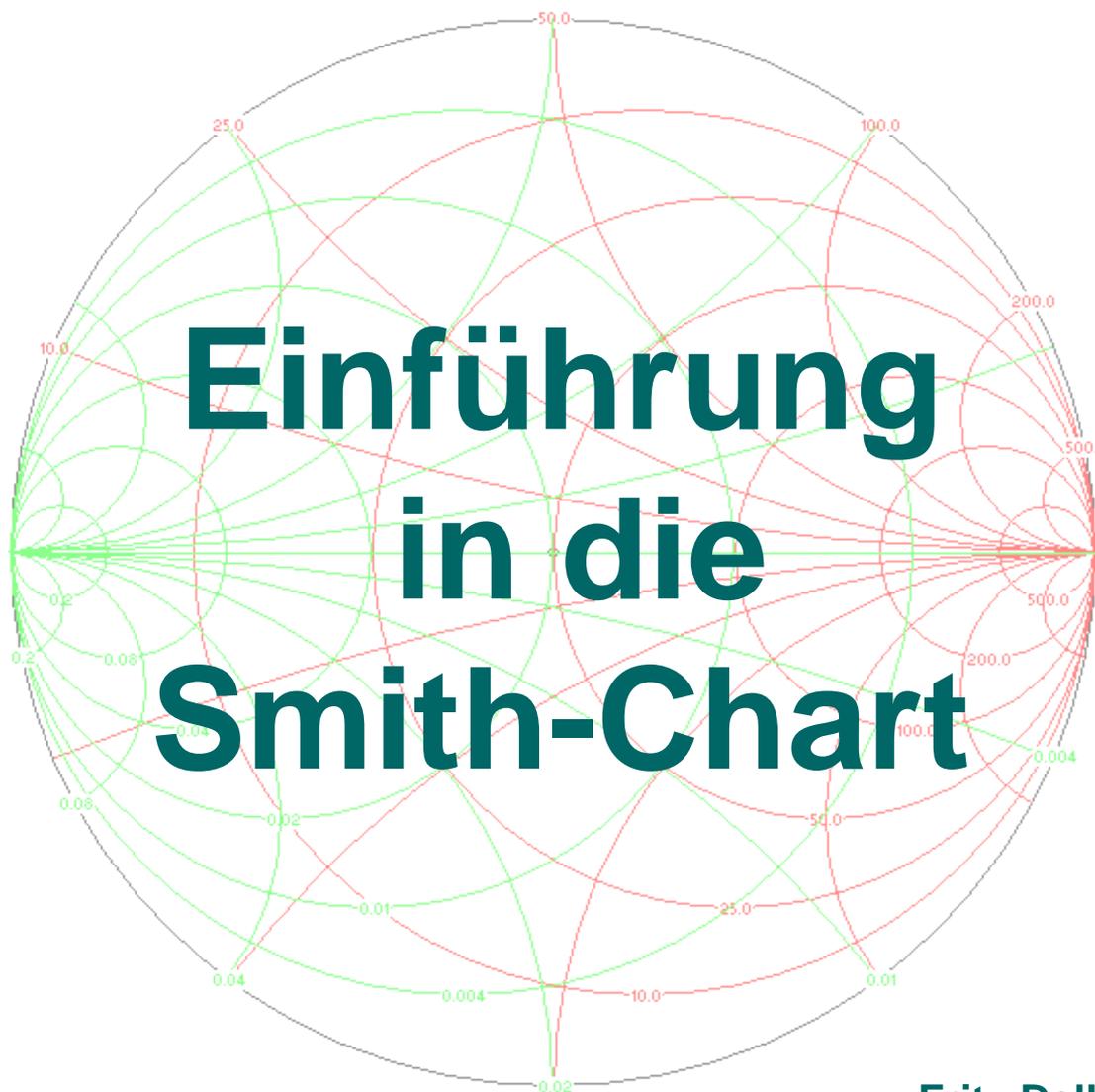


USKA HB9F 26.10.2022



Fritz Dellsperger HB9AJY

USKA HB9F 26.10.2022

Agenda:

- **Motivation und Geschichte**
- **Grundlagen**
- **Konstruktion der Smith-Chart**
- **Anwendung der SC**
- **Die Software «Smith V4.1»**
 - **Bsp 1: Transistor Eingangsanpassung**
 - **Bsp 2: Antennenanpassung für 12m und 17m**
- **Fragen**



1939 – 1944:

- ❖ Graphisches Hilfsmittel zur **Darstellung und Berechnung** komplexer Widerstände (Impedanzen) im Zusammenhang mit Leitungen und Anpassschaltungen



Phillip Hagar Smith, 29.4.1905 – 29.8.1987, Bell Telephone Laboratories Inc.

Electronics, Jan. 1939: Transmission Line Calculator

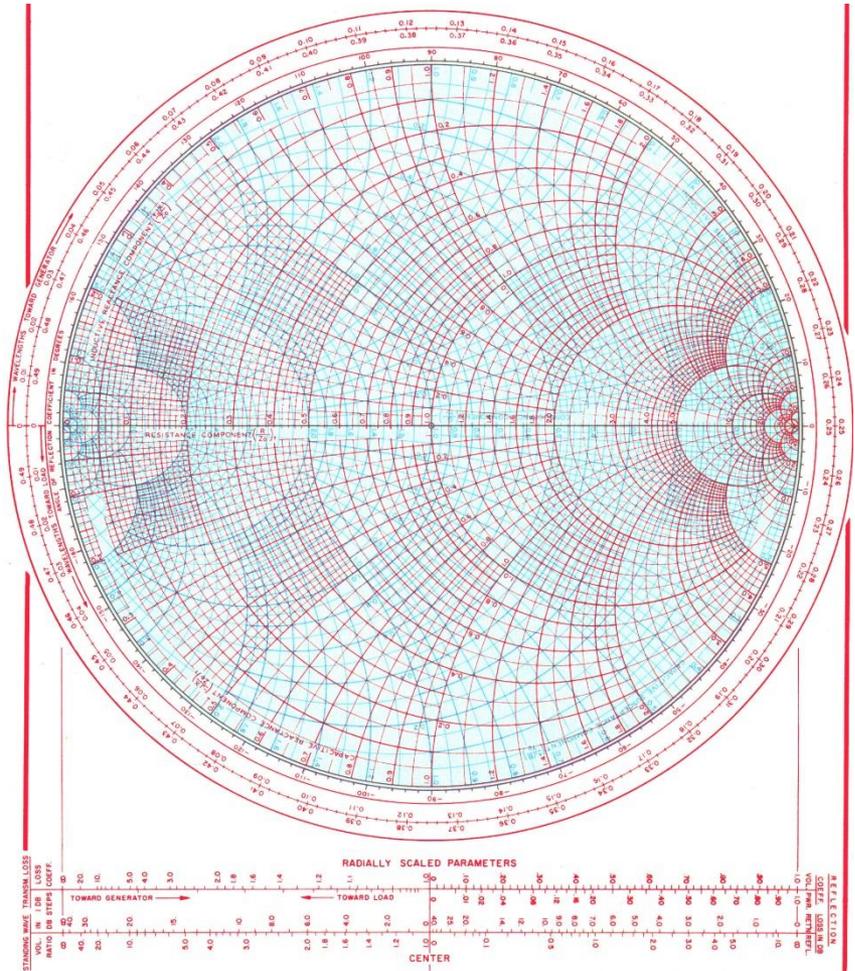
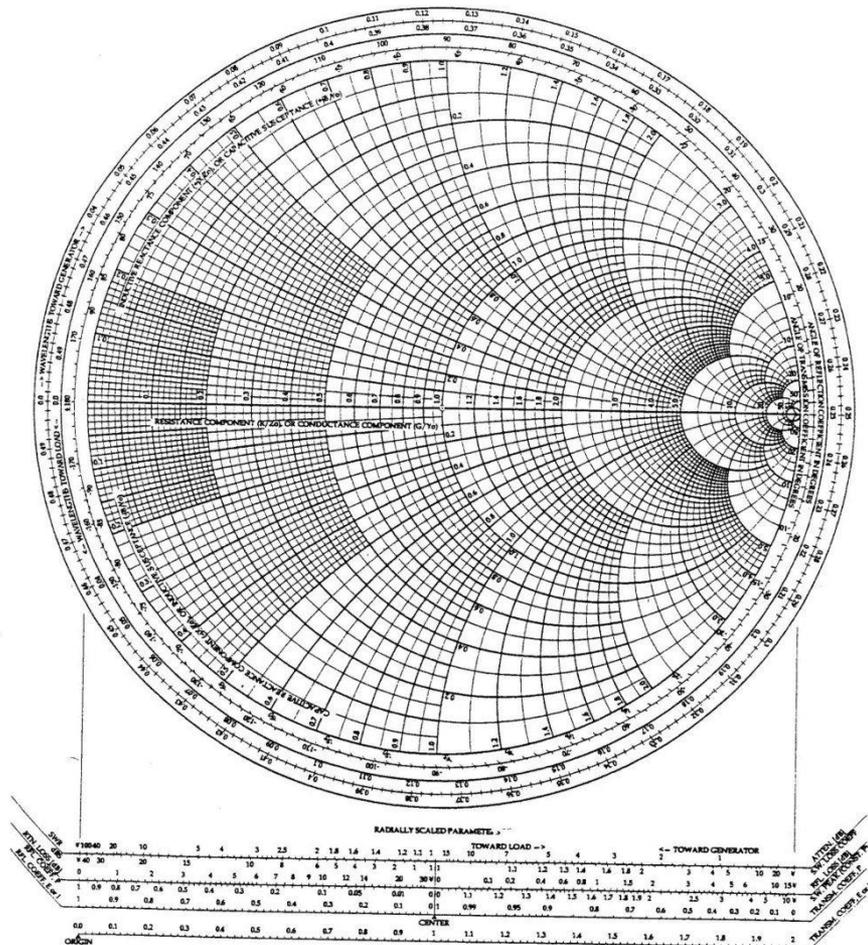
Electronics, Jan. 1944: An Improved Transmission Line Calculator

1944 – 1990:

1944 – 1972: Paperwork, Tabellen von Winkel- und Exponentialfunktionen und Rechenschieber

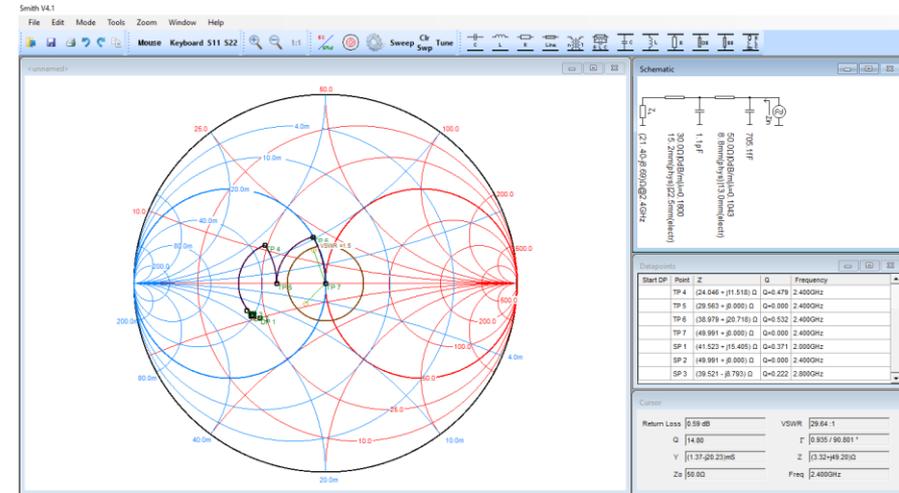
1972 – 1990: Paperwork und Taschenrechner (HP-35)

The Smith Chart



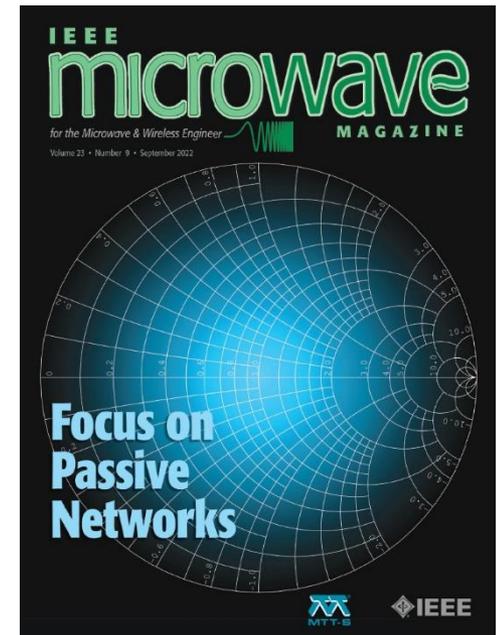
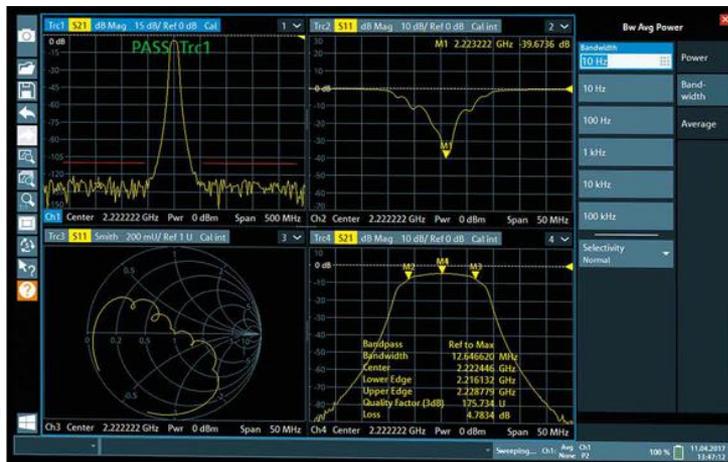
Heute (2022):

- Alle Berechnungen durch Computer
- Darstellung und Visualisierung auf Smith Chart



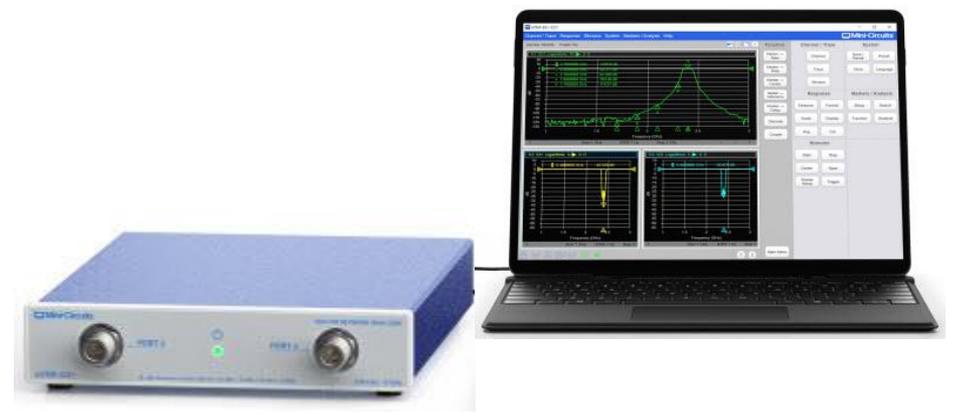
Smith Chart zur Visualisierung ist **unverzichtbar** in

