schaltung mit geradem und ungeradem Fall
- die Schaltung ist Linear, das Superpositionsprizip kann angewendet werden
- Überlagerung des geraden und ungeraden Falls gibt die gleiche Anregung wie im normierten ESB
- Verhalten der Schaltung kann durch Superposition des geraden und ungeraden Falls berechnet werden

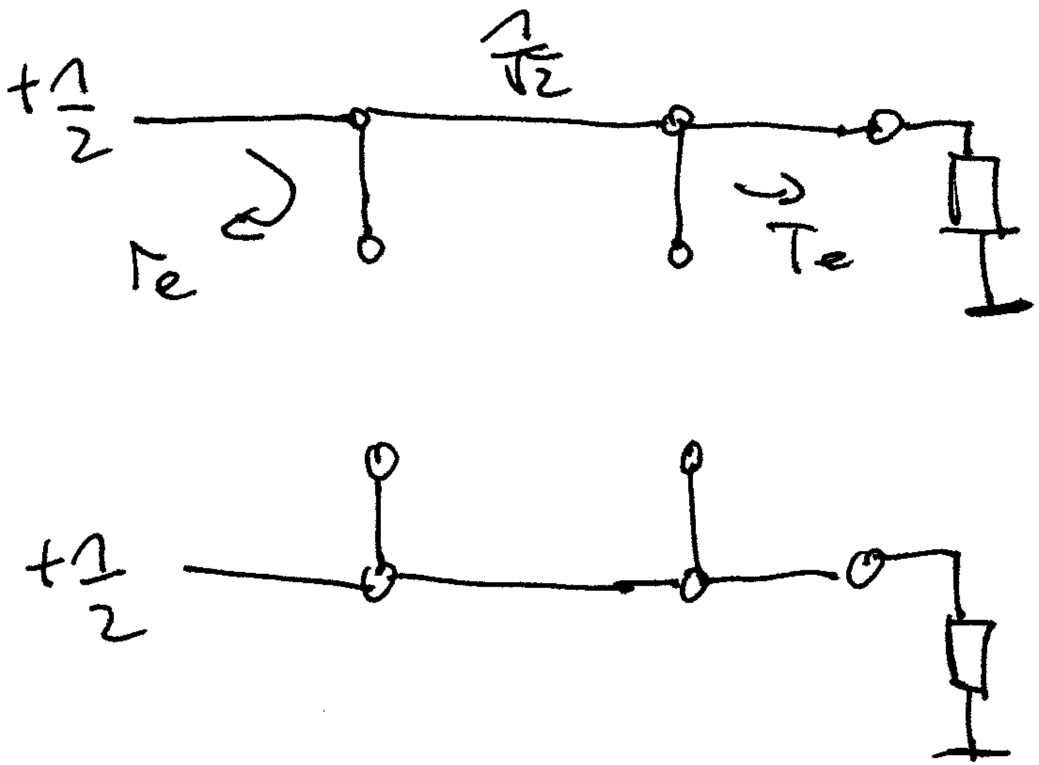
gerade Anregung des BL-Kopplers



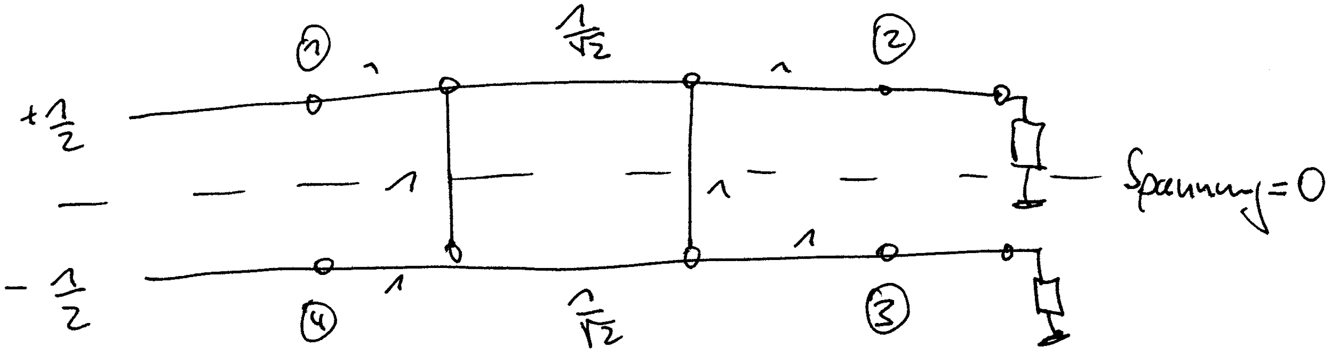
Zerlegung des ESB bei gerader Anregung

- die Ströme in der Symmetrieebene sind bei gerader Anregung null
- die Schaltung kann an der Symmetrieebene aufgetrennt werden
- die getrennten Leitungen werden mit einem Leerlauf abgeschlossen

