

aktive Antenne für den Frequenzbereich von ca. 100 MHz bis ca. 3 GHz --- Ingenieurbüro Baumann -
-- www.leobaumann.com --- 25. März 2007

- `reset:DIGITS:=16:Z0:=50:v:=float(10^(16/20)):`

Liste der betrachteten Frequenzen zu den Idizes

- `f:=[100,200,400,600,800,1000,1200,1400,1600,1800,2000,2200,2400,2600,2800,3000]:`

Scattering-Parameter des BGA2012 von Philips

- `s11b1:=[0.775,0.761,0.709,0.646,0.581,0.519,0.461,0.401,0.350,0.313,0.289,0.278,0.276,0.286,0.293,0.287]:`
- `s11w1:=[-8.390,-16.37,-31.51,-44.97,-56.47,-66.59,-75.41,-83.99,-93.12,-102.0,-110.6,-118.5,-125.0,-131.9,-136.5,-141.6]:`
- `s12b1:=[0.005,0.011,0.020,0.028,0.034,0.039,0.043,0.047,0.051,0.054,0.058,0.062,0.066,0.072,0.076,0.083]:`
- `s12w1:=[84.9,79.39,72.23,66.03,61.82,58.86,58.07,57.92,57.26,57.37,58.10,57.66,56.08,60.98,60.21,61.36]:`
- `s21b1:=[12.527,12.154,11.213,10.139,9.061,8.131,7.254,6.461,5.869,5.256,4.778,4.394,4.051,3.793,3.571,3.326]:`
- `s21w1:=[171.1,163.1,148.6,136.4,126.1,117.3,109.5,103.1,96.39,90.46,85.58,81.16,77.28,74.34,70.27,67.39]:`
- `s22b1:=[0.742,0.731,0.689,0.631,0.573,0.519,0.469,0.428,0.396,0.369,0.348,0.336,0.333,0.316,0.308,0.272]:`
- `s22w1:=[-6.684,-13.15,-24.85,-34.90,-43.40,-50.54,-57.19,-64.08,-70.03,-75.33,-80.47,-85.37,-89.83,-92.61,-94.44,-99.52]:`

Lastimpedanz des BGA 2012

- `ZL:=50+0*I:`

Funktionen zur Umrechnung der S-Parameter in Z-Parameter

- `Z11:=(S11,S12,S21,S22)->Z0*((1+S11)*(1-S22)+S12*S21)/((1-S11)*(1-S22)-S12*S21):`
- `Z12:=(S11,S12,S21,S22)->Z0*2*S12/((1-S11)*(1-S22)-S12*S21):`
- `Z21:=(S11,S12,S21,S22)->Z0*2*S21/((1-S11)*(1-S22)-S12*S21):`
- `Z22:=(S11,S12,S21,S22)->Z0*((1+S22)*(1-S11)+S12*S21)/((1-S11)*(1-S22)-S12*S21):`
- `DZ :=Z11*Z22-Z12*Z21:`
- `ZIn:=(z11,z12,z21,z22,zL)->(Z11*ZL+DZ)/(ZL+Z22):`

Berechnung der Liste der Z-Parameter sowie ZIn vom BGA2012

- `for k from 1 to 16 do`
 `h:=rectform(float(Z11(s11b1[k]*exp(I*s11w1[k]),s12b1[k]*exp(I*s12w1[k]),s21b1[k]*exp(I*s21w1[k]),s22b1[k]*exp(I*s22w1[k]))):Z111[k]:=h:`
 `h:=rectform(float(Z12(s11b1[k]*exp(I*s11w1[k]),s12b1[k]*exp(I*s12w1[k]),s21b1[k]*exp(I*s21w1[k]),s22b1[k]*exp(I*s22w1[k]))):Z121[k]:=h:`
 `h:=rectform(float(Z21(s11b1[k]*exp(I*s11w1[k]),s12b1[k]*exp(I*s12w1[k]),s21b1[k]*exp(I*s21w1[k]),s22b1[k]*exp(I*s22w1[k]))):Z211[k]:=h:`
 `h:=rectform(float(Z22(s11b1[k]*exp(I*s11w1[k]),s12b1[k]*exp(I*s12w1[k]),s21b1[k]*exp(I*s21w1[k]),s22b1[k]*exp(I*s22w1[k]))):Z221[k]:=h:`