- Messtechnik: VNA's (Vector Network Analyzer)
- Programmen für Schaltungs-Analyse und –Synthese (ADS (Keysight), Microwave Office (National Instruments), Ansoft Designer, QUCS)



Heute (2022):

- Messtechnik: VNA's (Vector Network Analyzer)



Reflexionsfaktor



$\underline{\Gamma}$: Komplexer Reflexionsfaktor = $|\Gamma| \angle \theta$ $\underline{\Gamma} = \frac{|u_r|}{|u_h|}$

Weitere (skalare) Grössen zur Angabe der Reflexion:

Stehwellenverhältnis: $VSWR = \frac{|u_{\max}|}{|u_{\min}|}$

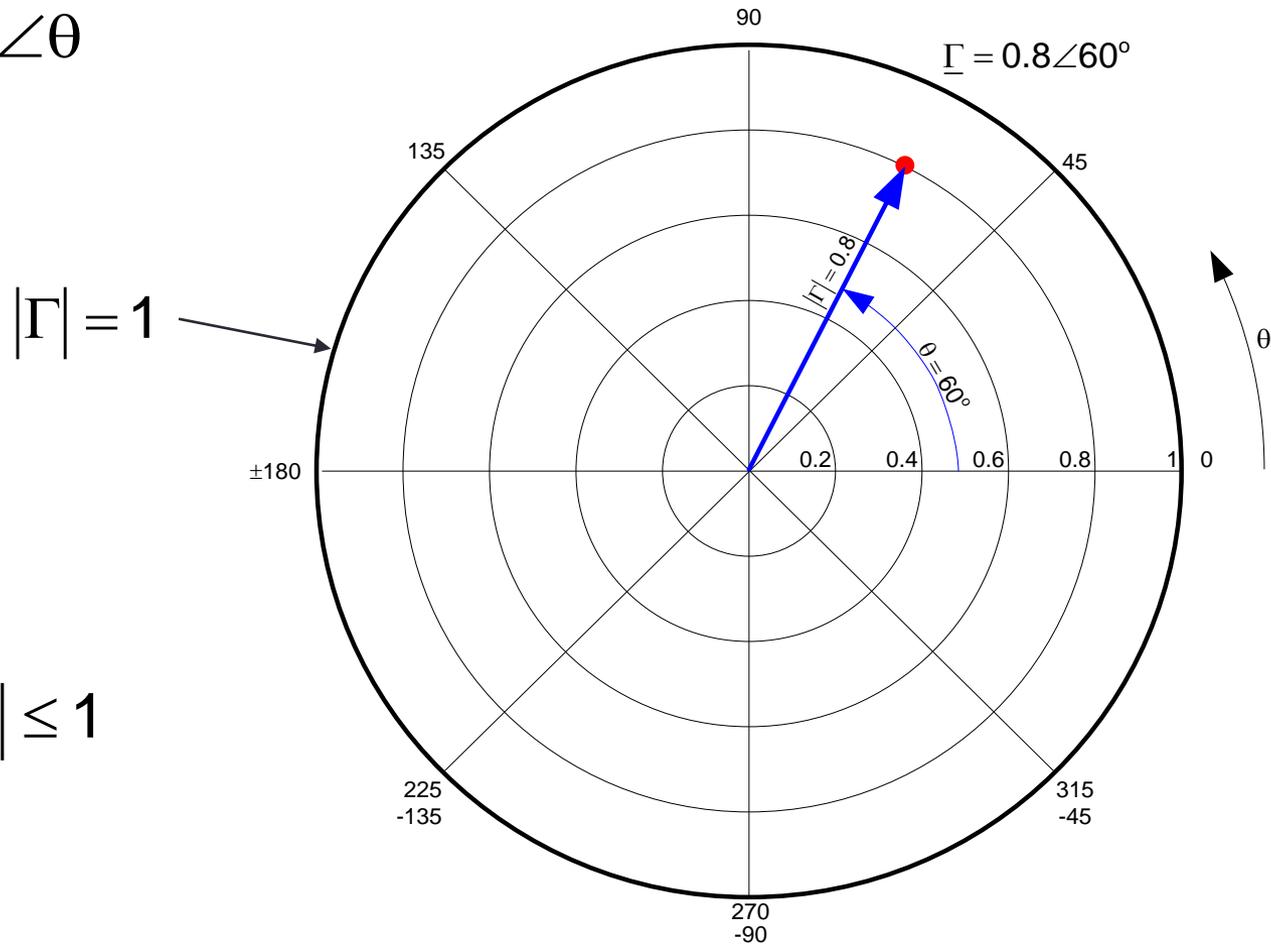
Rückflussdämpfung: Returnloss = RL = $10 \cdot \log \frac{P_h}{P_r}$ dB

Reflexionsfaktor

Darstellung des Reflexionsfaktor im Polar Diagramm:

$$\underline{\Gamma} = \frac{\underline{u}_r}{\underline{u}_h} = |\Gamma| \angle \theta$$

$$0 \leq |\Gamma| \leq 1$$



Zusammenhänge der verschiedenen Reflexionsgrößen

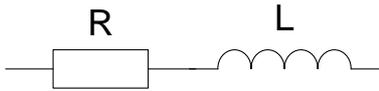
$$\underline{\Gamma} = \frac{\bar{u}_r}{\bar{u}_h} = -\frac{\bar{i}_r}{\bar{i}_h} = \frac{\underline{Z} - Z_o}{\underline{Z} + Z_o} = |\Gamma| \angle \theta \qquad |\underline{\Gamma}| = \frac{VSWR - 1}{VSWR + 1} = 10^{-\frac{RL}{20}} = \frac{|\underline{Z} - Z_o|}{|\underline{Z} + Z_o|}$$

$$VSWR = \frac{|u_{\max}|}{|u_{\min}|} = \frac{|i_{\max}|}{|i_{\min}|} = \frac{|\bar{u}_h + \bar{u}_r|}{|\bar{u}_h - \bar{u}_r|} = \frac{1 + |\underline{\Gamma}|}{1 - |\underline{\Gamma}|} = \frac{1 + 10^{-\frac{RL}{20}}}{1 - 10^{-\frac{RL}{20}}} = \frac{|Z_o|}{|\underline{Z}|} \Big|_{Z < Z_o} = \frac{|\underline{Z}|}{|Z_o|} \Big|_{Z > Z_o}$$

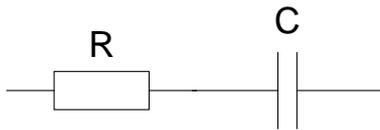
$$\text{Returnloss} = RL = 10 \cdot \log \frac{P_h}{P_r} = -20 \cdot \log |\underline{\Gamma}| = -20 \cdot \log \frac{VSWR - 1}{VSWR + 1} = -20 \cdot \log \frac{|\underline{Z} - Z_o|}{|\underline{Z} + Z_o|} \quad \text{dB}$$

Impedanz

Serieschaltung



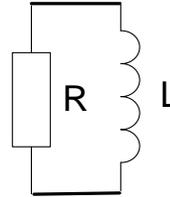
$$\underline{Z} = R + jX = R + j\omega L$$



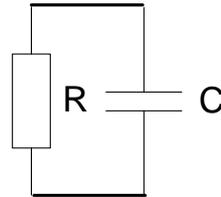
$$\underline{Z} = R - jX = R - j\frac{1}{\omega C}$$

Admittanz

Parallelschaltung



$$\underline{Y} = \frac{1}{\underline{Z}} = G - jB = \frac{1}{R} - j\frac{1}{\omega L}$$



$$\underline{Y} = \frac{1}{\underline{Z}} = G + jB = \frac{1}{R} + j\omega C$$

Expressions for Impedance and Admittance
Normalised by Impedance Z_0 or Admittance Y_0

| Element Type | Impedance (Z or z) or Reactance (X or x) | | Admittance (Y or y) or Susceptance (B or b) | |
|-----------------|--|---|---|---|
| | Real (Ω) | Normalised (No Unit) | Real (S) | Normalised (No Unit) |
| Resistance (R) | $Z = R$ | $z = \frac{R}{Z_0} = RY_0$ | $Y = G = \frac{1}{R}$ | $y = g = \frac{1}{RY_0} = \frac{Z_0}{R}$ |
| Inductance (L) | $Z = jX_L = j\omega L$ | $z = jx_L = j\frac{\omega L}{Z_0} = j\omega LY_0$ | $Y = -jB_L = \frac{-j}{\omega L}$ | $y = -jb_L = \frac{-j}{\omega LY_0} = \frac{-jZ_0}{\omega L}$ |
| Capacitance (C) | $Z = -jX_C = \frac{-j}{\omega C}$ | $z = -jx_C = \frac{-j}{\omega CZ_0} = \frac{-jY_0}{\omega C}$ | $Y = jB_C = j\omega C$ | $y = jb_C = j\frac{\omega C}{Y_0} = j\omega CZ_0$ |

Aus der Leitungstheorie:

$$\underline{\Gamma} = \frac{\underline{Z} - Z_0}{\underline{Z} + Z_0} = \frac{\frac{\underline{Z}}{Z_0} - 1}{\frac{\underline{Z}}{Z_0} + 1} \quad \text{Gl. 1}$$

$\underline{\Gamma}$: Komplexer Reflexionsfaktor = $|\Gamma| \angle \theta$

\underline{Z} : Komplexe Impedanz = $R + jX$

Z_0 : Normierungsimpedanz (normalerweise reell)

Normiertes \underline{Z} : $\underline{z} = r + jx$

$$\underline{z} = \frac{\underline{Z}}{Z_0} = \frac{R}{Z_0} + j \frac{X}{Z_0} = r + jx \quad \text{Gl. 2}$$

$$\underline{\Gamma} = \frac{\underline{z} - 1}{\underline{z} + 1} = \frac{r + jx - 1}{r + jx + 1} \quad \text{Gl. 3}$$

Nach Gl.1 muss jeder Reflexionskoeffizient auch eine komplexe Impedanz \underline{Z} , oder nach Gl.3 eine komplexe normierte Impedanz \underline{z} darstellen.



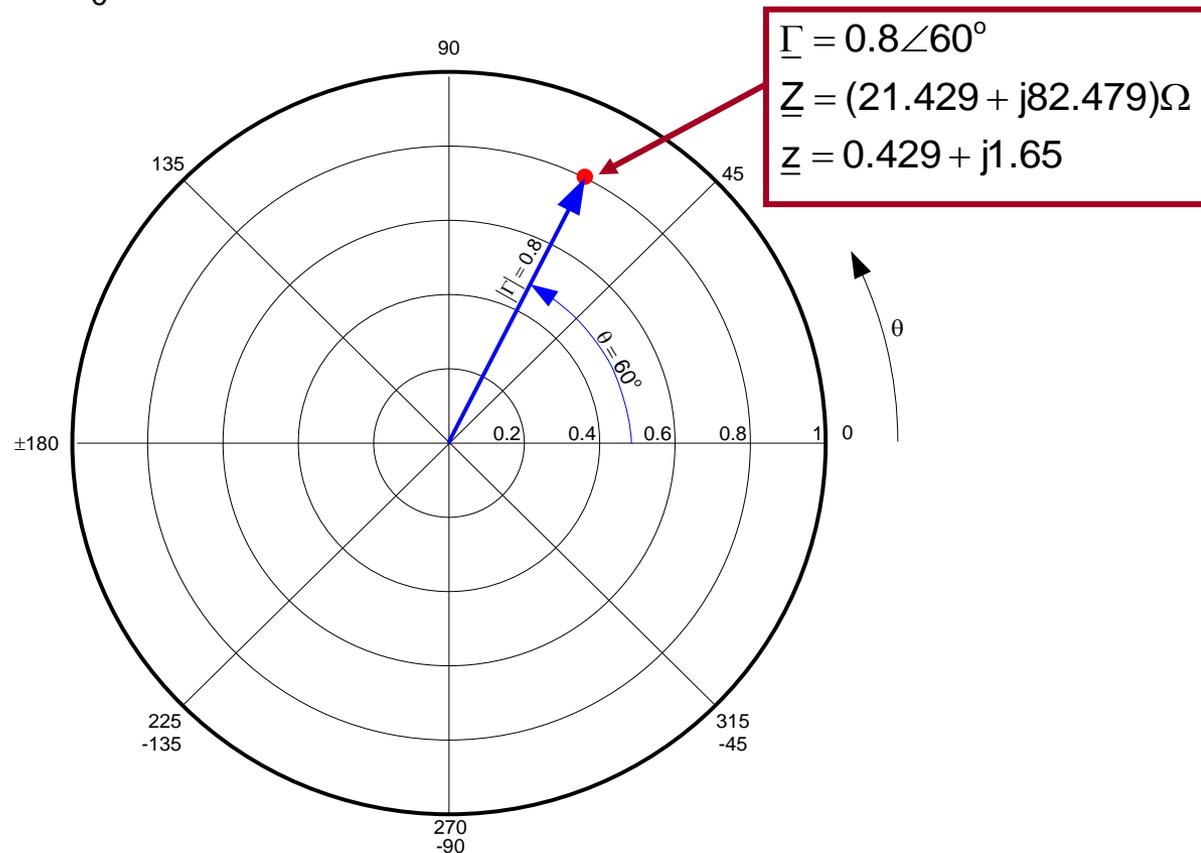
Aus der Leitungstheorie:

Nach Gl.1 muss jeder Reflexionskoeffizient auch eine komplexe Impedanz \underline{Z} , oder nach Gl.3 eine komplexe normierte Impedanz \underline{z} darstellen.