Trennung des ESB bei gerader Anregung des BL-Kopplers



ungerade Anregung des BL-Kopplers



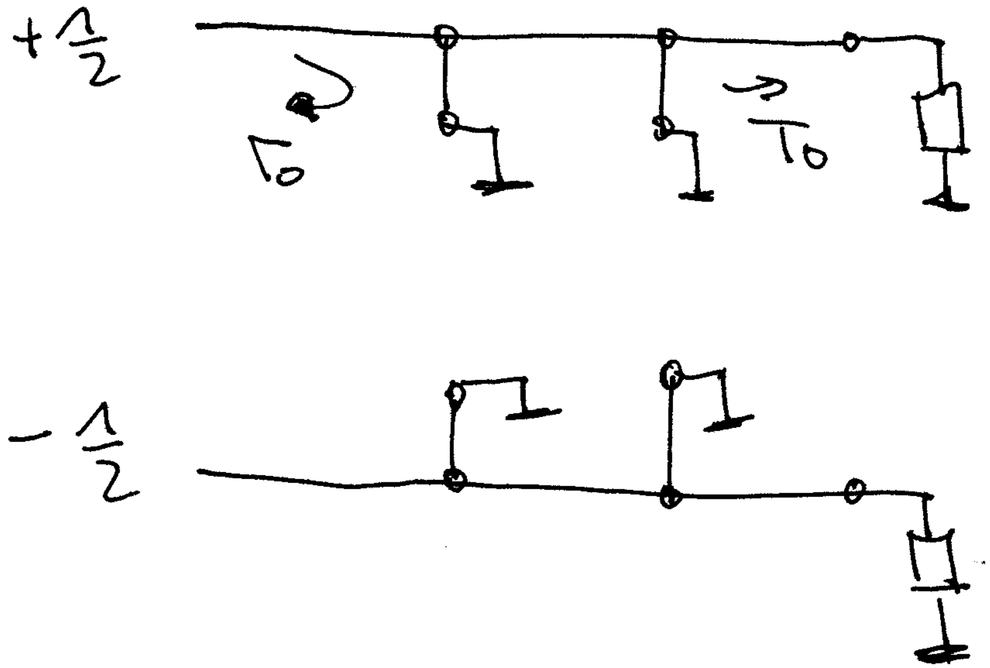
Zerlegung des ESB bei ungerader Anregung

- die Spannungen in der Symmetrieebene sind bei ungerader Anregung null

- die Schaltung kann an der Symmetrieebene aufgetrennt werden

- die getrennten Leitungen werden an Masse angeschlossen

Trennung des ESB bei ungerader Anregung des BL-Kopplers



An den Toren ausfallende Wellen

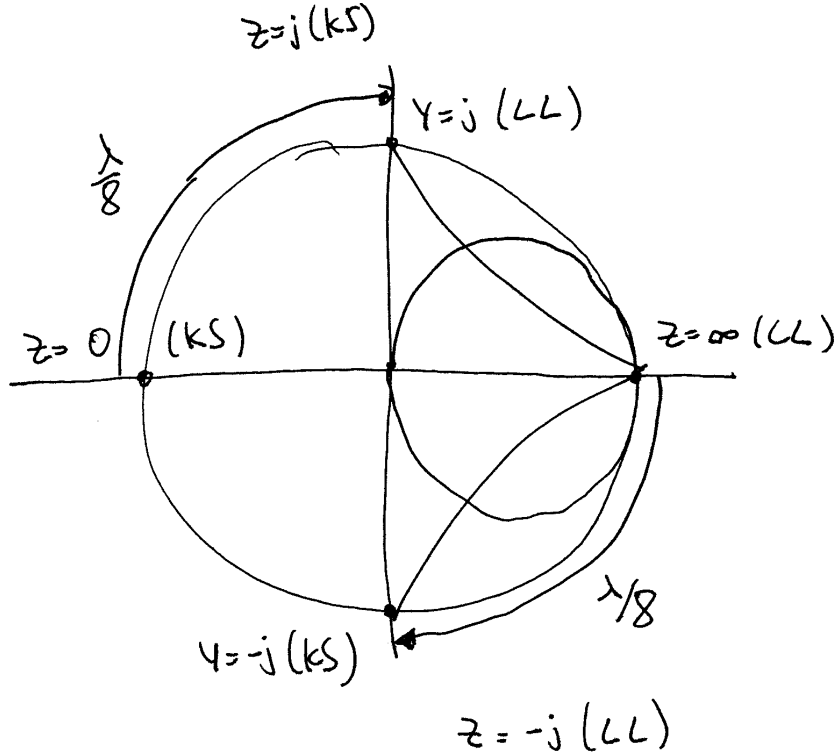
- $U_1^- = \frac{1}{2}\Gamma_e + \frac{1}{2}\Gamma_o$
- $U_2^- = \frac{1}{2}T_e + \frac{1}{2}T_o$
- $U_3^- = \frac{1}{2}T_e - \frac{1}{2}T_o$
- $U_4^- = \frac{1}{2}\Gamma_e - \frac{1}{2}\Gamma_o$