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k]), s21b1[k]*exp(I*s21w1[k]), s22b1[k]*exp(I*s22w1[k]))):Z221[k]:=
h:
h:=Z111[k]*Z221[k]-Z121[k]*Z211[k]:
h:=(Z111[k]*ZL+h)/(ZL+Z221[k]):ZIn1[k]:=h:
end_for:

```

T-Hochpassfilter 88 MHz vor den Halbleitern Lf in nH, Cf1, Cf2, Cf3 in pF

- $Z_{fi} := \text{float}(\sqrt{\text{Re}(\text{op}(\text{op}(Z_{In1}, 1), 2))^2 + \text{Im}(\text{op}(\text{op}(Z_{In1}, 1), 2))^2} * 1.25)$
- $L_f := \text{float}(Z_{fi}/2/\pi/108e6/2)$; $L_{fp} := \text{float}(L_f/1e-9)$; $C_f := \text{float}(1/(Z_{fi}*2*\pi*108e6))$; $C_{fp} := \text{float}(C_f/1e-12)$; $C_{fp} := \text{float}(C_f/1e-12/2)$; $C_{fp} := \text{float}(C_f/1e-12)$;

26.78072729434145

40.54528798862027

20.27264399431014

40.54528798862027

gewählte Bauelemente und Resonanzfrequenz des Hochpassfilters in MHz

- $C_f := 47e-12$; $L_f := 39e-9$; $f_{rf} := \text{float}(1/(2*\pi*\sqrt{C_f*2*L_f}))/1e6$;

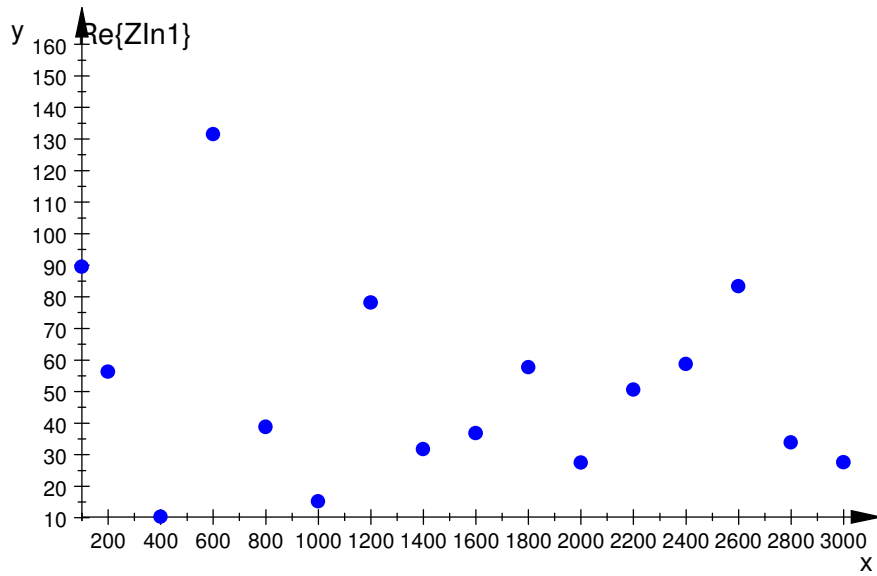
83.12351530832555