Für $\underline{\Gamma} = 0.8 \angle 60^\circ$ und $Z_0 = 50 \Omega$ nach Gl.1 und 3:

$$\underline{Z} = Z_0 \frac{1 + \underline{\Gamma}}{1 - \underline{\Gamma}} = 50 \Omega \frac{1 + 0.8 \angle 60^\circ}{1 - 0.8 \angle 60^\circ} \\ = (21.429 + j82.479) \Omega$$

$$\underline{z} = \frac{1 + \underline{\Gamma}}{1 - \underline{\Gamma}} = \frac{1 + 0.8 \angle 60^\circ}{1 - 0.8 \angle 60^\circ} \\ = 0.429 + j1.65$$



Einige spezielle Impedanzen:

Kurzschluss: $R=0, X=0, (r=0, x=0)$

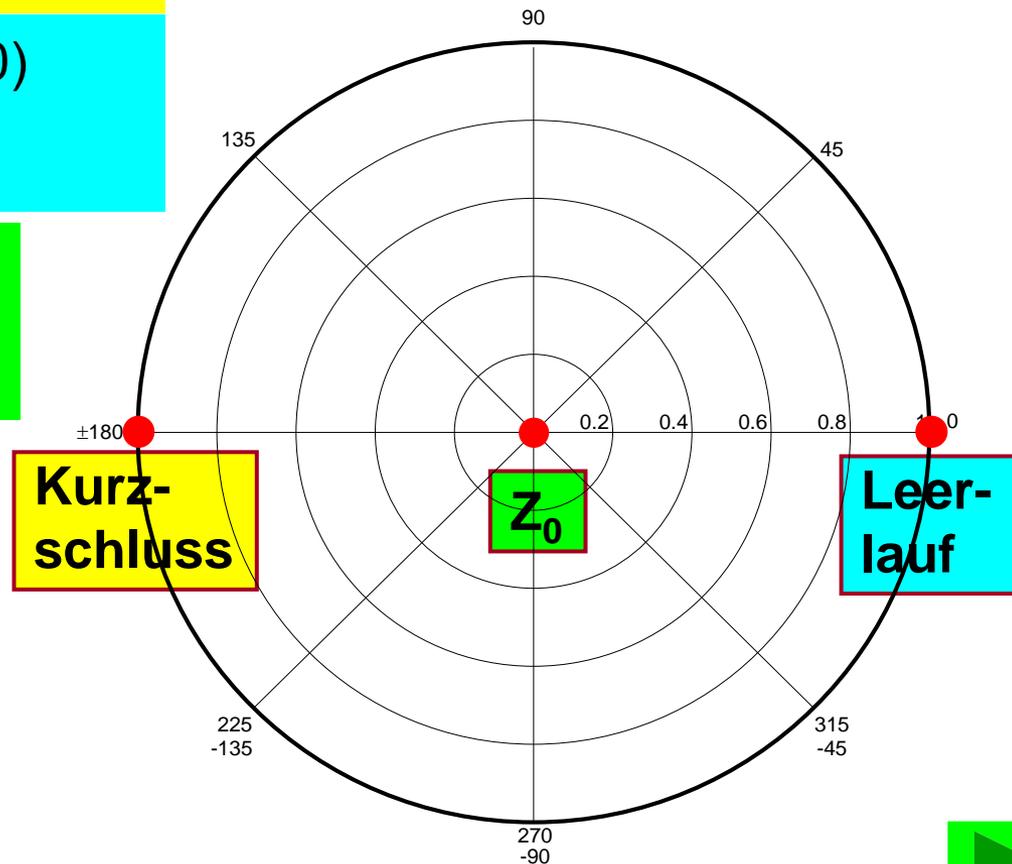
$$\underline{\Gamma} = \frac{-1}{1} = -1 = 1 \angle 180^\circ$$

Leerlauf: $R=\infty, X=0, (r=\infty, x=0)$

$$\underline{\Gamma} = 1 = 1 \angle 0^\circ$$

$\underline{Z} = Z_0$: $R=50, X=0, (r=1, x=0)$

$$\underline{\Gamma} = 0$$



Ortskreise für konstanten **Realteil** der Impedanz

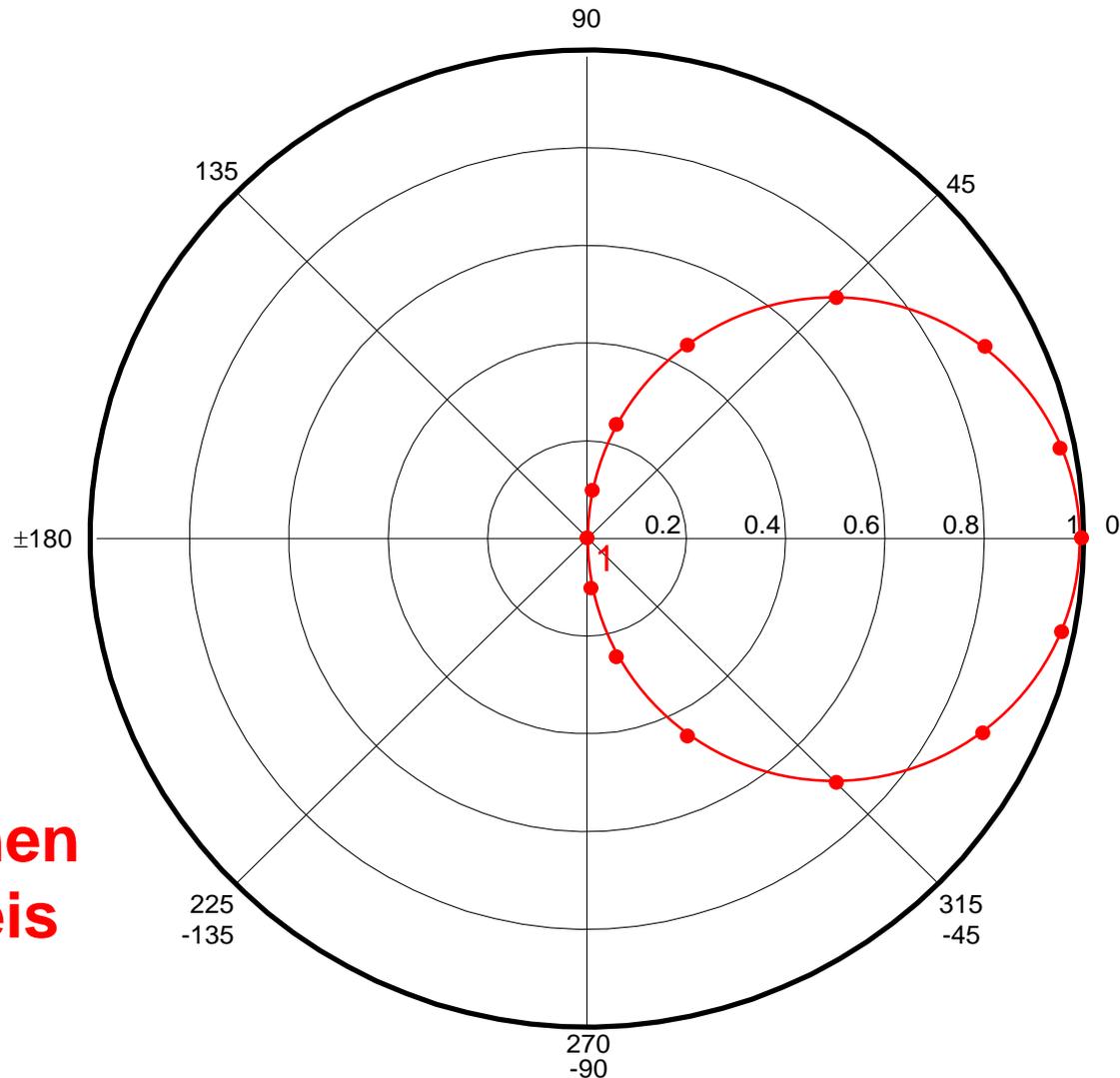
Zeichne den Ortskreis für **$r = 1$** ($R=Z_0$) und **$-\infty < X < +\infty$**

$$\underline{\Gamma} = \frac{r + jx - 1}{r + jx + 1} = \frac{jx}{2 + jx}$$

$$r = 1$$

$$X = +\infty$$

**Dies ergibt einen
konstant-r-Kreis
für $r = 1$**



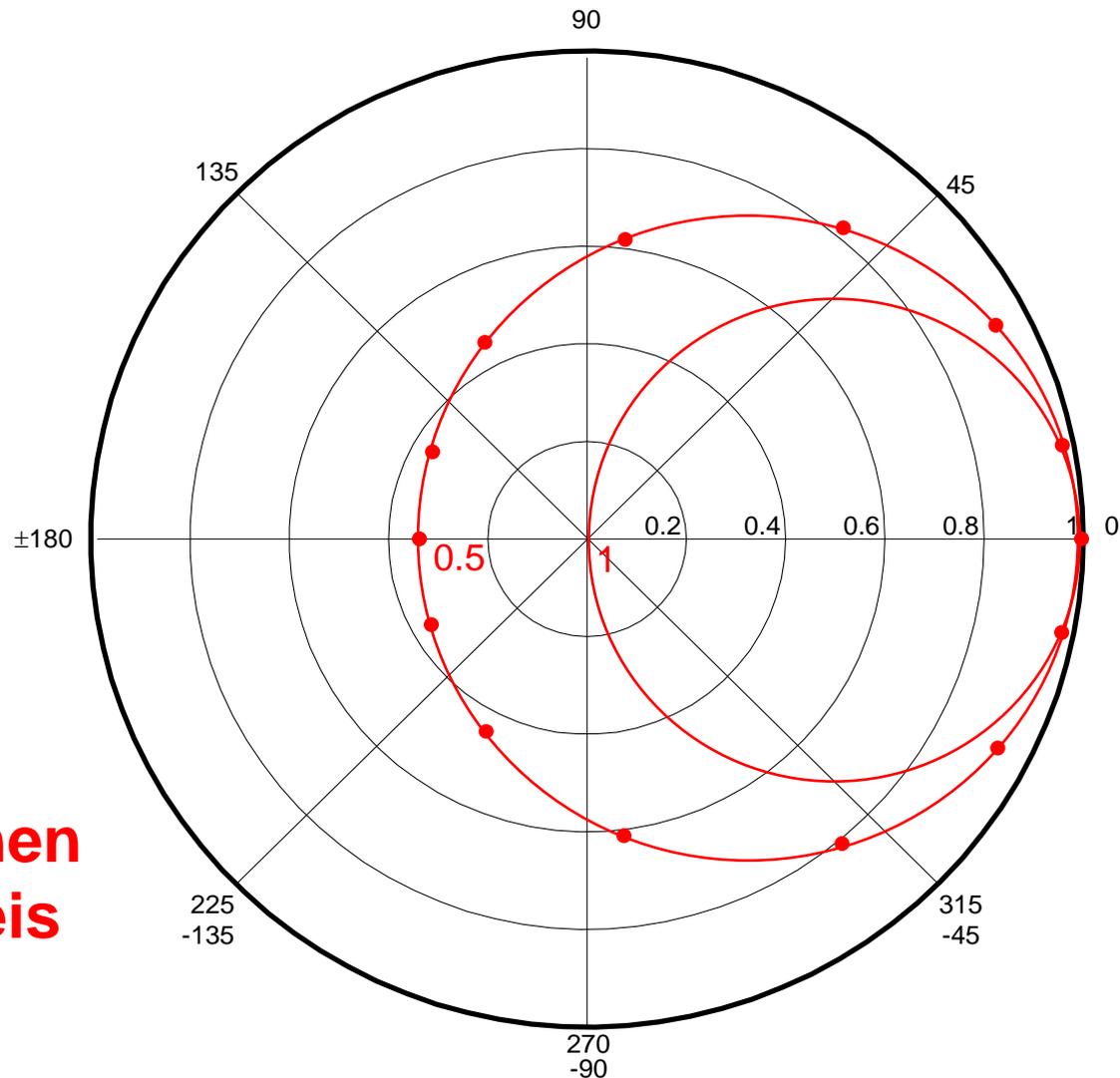
Ortskreise für konstanten **Realteil** der Impedanz

Zeichne den Ortskreis für **$r = 0.5$** ($R=0.5Z_0$) und **$-\infty < X < +\infty$**

$$\underline{\Gamma} = \frac{r + jx - 1}{r + jx + 1} = \frac{-0.5 + jx}{1.5 + jx}$$

$$r = 0.5$$

$$X = +\infty$$



**Dies ergibt einen
konstant-r-Kreis
für $r = 0.5$**



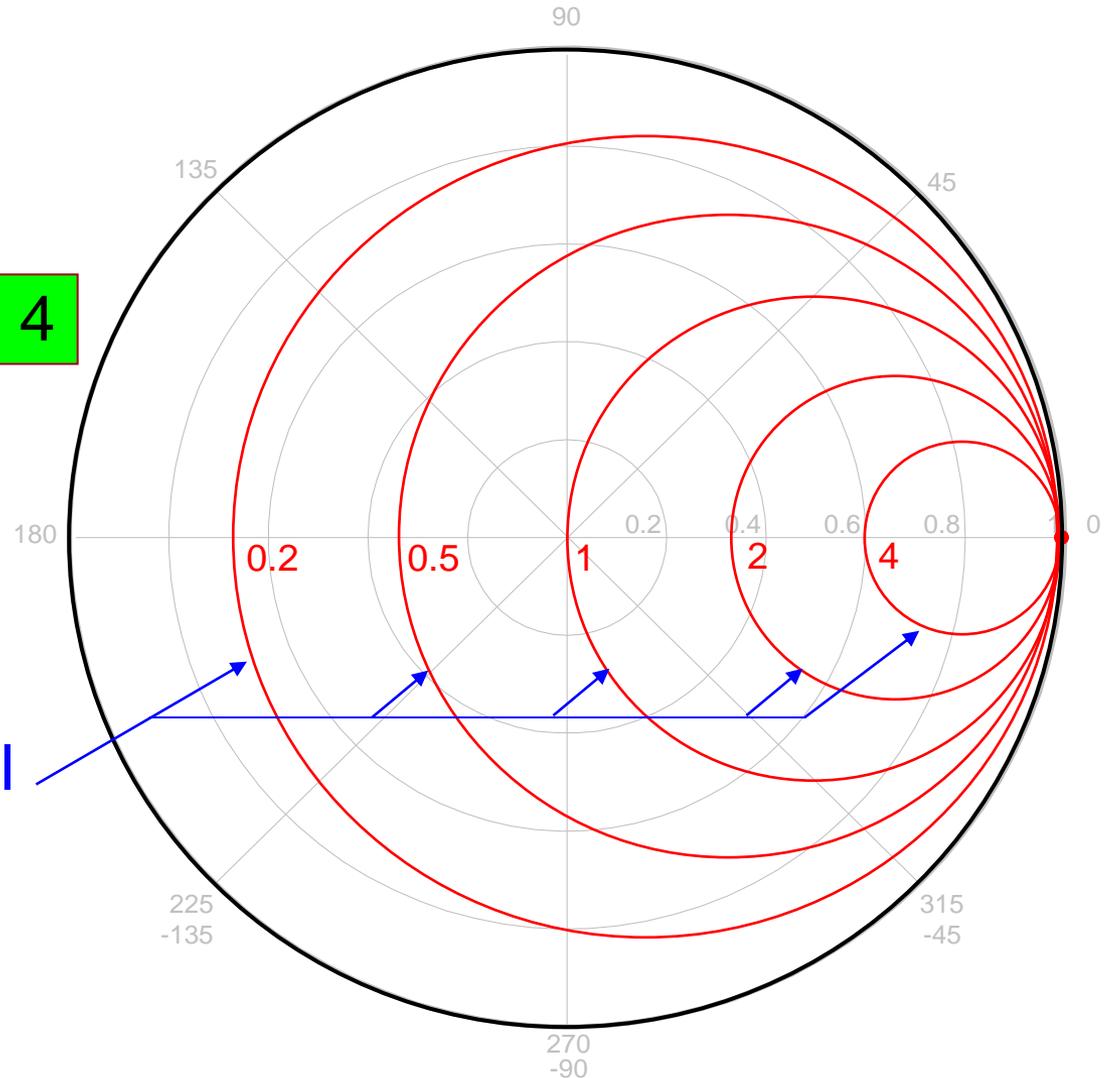
Ortskreise für konstanten Realteil der Impedanz