Verwendung der ABCD Matrix zur Berechnung von $\Gamma_{e/o}$ und $T_{e/o}$

- $\begin{bmatrix} U_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} U_2 \\ I_2 \end{bmatrix}$

- $\lambda/8$ Stichleitung
  $\begin{bmatrix} U_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix} \begin{bmatrix} U_2 \\ I_2 \end{bmatrix}$

Admittanz Matrix einer $\lambda/8$ Stichleitung



ABCD Matrix eines $\lambda/4$ langen Leitungsabschnittes

- $\begin{bmatrix} U_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} \cos(\beta l) & jZ_0 \sin(\beta l) \\ jY_0 \sin(\beta l) & \cos(\beta l) \end{bmatrix} \begin{bmatrix} U_2 \\ I_2 \end{bmatrix}$

- $\beta l = \frac{2\pi}{\lambda}\frac{\lambda}{4} = \frac{\pi}{2}$

- $\sin(\beta l) = 1$
  $\cos(\beta l) = 0$

- $\begin{bmatrix} U_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} 0 & j\frac{1}{\sqrt{2}}Z_0 \\ j\sqrt{2}Y_0 & 0 \end{bmatrix} \begin{bmatrix} U_2 \\ I_2 \end{bmatrix}$

ABCD Matrix gerade

- $$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ jY_0 & 1 \end{bmatrix} \begin{bmatrix} 0 & j/\sqrt{2}Z_0 \\ j\sqrt{2}Y_0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ jY_0 & 1 \end{bmatrix}$$

- $$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ jY_0 & 1 \end{bmatrix} \begin{bmatrix} -1/\sqrt{2} & j/\sqrt{2}Z_0 \\ j\sqrt{2}Y_0 & 0 \end{bmatrix} =$$
$$\begin{bmatrix} -1/\sqrt{2} & j/\sqrt{2}Z_0 \\ -j/\sqrt{2}Y_0 + j\sqrt{2}Y_0 & -1/\sqrt{2} \end{bmatrix}$$

- $$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} -1 & jZ_0 \\ jY_0 & -1 \end{bmatrix}$$

Konversion ABCD- auf S-Matrix

- $S_{11} = \frac{A+B/Z_0-CZ_0-D}{A+B/Z_0+CZ_0+D}$

- $S_{11} = \frac{-1+j-j-(-1)}{''} = \Gamma_e = 0$

- $S_{21} = \frac{2(AD-BC)}{A+B/Z_0+CZ_0+D} = \frac{2\frac{1}{2}(1+1)}{\frac{1}{\sqrt{2}}(-1+j+j-1)}$

- $S_{21} = \frac{2\sqrt{2}}{2(-1+j)} = \frac{\sqrt{2}(-1-j)}{(-1+j)(-1-j)} = \frac{-(1+j)}{\sqrt{2}} = T_e$

Analoge Analyse ungerade Anregung

- $\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -jY_0 & 1 \end{bmatrix} \begin{bmatrix} 0 & j/\sqrt{2}Z_0 \\ j\sqrt{2}Y_0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -jY_0 & 1 \end{bmatrix}$