Berücksichtigung der vorliegenden Filterschaltung bei der Eingangsimpedanz des BGA2012

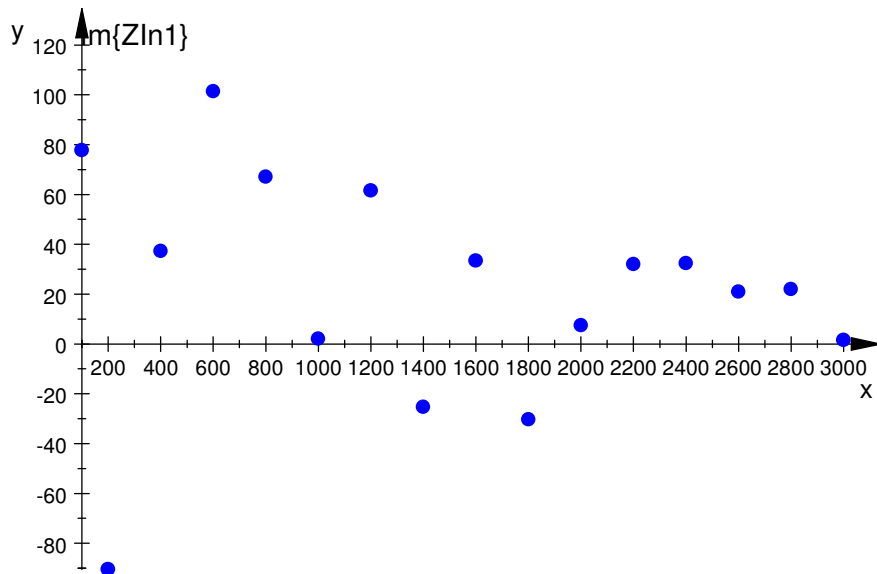
- for k from 1 to 16 do
 $Z_{C3} := 1/(I*2*\pi*f[k]*1e6*C_f)$;
 $Y_{L2} := 1/(I*2*\pi*f[k]*1e6*L_f)$;
 $Z_{C2} := 1/(I*2*\pi*f[k]*1e6*C_f/2)$;
 $Y_{L1} := 1/(I*2*\pi*f[k]*1e6*L_f)$;
 $Z_{C1} := 1/(I*2*\pi*f[k]*1e6*C_f)$;
 $h := \text{float}(1/(1/(1/(1/(Z_{In1}[k]+Z_{C3})+Y_{L2})+Z_{C2})+Y_{L1})+Z_{C1}))$; $Z_{In1}[k] := h$;
end_for:

die Impedanz am Filtereingang, Realteil, Imaginärteil und Betrag

- $\text{plot}(\text{plot}::\text{PointList2d}([\text{op}(f, k), \text{Re}(\text{op}(\text{op}(Z_{In1}, k), 2))], \$k=1..16], \text{PointSize}=2, \text{Color}=\text{RGB}::\text{Blue}, \text{TitlePosition}=[300, 160], \text{Title}=\text{"Re}\{Z_{In1}\}", \text{TicksNumber}=\text{High}))$;



- `plot(plot::PointList2d([[op(f,k),Im(op(op(ZIn1,k),2))]] $ k=1..16],PointSize=2,Color=RGB::Blue,TitlePosition=[300,120],Title="Im{ZIn1}",TicksNumber=High)):`



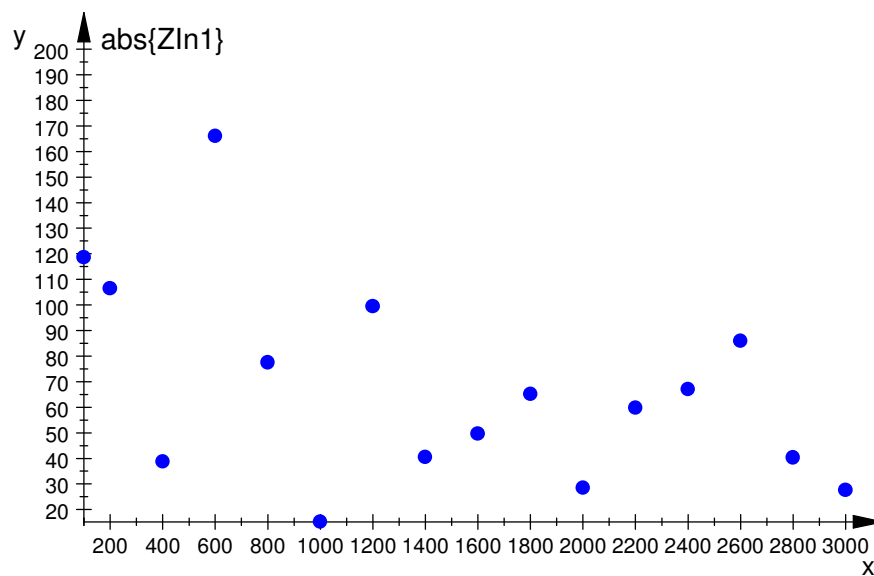
- `ZIn1;`