Ortskreise für $r = 0.2, 0.5, 1, 2, 4$ und $-\infty < x < +\infty$

$$\Gamma = \frac{r + jx - 1}{r + jx + 1}$$

 $r = 0.2, 0.5, 1, 2, 4$ $-\infty < x < +\infty$

Ortskreise für
konstanten Realteil
der Impedanz



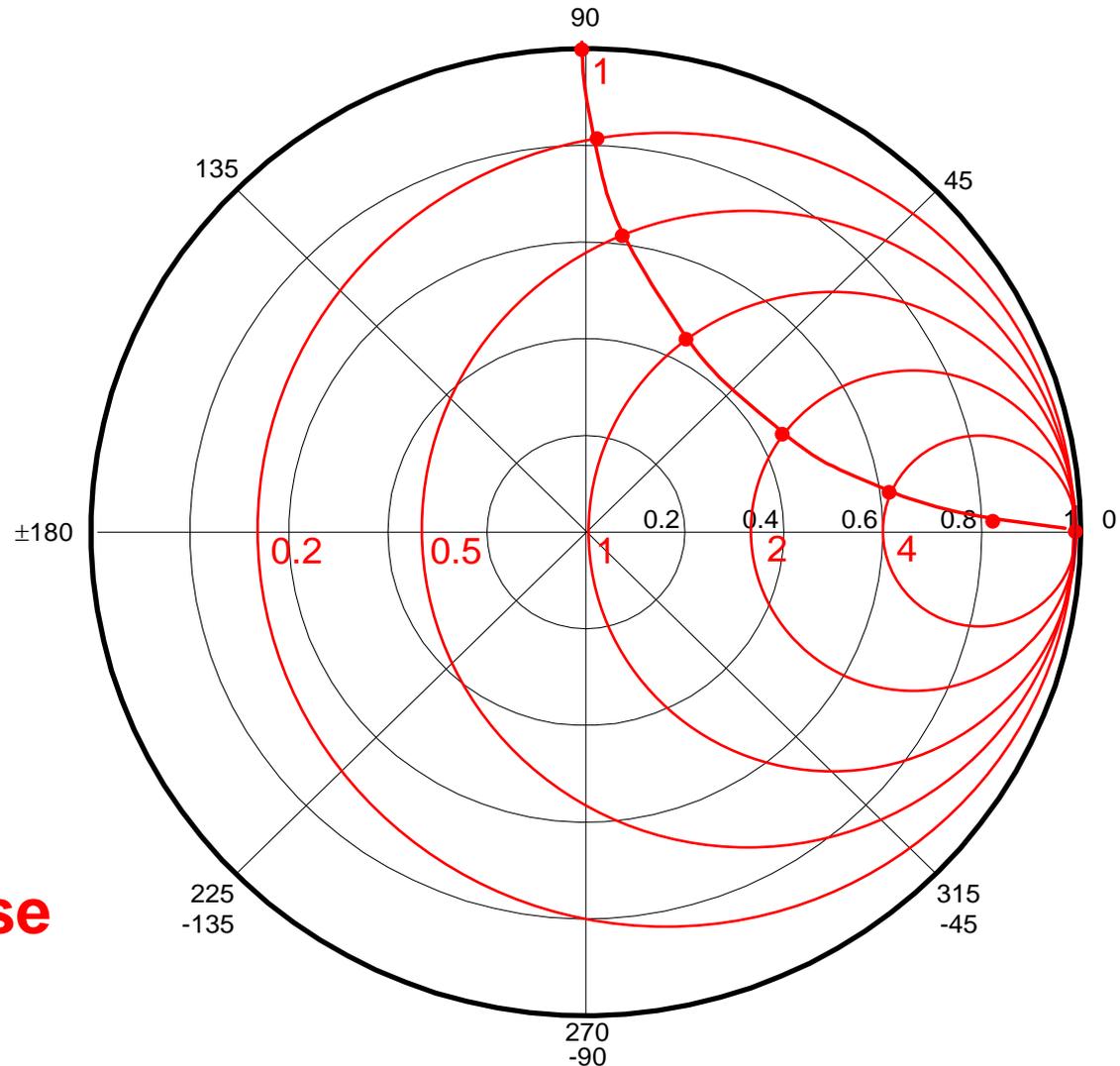
Ortskreise für konstanten **Imaginärteil** der Impedanz

Zeichne den Ortskreis für **$x = 1$** ($X=Z_0$) und **$0 < r < +\infty$**

$$\underline{\Gamma} = \frac{r + jx - 1}{r + jx + 1} = \frac{r + j1 - 1}{r + j1 + 1}$$

$$x = 1$$

$$r = +\infty$$



**Dies ergibt
konstant-x-Kreise
für $x = 1$**



Ortskreise für konstanten Imaginärteil der Impedanz

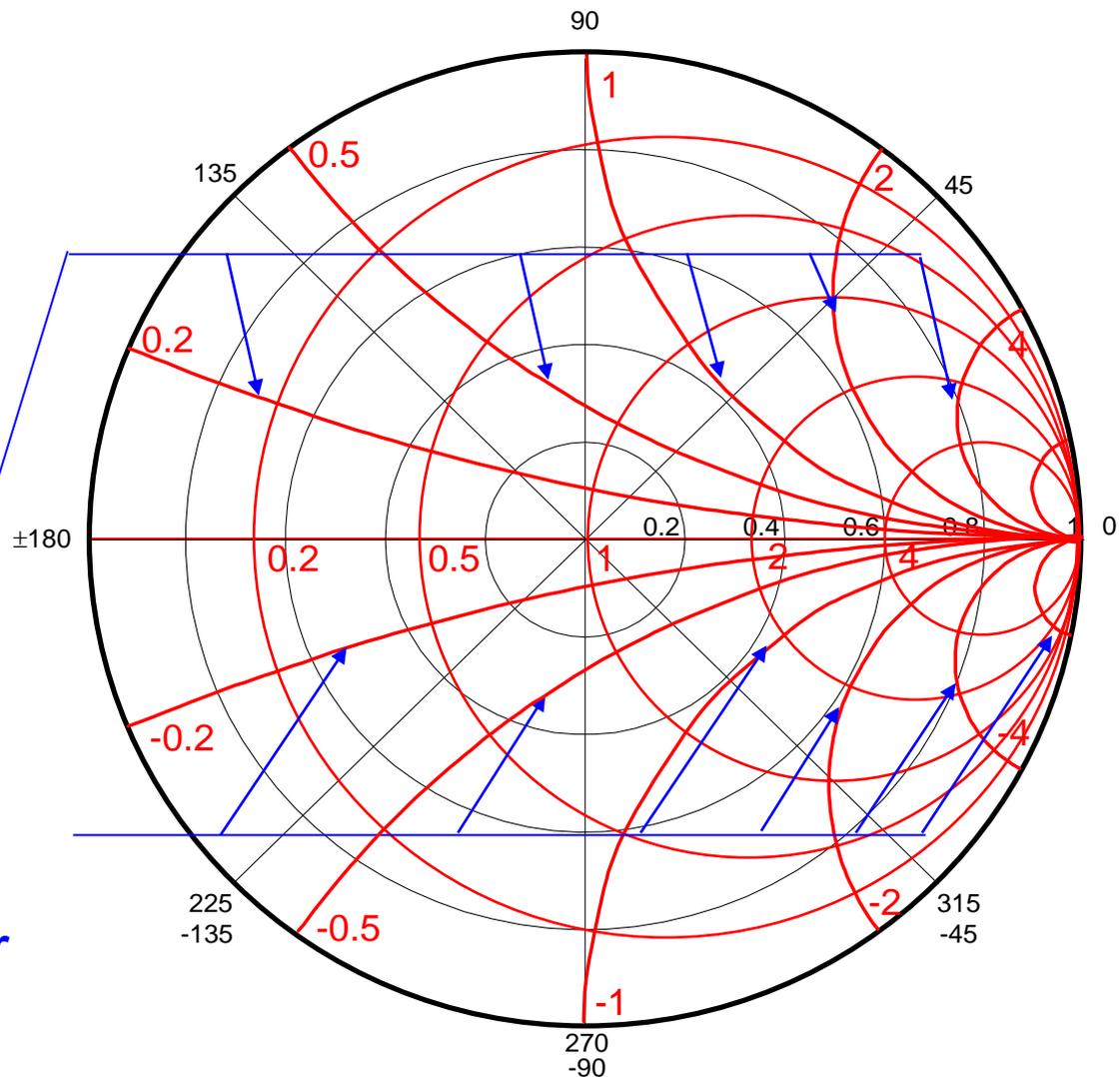
Zeichne die Ortskreise für $x = \pm 0.2, \pm 0.5, \pm 2, \pm 4, \pm 10$ und $0 < r < +\infty$