- $\Gamma_o = 0$

- $T_o = \frac{1-j}{\sqrt{2}}$

An den Toren ausfallende Wellen

- $U_1^- = \frac{1}{2}\Gamma_e + \frac{1}{2}\Gamma_o = 0$

- $U_2^- = \frac{1}{2}T_e + \frac{1}{2}T_o = \frac{1}{2}\frac{-(1+j)}{\sqrt{2}} + \frac{1}{2}\frac{(1-j)}{\sqrt{2}} = \frac{-1-j+1-j}{2\sqrt{2}} = \frac{-j}{\sqrt{2}}$

- $U_3^- = \frac{1}{2}T_e - \frac{1}{2}T_o = \frac{1}{2}\frac{-(1+j)}{\sqrt{2}} - \frac{1}{2}\frac{(1-j)}{\sqrt{2}} = \frac{-1-j-1+j}{2\sqrt{2}} = \frac{-1}{\sqrt{2}}$

- $U_4^- = \frac{1}{2}\Gamma_e - \frac{1}{2}\Gamma_o = 0$

1. Spalte der S-Matrix

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

- Reziprozität, Anpassung

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

- Die restlichen Elemente können ohne weitere Berechnung aus den Symmetrieeigenschaften bestimmt werden.

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

RF-Phase Shifters

1. Introduction

- RF phase shifters are two port devices which allow to control the phase of the signal transmitted.
- Phase shifters can be classified by how they change the phase of the transmitted signal.
- If the phase change can be varied continuously the term analog phase shifter is used, whereas a digital phase shifter can only produce step changes in transmitted signal phase.

2. Applications

- RF phase shifters are used in a variety of communications equipment.
- Most important application is in microwave phased array antennas which have gained much popularity because of their superior capabilities and ease of implementation in microstrip and other planar technologies.
- Due to the large number of array elements employed in these antennas a large demand for small, low-loss, cheap phase shifters has been created.
- For the application in modern communication systems the electronically controlled digital phase shifter is most important at the moment because of its good properties which meet the requirements of many applications.

3. Requirements on phase shifters:

- low insertion loss
- low return loss
- high phase accuracy
- large bandwidth
- high switching speed in digital or fast response to control signal in analog phase shifters
- small size
- low cost
- integrability in planar circuitry (ideally totally planar construction)

4 PIN diode phase shifters

PIN diode phase shifters have been the first electronically controlled phase shifters.

There are three basic types: switched line, loaded line and reflection

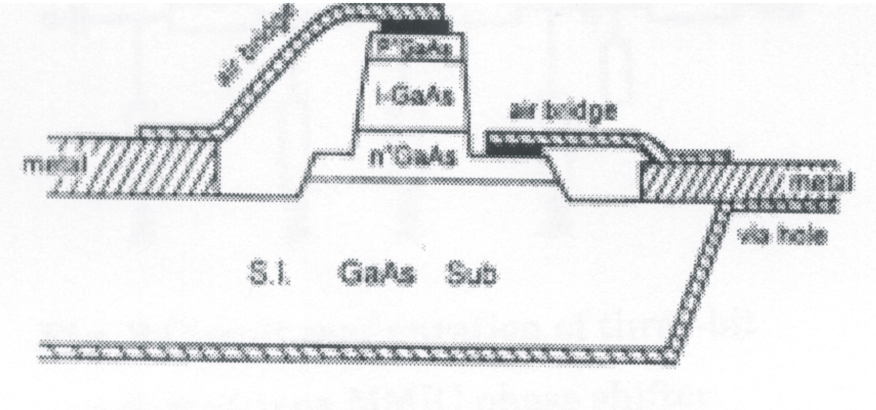
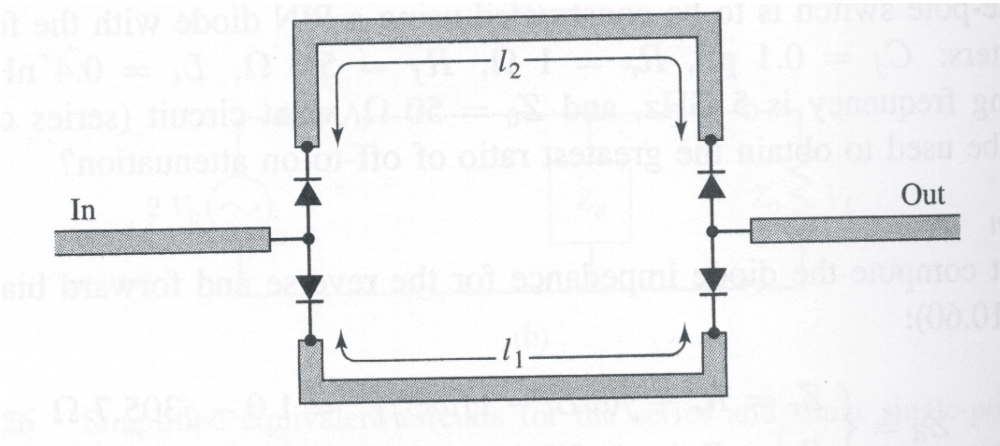