$$\Gamma = \frac{r + jx - 1}{r + jx + 1}$$

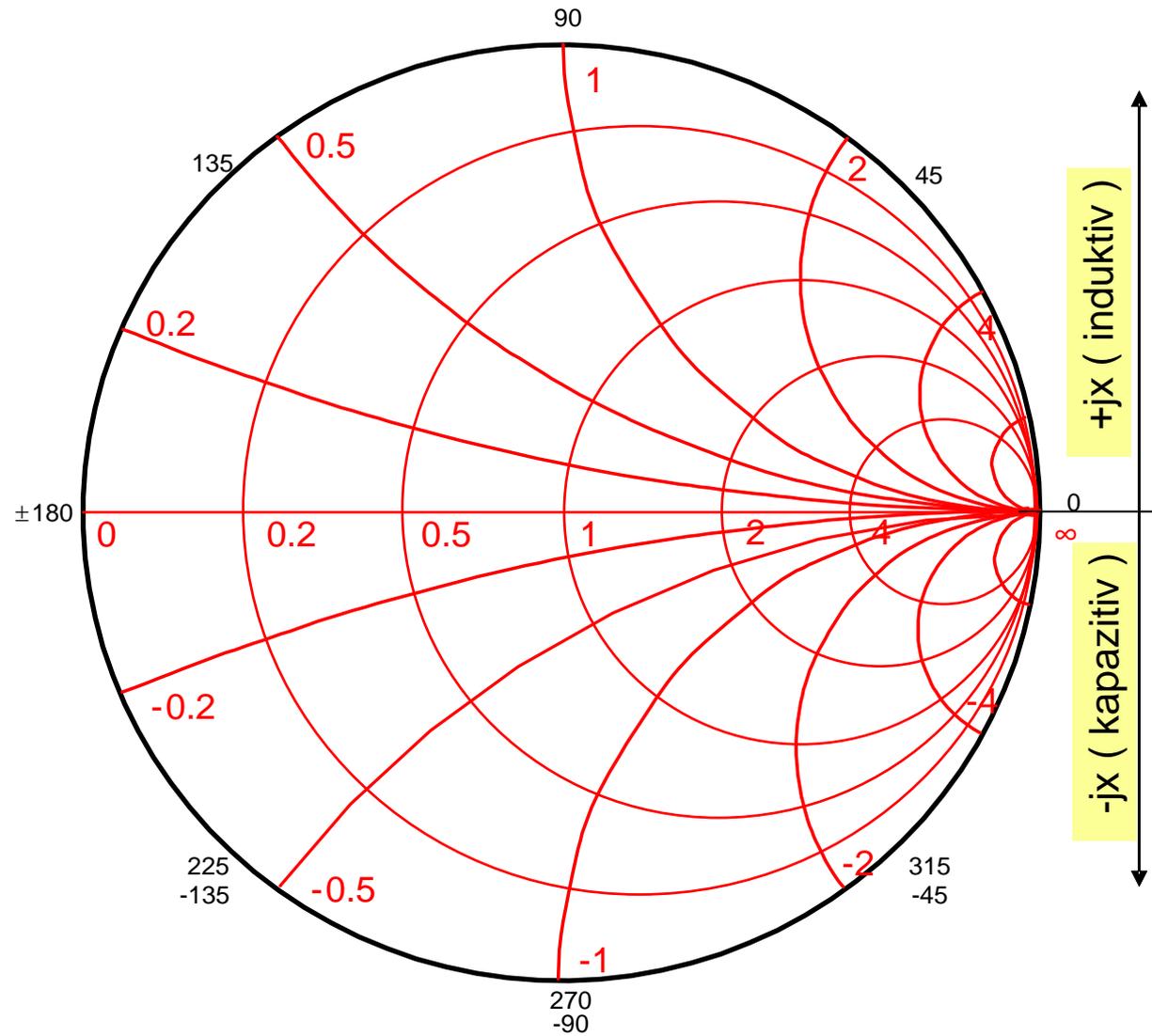
$$x = -10$$

$$r = 0 < r < +\infty$$

Ortskreise für
konstanten
Imaginärteil der
Impedanz

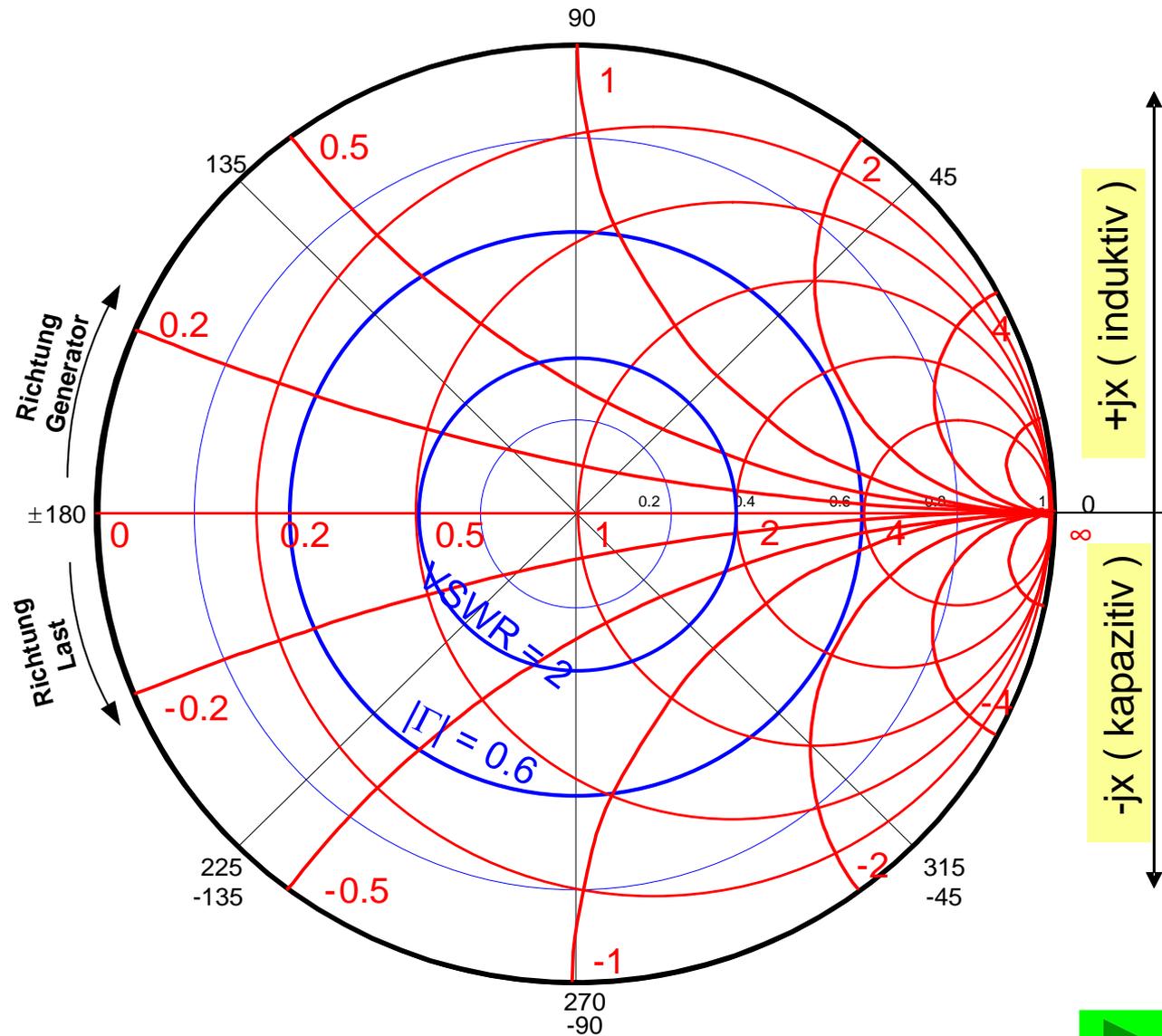


Impedanz-Ebene



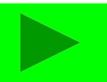
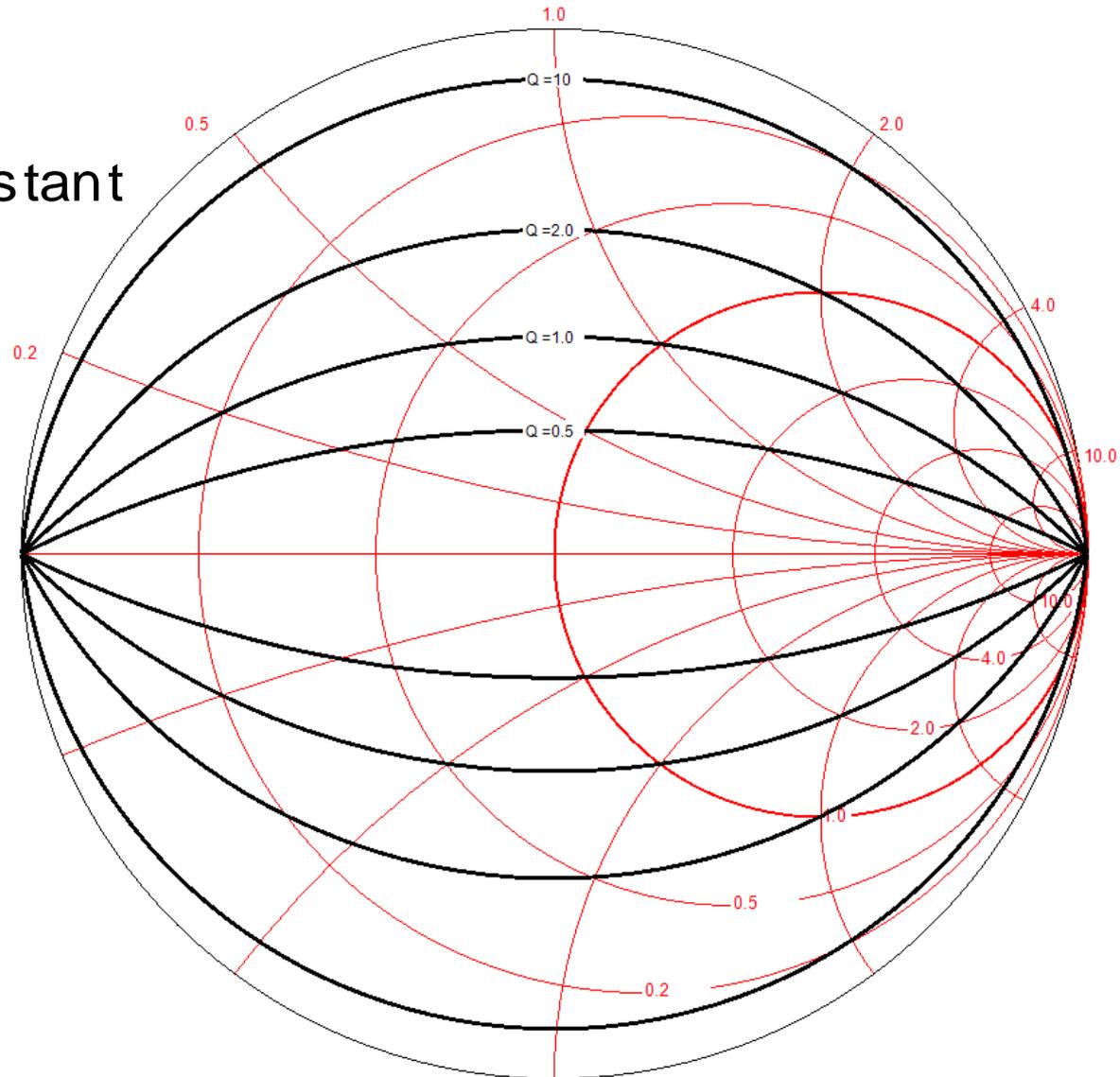
Kreise mit konstantem $|\Gamma|$ und VSWR

$$\text{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$



Konstant-Q Kreise

$$Q = \frac{X}{R} = \frac{G}{B} = \text{konstant}$$



Admittanz-Ebene

$$\underline{Y} = \frac{1}{\underline{Z}}$$

$$\underline{\Gamma} = \frac{Y_0 - \underline{Y}}{Y_0 + \underline{Y}} = \frac{1 - \frac{\underline{Y}}{Y_0}}{1 + \frac{\underline{Y}}{Y_0}}$$

Gl. 4

$\underline{\Gamma}$: komplexer Reflexionskoeffizient = $|\Gamma| \angle \theta$

\underline{Y} : komplexe Admittanz = $G + jB = \frac{1}{\underline{Z}}$

Y_0 : Normierungs-Admittanz (normalerweise reell)

$$Y_0 = 1/Z_0$$

Normiertes Y: y

$$\underline{y} = \frac{\underline{Y}}{Y_0} = \frac{G}{Y_0} + j \frac{B}{Y_0} = g + jb \quad \text{Gl. 5}$$

$$\underline{\Gamma} = \frac{1 - \underline{y}}{1 + \underline{y}} = \frac{1 - g - jb}{1 + g + jb} \quad \text{Gl. 6}$$

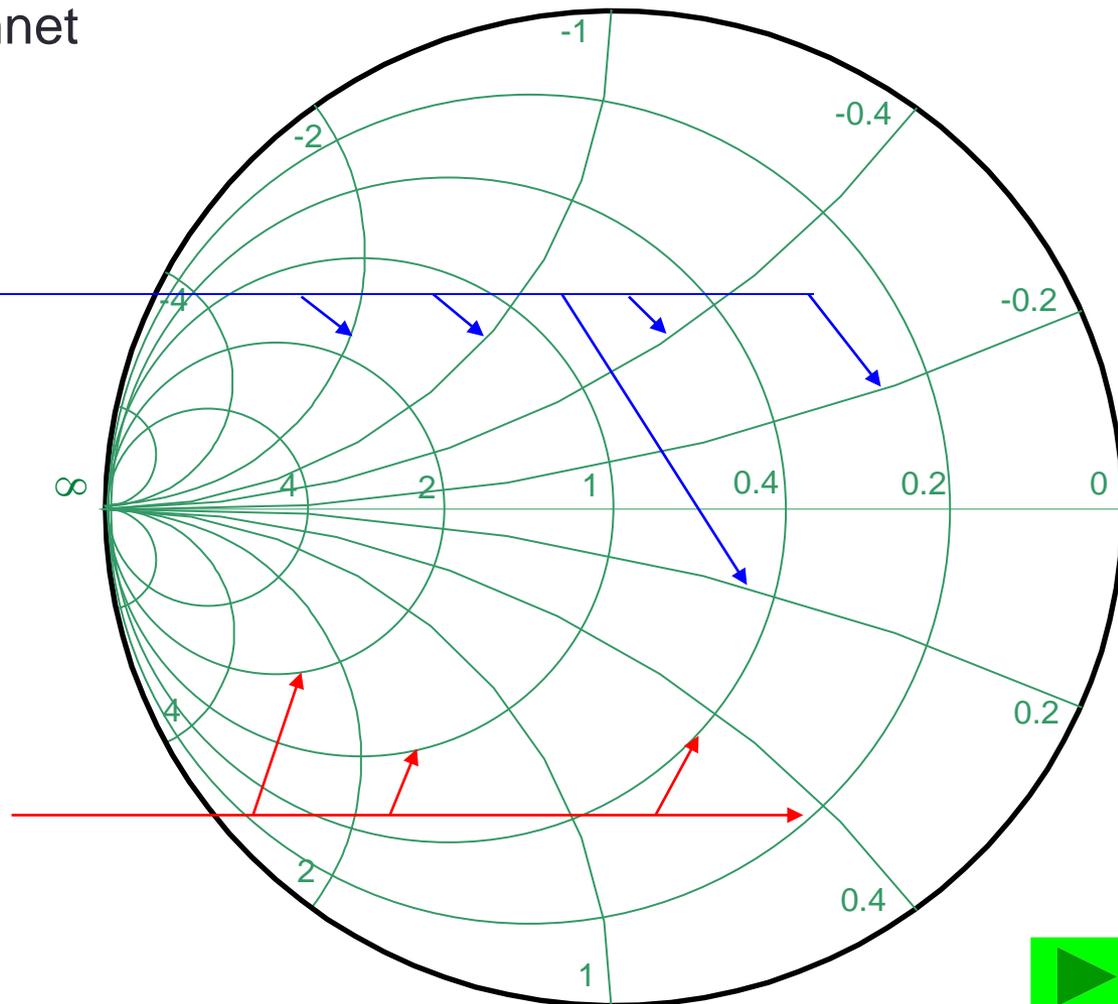


Admittanz-Ebene

Mit dem gleichen Vorgehen wie bei der Impedanz-Ebene können die Ortskreise für konstante Konduktanz g und konstante Suszeptanz b gezeichnet werden.

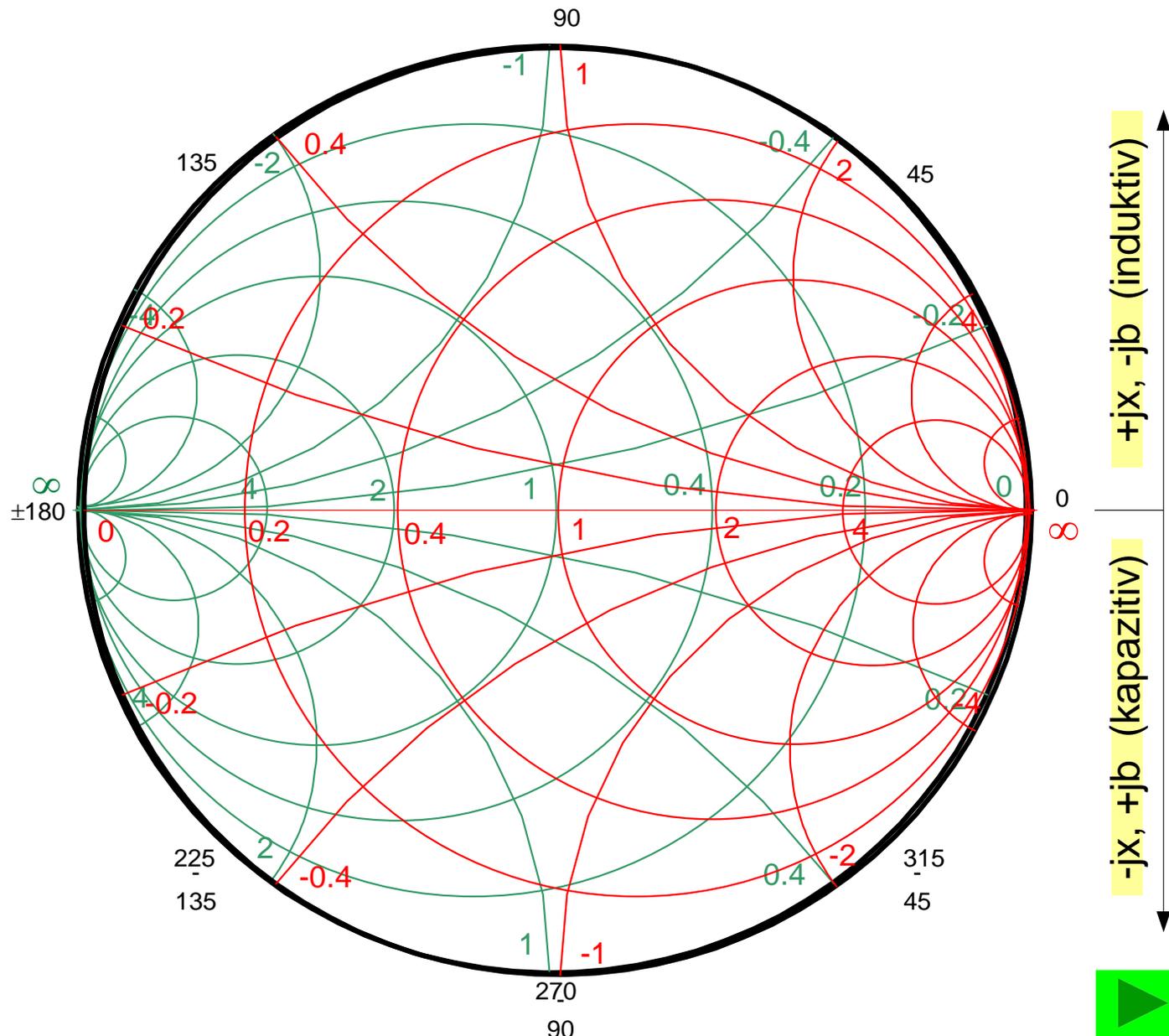
Ortskreise für
konstanten
Imaginärteil der
Admittanz

Ortskreise für
konstanten
Realteil der
Admittanz



Impedanz-Karte

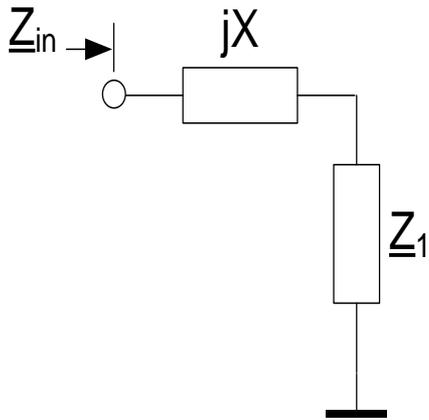
Impedanz-
Ebene und
Admittanz-
Ebene
übereinander
gelegt.



Serieschaltung von L und C

$$jX = j\omega L$$

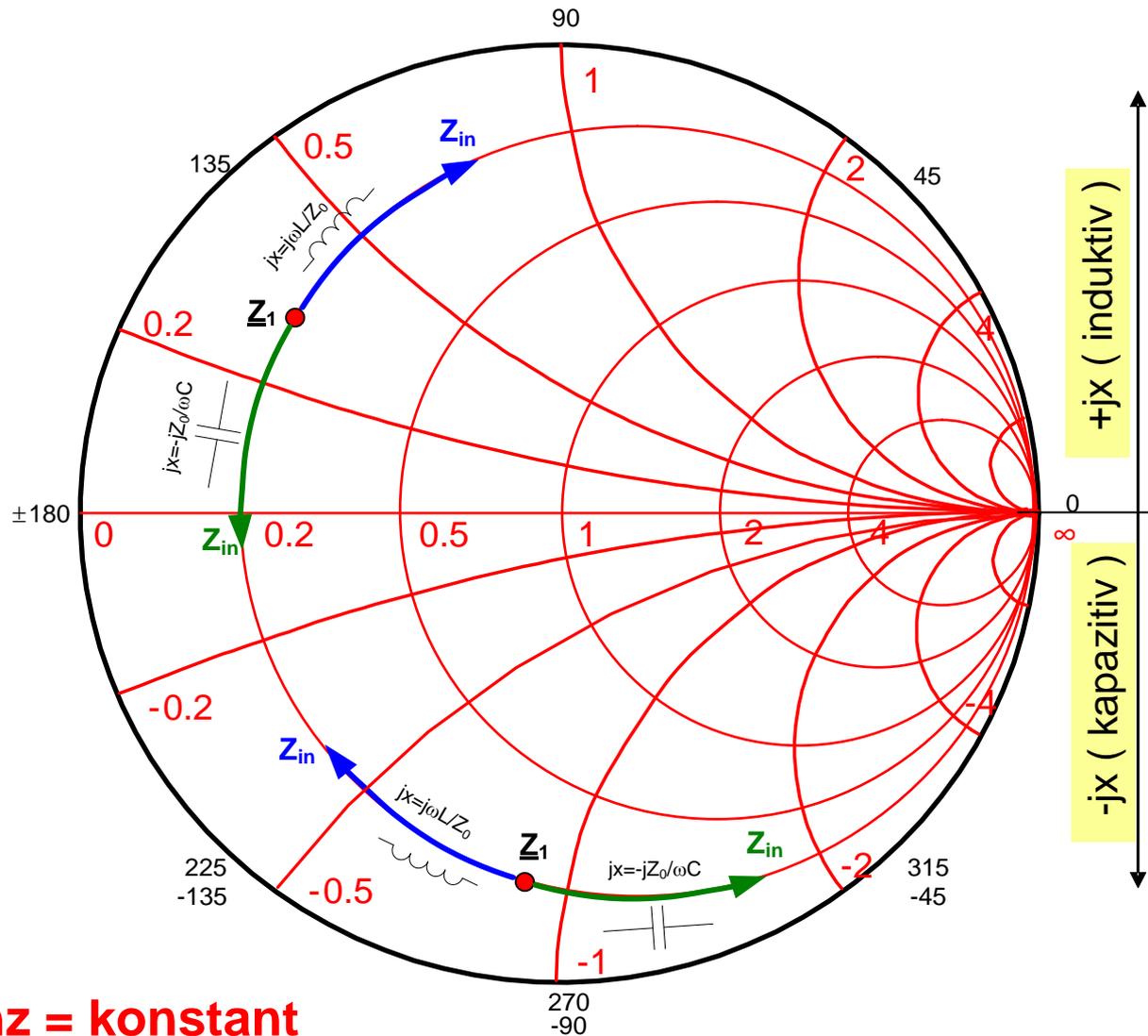

$$jX = -j1/\omega C$$

$$\underline{Z}_1 = R_1 + jX_1$$

$$\underline{Z}_{in} = R + j(X_1 \pm X)$$

↑
Realteil der Impedanz = konstant

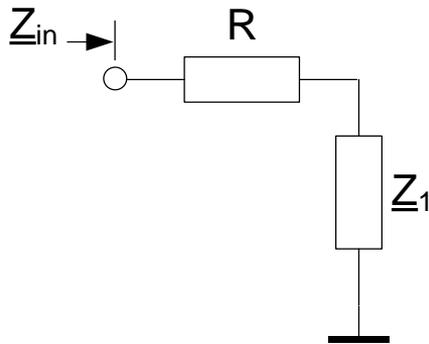


+jx (induktiv)

-jx (kapazitiv)



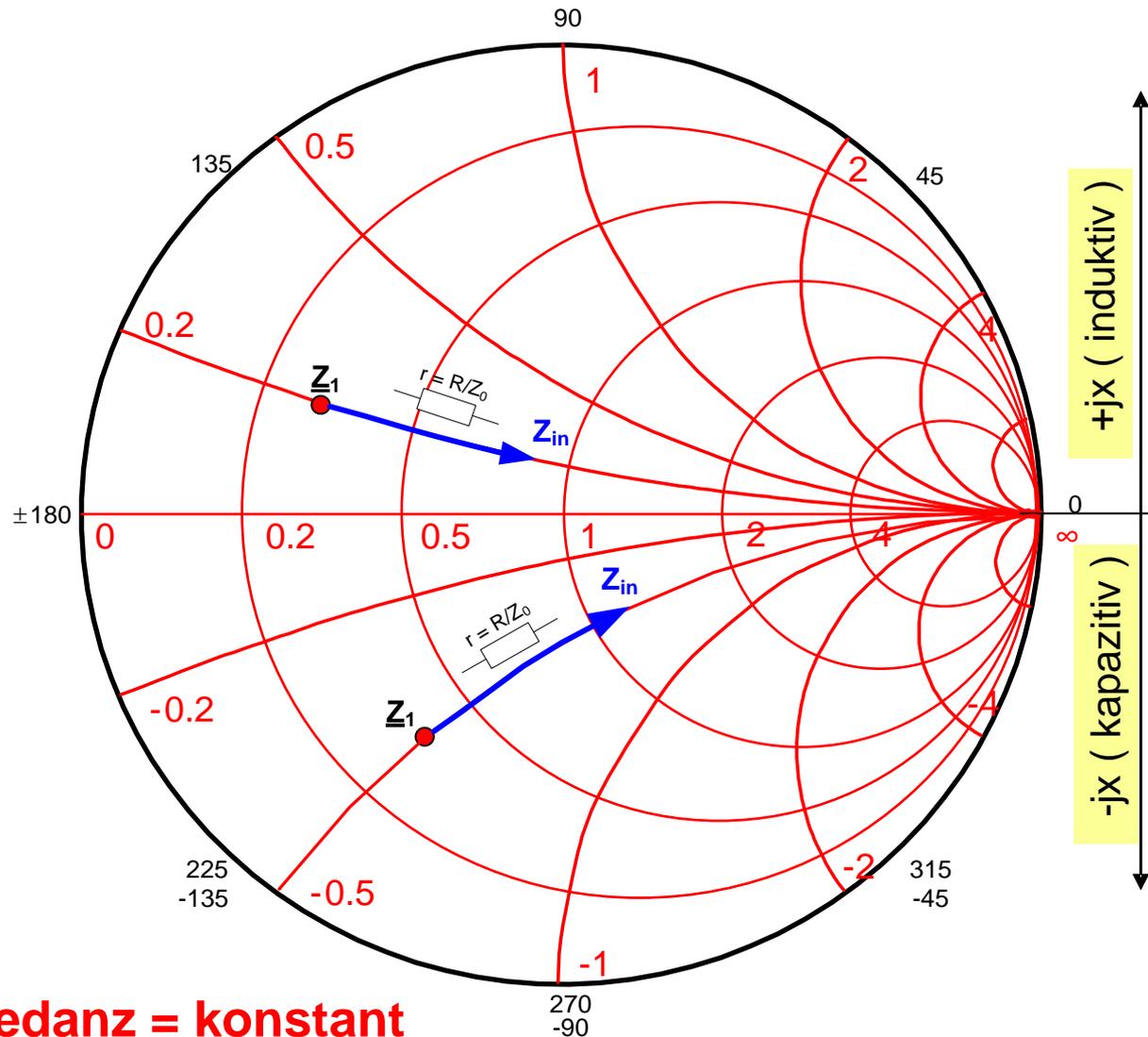
Serieschaltung von R



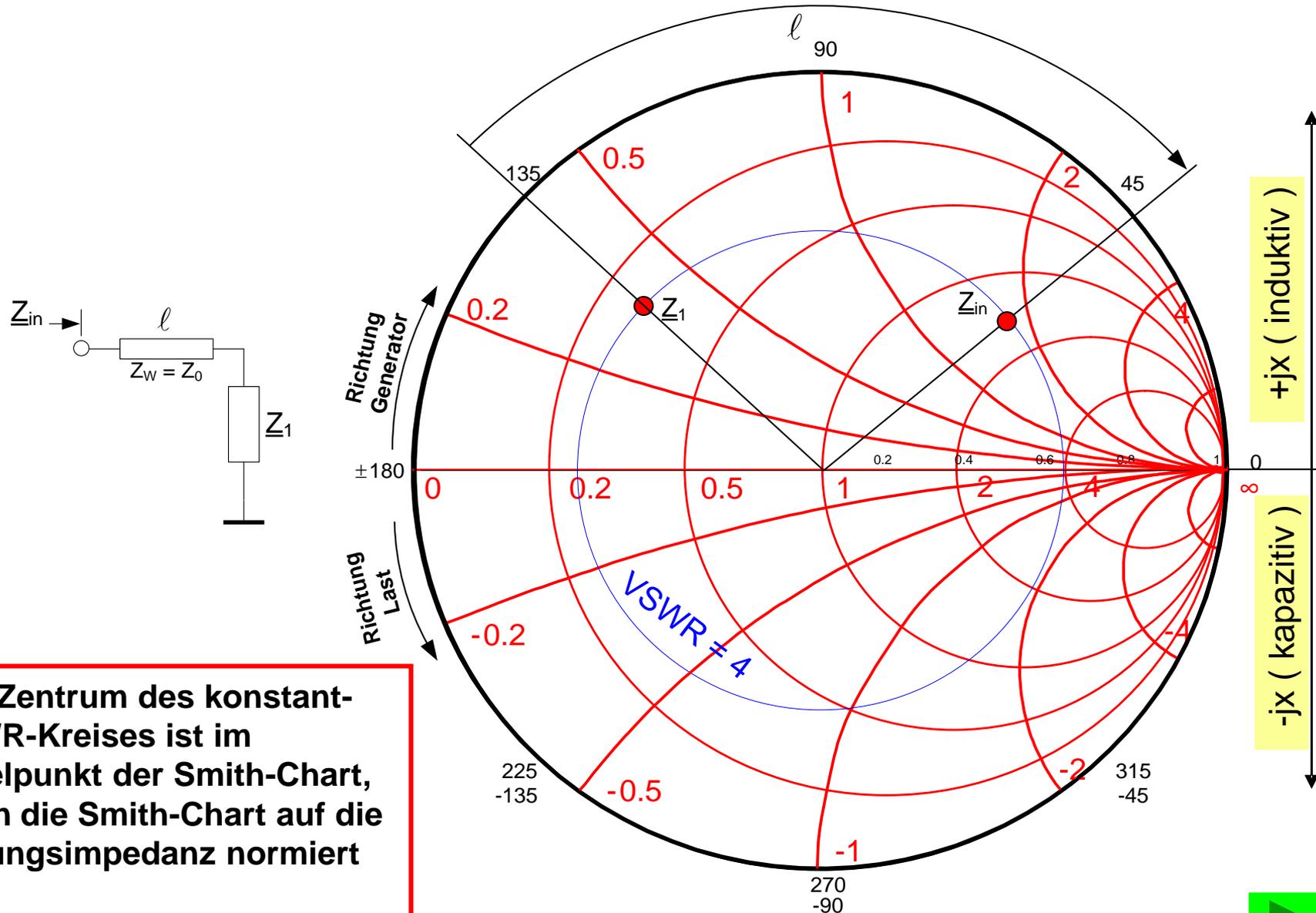
$$\underline{Z}_1 = R_1 + jX_1$$

$$\underline{Z}_{in} = (R_1 + R) + jX_1$$

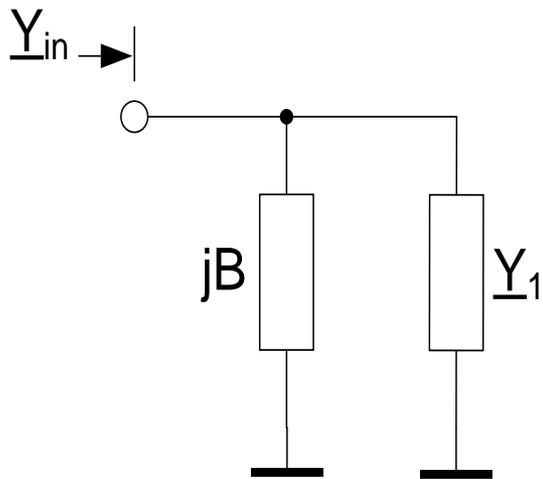
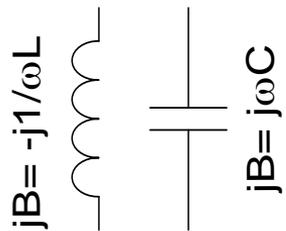
Imaginärteil der Impedanz = konstant