Figure 4 Vertical PIN diode

5 Switched line phase shifters

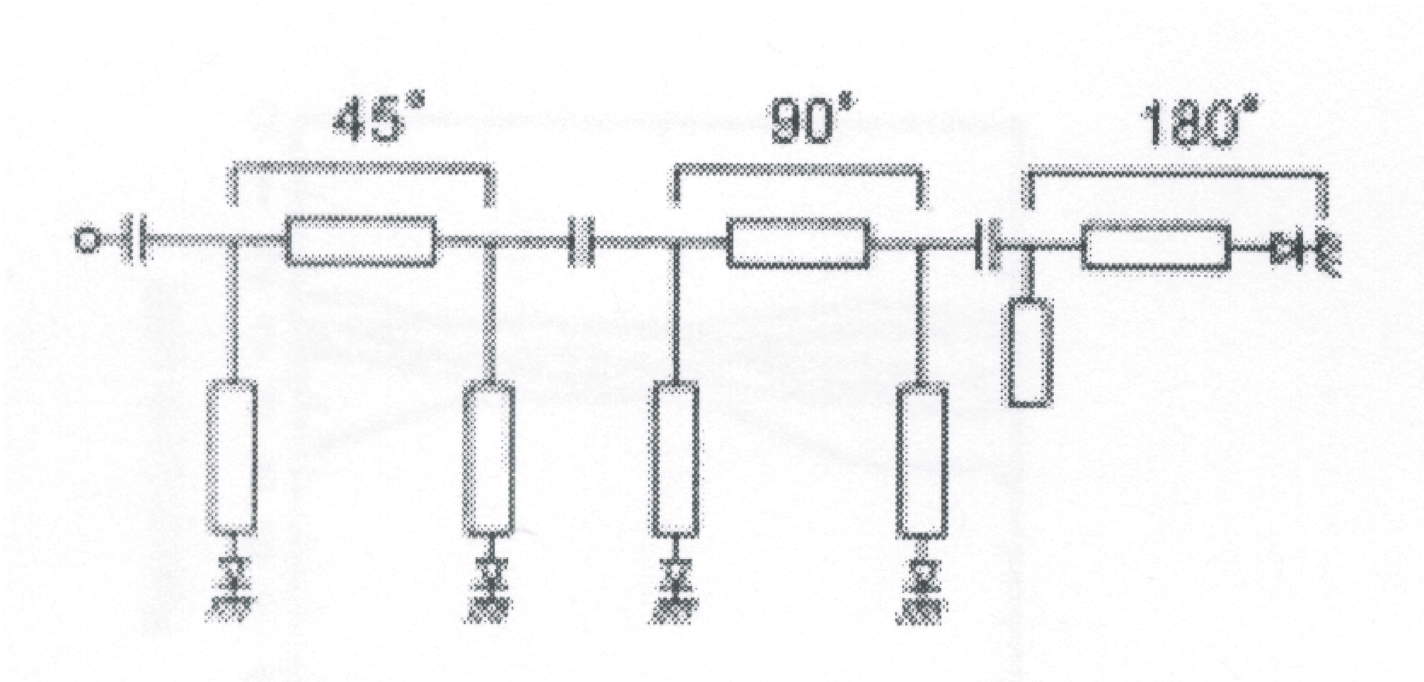
- Switched line phase shifters use PIN diodes to guide the input signal through paths of different length creating a predefined fixed change in the phase of the transmitted signal.
- In order to allow for an adjustable range from 0 to 360 degrees several simple phase shifter elements must be cascaded.
- 4 and 5 bit configurations are most commonly used at the moment