Serie-Leitung (verlustlos) mit $Z_W = Z_0$



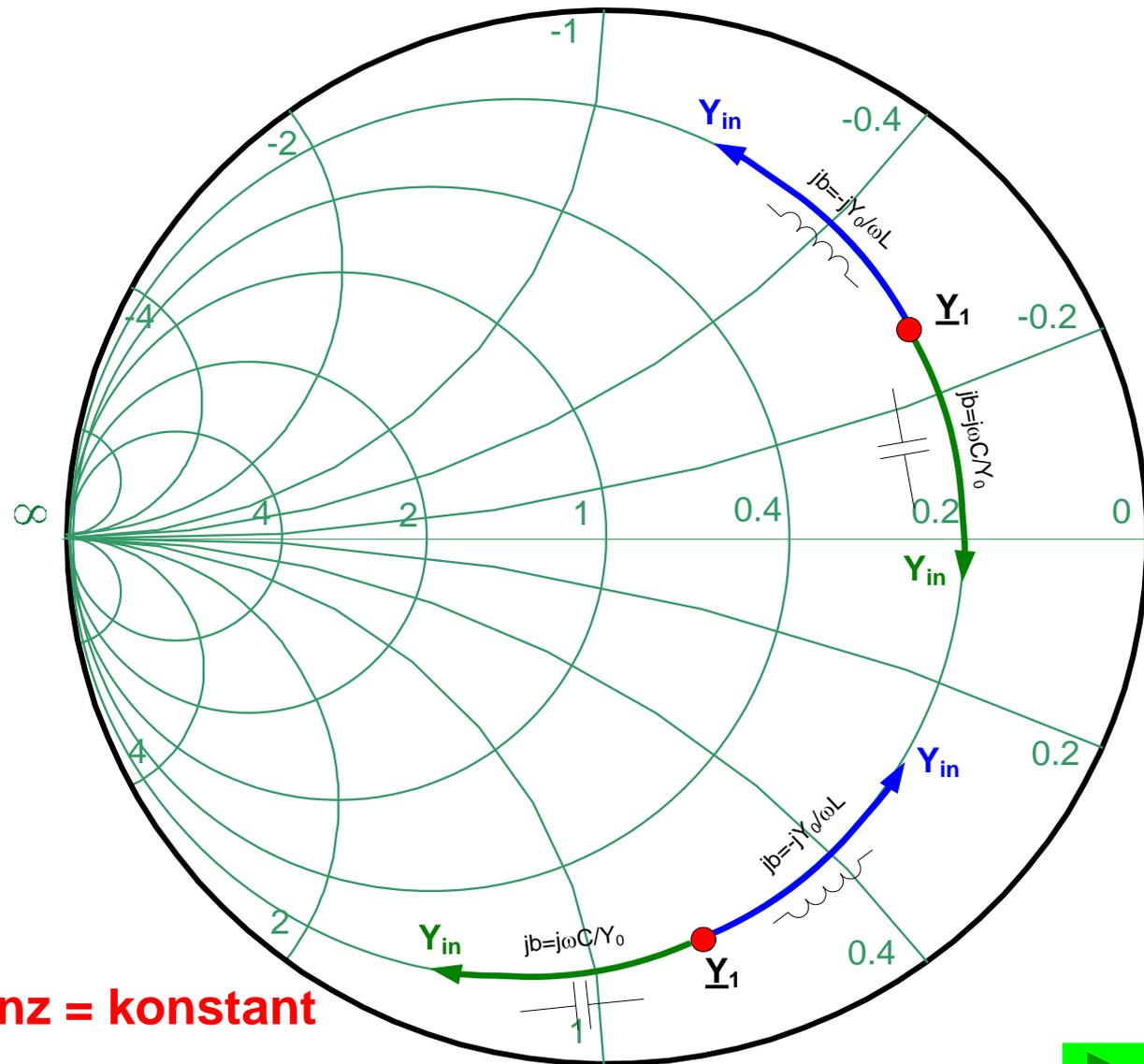
Parallelschaltung von L und C



$$Y_1 = G_1 + jB_1$$

$$Y_{in} = G + j(B_1 \pm B)$$

↑
Realteil der Admittanz = konstant



Software: Smith V4.1

www.fritz.dellsperger.net

fritz@dellsperger.net

Smith V4.1

File Edit Mode Tools Zoom Window Help

Mouse Keyboard S11 S22

Sweep Clr Tune

The software interface displays a Smith Chart with various points and curves. A central point is labeled $Q=1.0$ and $VSWR=1.5$. Several points are marked: TP 4, TP 5, TP 6, SP 1, SP 2, SP 3, DP 1, DP 2, and DP 3. The chart includes scales for SWR, dBS, and reflection coefficient.

Schematic

Datapoints

| Start DP | Point | Z | Q | Frequency |
|-------------------------------------|-------|-----------------------------|---------|------------|
| <input type="checkbox"/> | DP 1 | (11.176 + j11.027) Ω | Q=0.986 | 144.000MHz |
| <input checked="" type="checkbox"/> | DP 2 | (12.969 + j11.597) Ω | Q=0.894 | 145.000MHz |
| <input type="checkbox"/> | DP 3 | (15.664 + j10.651) Ω | Q=0.680 | 146.000MHz |
| | TP 4 | (23.339 + j0.000) Ω | Q=0.000 | 145.000MHz |
| | TP 5 | (23.339 + j24.903) Ω | Q=1.067 | 145.000MHz |
| | TP 6 | (49.910 + j0.000) Ω | Q=0.000 | 145.000MHz |
| | SP 1 | (57.403 + j3.926) Ω | Q=0.068 | 144.000MHz |
| | SP 2 | (49.910 + j0.000) Ω | Q=0.000 | 145.000MHz |
| | SP 3 | (41.185 + j1.970) Ω | Q=0.048 | 146.000MHz |

Circles

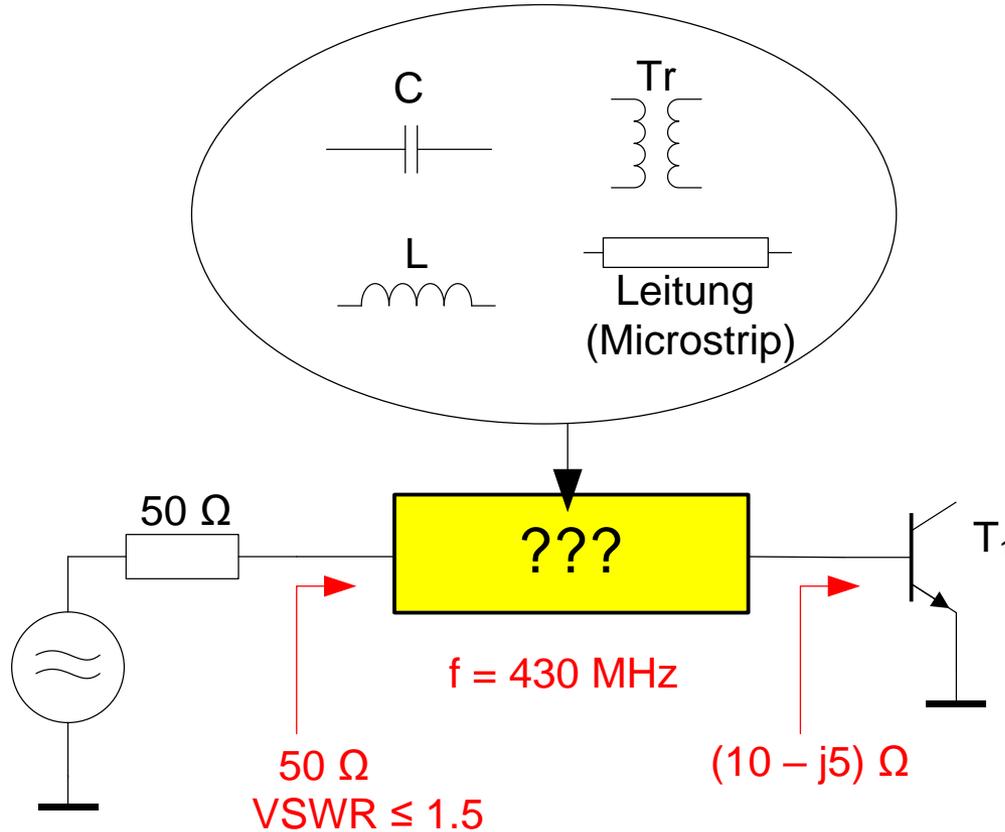
Visible | Highlighted | Details

Cursor

Return Loss: 1.05 dB VSWR: 16.57 :1
 Q: 0.61 Γ : 0.886 / -4.231 °
 Y: (1.21 + j0.74) mS Z: (603.61 - j367.66) Ω
 Zo: 50.0 Ω Freq: 145.000MHz

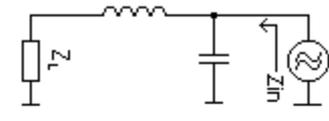
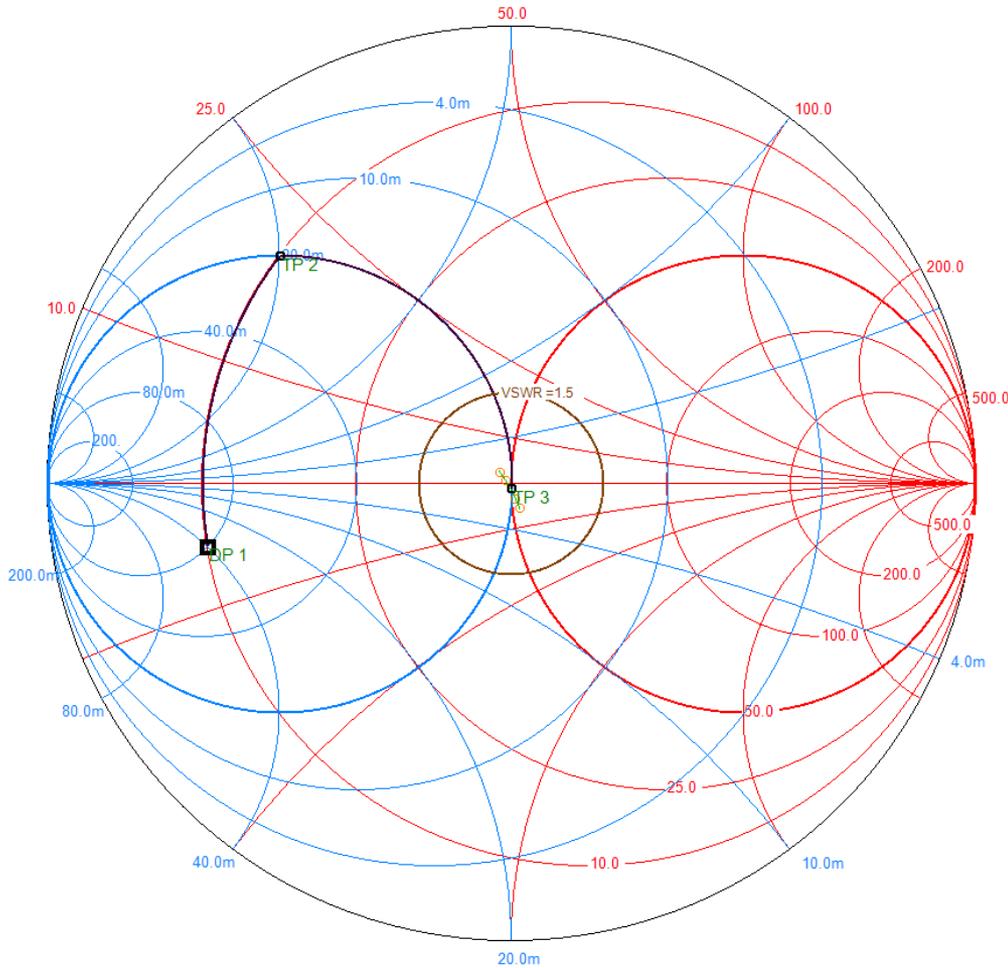


Beispiel 1: Transistor Eingangsanpassung

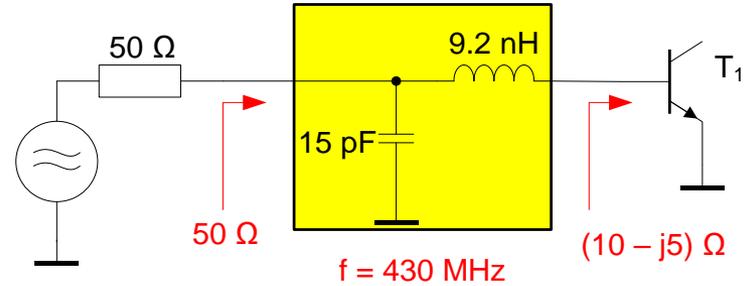


Beispiel 1: Transistor Eingangsanpassung

Lösung 1

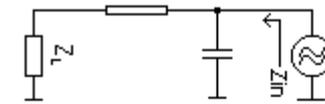
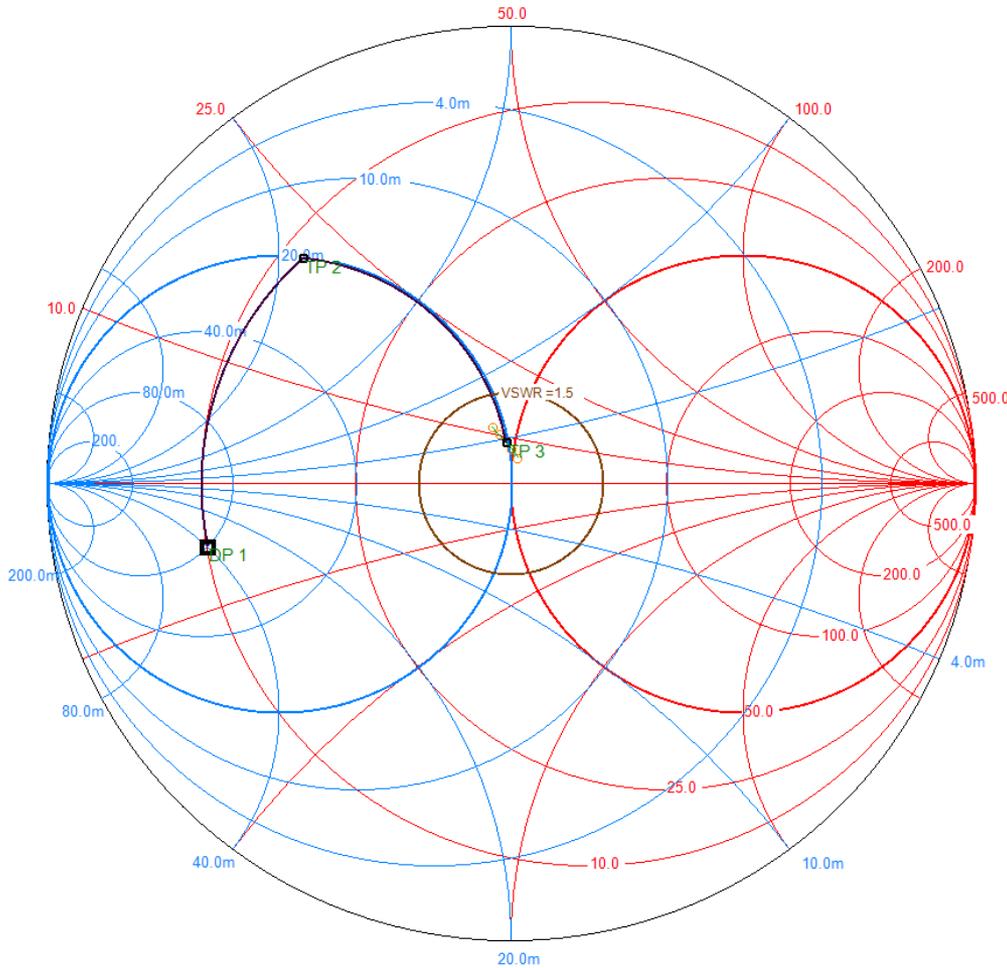


$(10.00 - j5.00) \Omega @ 430.0 \text{ MHz}$
 9.2 nH
 15.0 pF

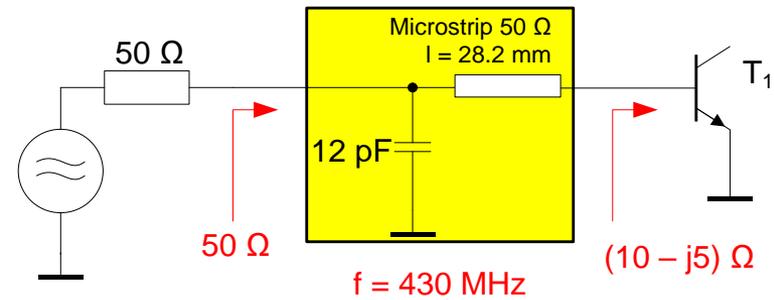


Beispiel 1: Transistor Eingangsanpassung

Lösung 2



12.0pF
 50.0Ω(DdB/m)λ=0.0828
 28.2mm(phys) | 57.7mm(electr)
 (10.00-j5.00)Ω@430.0MHz



Beispiel 2: Antennenanpassung



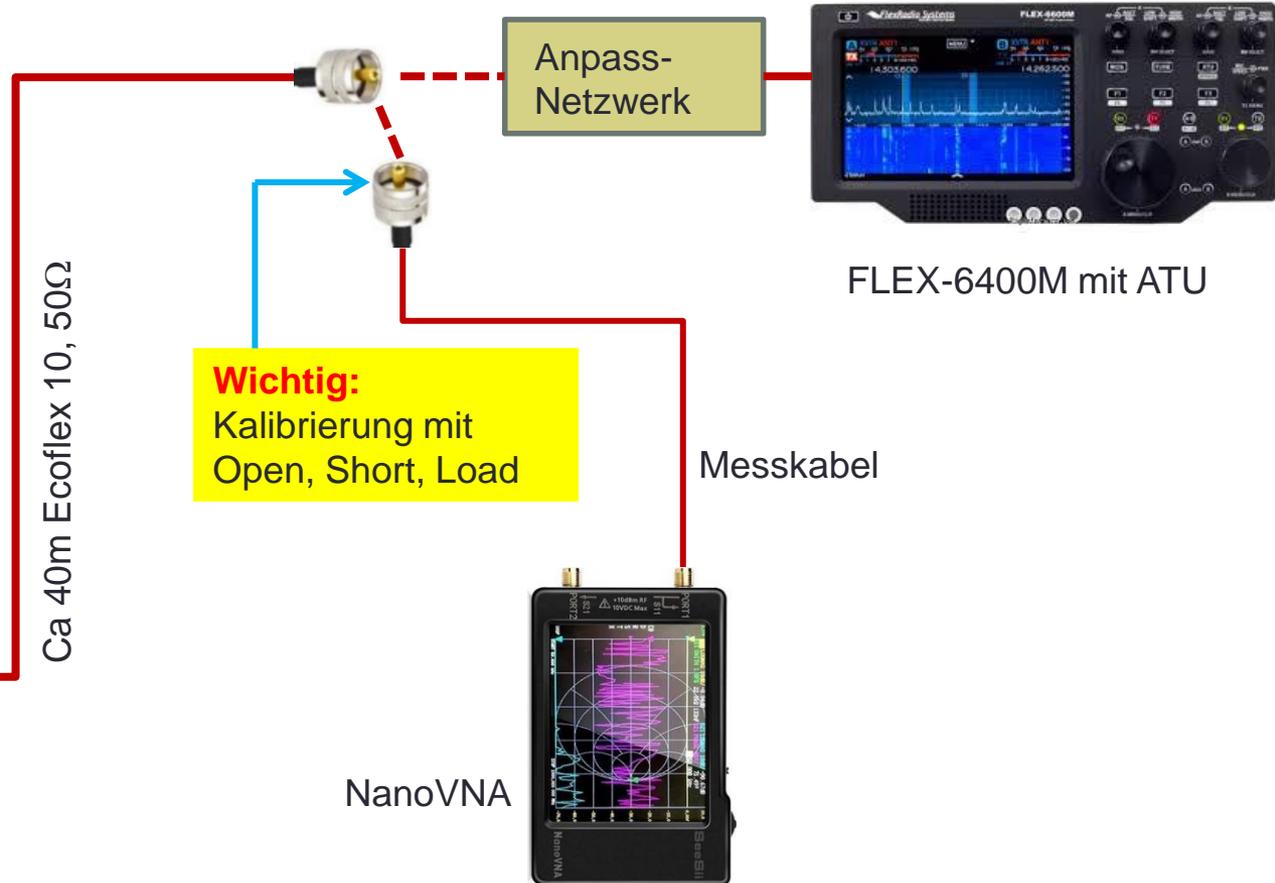
10m
15m
20m
30m
40m
80m

Hustler 6-BTV

Fehlend:

12m: 24.890 – 24.915 MHz (CW)

17m: 18.068 – 18.095 MHz (CW)

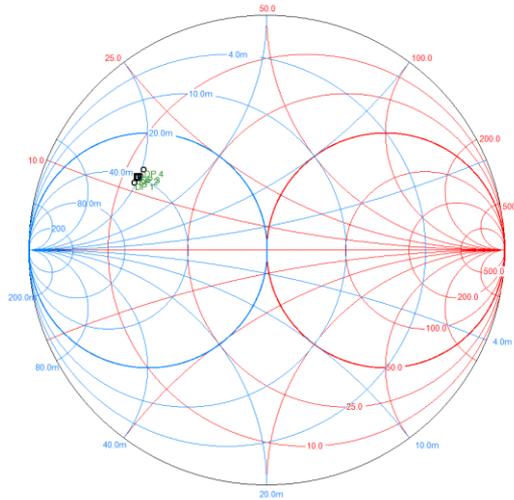


Messung der Antennenimpedanzen im Shack

Touchstone-File xx.s1p

12m: 24.890 – 24.915 MHz (CW)

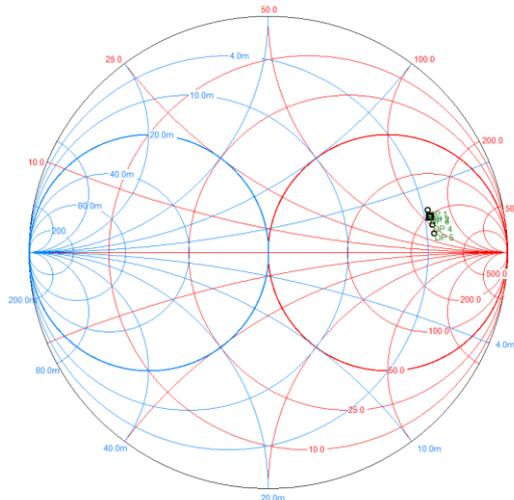
```
# MHZ S MA R 50.0
! Rohde & Schwarz ZVL
!
24.890 6.284E-1 152.53
24.900 6.249E-1 150.14
24.910 6.218E-1 149.23
24.920 6.240E-1 146.45
!
! 20.5.2019 DGF
```



| Datapoints | | | | |
|-------------------------------------|-------|----------------------|---------|-----------|
| Start DP | Point | Z | Q | Frequency |
| <input type="checkbox"/> | DP 1 | (12.054 + j11.549) Ω | Q=0.958 | 24.890MHz |
| <input checked="" type="checkbox"/> | DP 2 | (12.316 + j12.574) Ω | Q=1.021 | 24.900MHz |
| <input type="checkbox"/> | DP 3 | (12.491 + j12.957) Ω | Q=1.037 | 24.910MHz |
| <input type="checkbox"/> | DP 4 | (12.567 + j14.195) Ω | Q=1.130 | 24.920MHz |

17m: 18.068 – 18.095 MHz (CW)

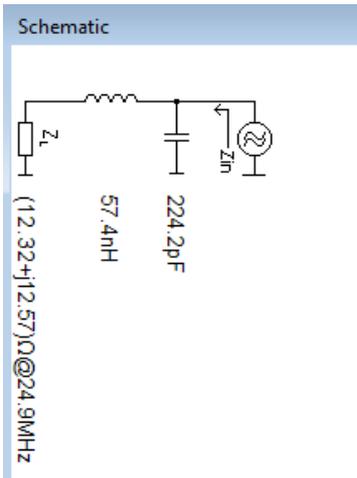
```
# MHZ S MA R 50.0
! Rohde & Schwarz ZVL
!
18.060 6.916E-1 15.35
18.070 6.942E-1 13.39
18.080 6.927E-1 12.80
18.090 6.972E-1 9.954
18.100 6.990E-1 6.947
!
! 20.5.2019 DGF
```



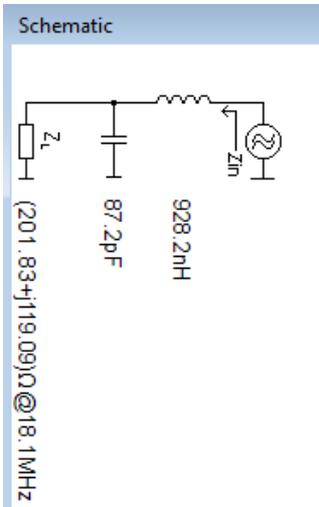
| Datapoints | | | | |
|-------------------------------------|-------|------------------------|---------|-----------|
| Start DP | Point | Z | Q | Frequency |
| <input type="checkbox"/> | DP 1 | (180.573 + j126.737) Ω | Q=0.702 | 18.060MHz |
| <input type="checkbox"/> | DP 2 | (197.358 + j122.480) Ω | Q=0.621 | 18.070MHz |
| <input checked="" type="checkbox"/> | DP 3 | (201.832 + j119.094) Ω | Q=0.590 | 18.080MHz |
| <input type="checkbox"/> | DP 4 | (228.045 + j106.956) Ω | Q=0.469 | 18.090MHz |
| <input type="checkbox"/> | DP 5 | (253.508 + j83.820) Ω | Q=0.331 | 18.100MHz |

Anpassnetzwerke

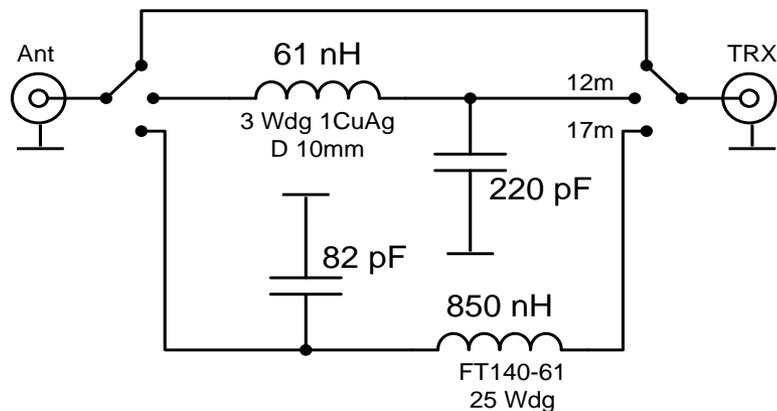
12m: 24.890 – 24.915 MHz (CW)



17m: 18.068 – 18.095 MHz (CW)

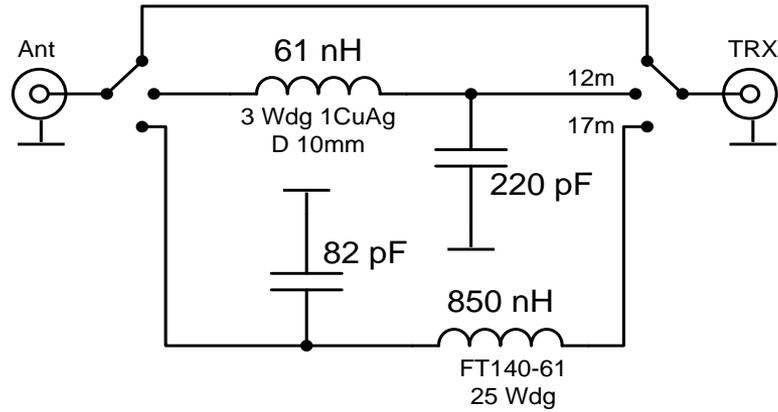


Realisation



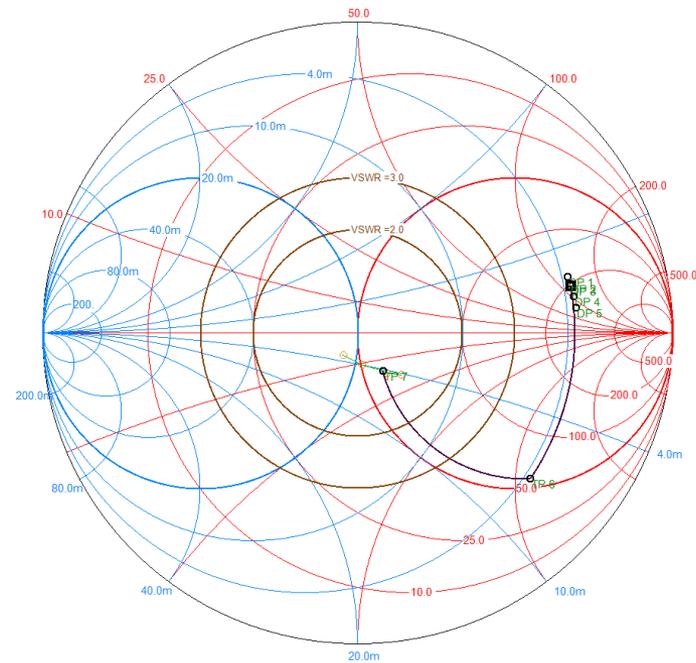
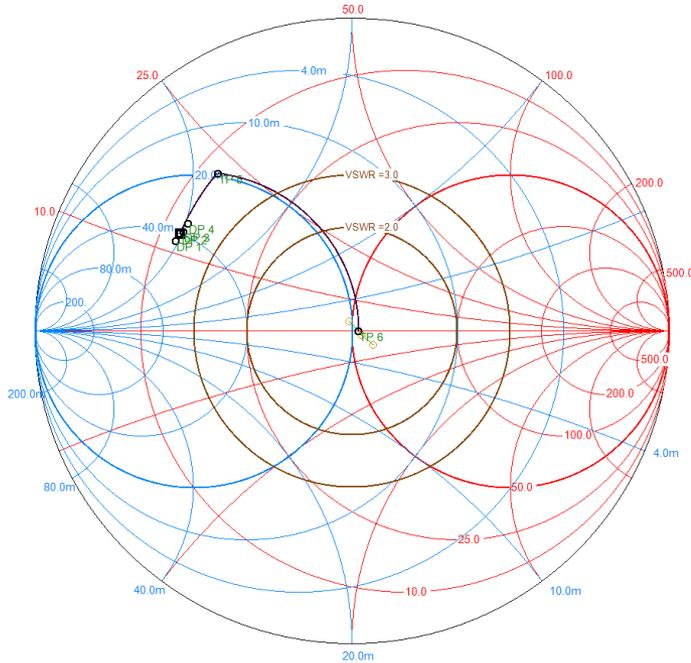
Anpassnetzwerke

Realisation



12m: 24.890 – 24.915 MHz (CW)

17m: 18.068 – 18.095 MHz (CW)



Software: Smith V4.1

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Danke fürs Zuhören



USKA HB9F 10.2022

Fritz Dellsperger HB9AJY