switched line phase shifter

5 Loaded line phase shifters

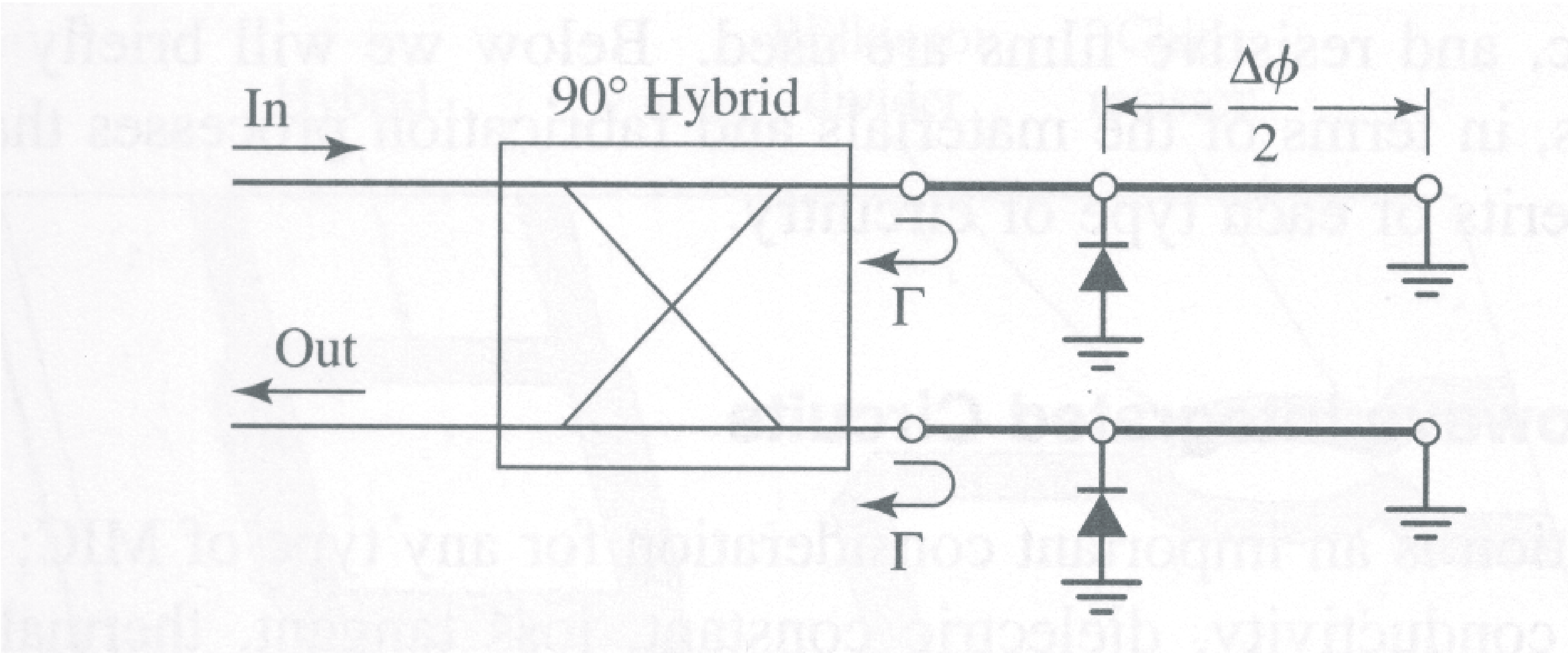
- use a shunt susceptance to produce a phase shift of the output signal
- Only small amounts of phase shift (up to 45 degrees) can be produced with one phase shifting element.
- large reflection loss is produced by the shunt susceptance.
- By connecting two shunt susceptances a quarter wavelength apart their reflection will be 180 degrees out of phase and therefore cancel out.
- Still the match will only be good for the design frequency resulting in a narrowband device.
- If simplicity of the circuit has high priority and the amount of phase shift required is rather low the loaded line phase shifter can be a good choice especially when combined with other phase bit configurations for the larger phase bits.



Phase shifter using two loaded line and one reflection phase bit

6. Reflection phase shifters

- PIN diodes are used to short the output lines of a quadrature hybrid.
- The phase of the output wave can therefore be switched by twice the electrical length between the shorts terminating the output lines and the position of the diodes.
- The whole device can be produced in planar technology but is somewhat more complex than other configurations.
- A good diode match is required for low reflection loss.



Reflection phase shifter

- Analog configurations are also possible using varactors instead of PIN diodes as bias controllable tuning devices.
- The reflection type phase shifter has superior abilities compared to the other two configurations.