```

1 = 89.50702189075831 + 77.72353833452895 · i
2 = 56.18944126049609 - 90.48114838007525 · i
3 = 10.33220749988541 + 37.32039234811158 · i
4 = 131.4796331717872 + 101.427295138228 · i
5 = 38.74111029574001 + 67.08203925066983 · i
6 = 15.1252987571235 + 2.113161647920284 · i
7 = 78.13699533190847 + 61.52163548238499 · i
8 = 31.6863721313596 - 25.27037562269451 · i
9 = 36.78021771011304 + 33.38474641691842 · i
10 = 57.65512095434675 - 30.36081646799404 · i
11 = 27.46858678415768 + 7.412956923897085 · i
12 = 50.55402231636509 + 31.95954982198183 · i
13 = 58.7032143344034 + 32.3748483761332 · i
14 = 83.31988187839569 + 20.8874398224901 · i
15 = 33.84665734831852 + 21.94966509611709 · i
16 = 27.53804585458762 + 1.512606433371121 · i

```

- `plot(plot::PointList2d([[op(f,k),abs(op(op(ZIn1,k),2))]] $ k=1..16],PointSize=2,Color=RGB::Blue,TitlePosition=[400,200],Title="abs{ZIn1}",TicksNumber=High)) :`



Leitungs-Transformationsversuch zur Optimierung der Anpassung an die Antenne

- `l:=300/2000/8:for k from 1 to 16 do
bet:=2*PI/(300/f[k]):
h:=(ZIn1[k]*cos(bet*l)+I*ZL*sin(bet*l))/(I*ZIn1[k]/ZL*sin(bet*l)+cos(bet*l)):ZIn1t[k]:=float(h):
end_for:`

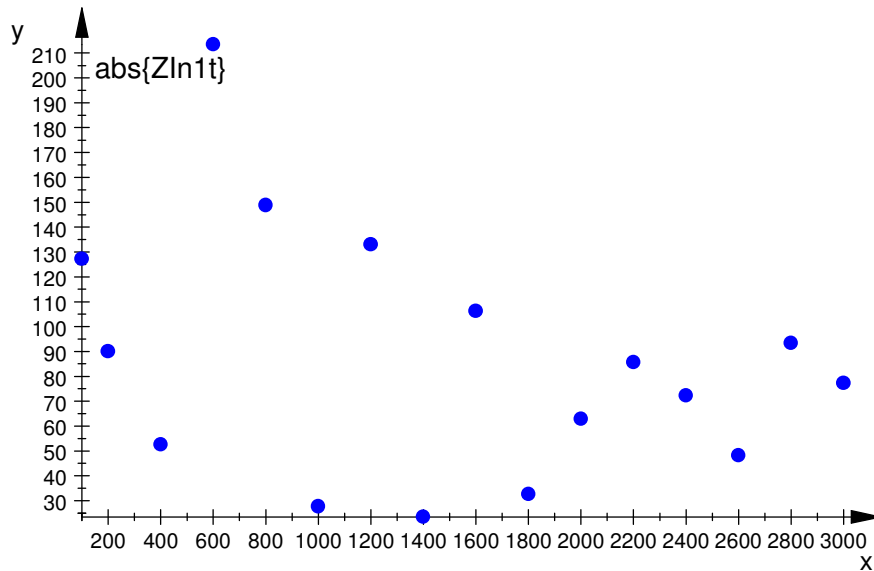
Berücksichtigung des Verkürzungsfaktors ($\epsilon_{r,eff}=3.6$) für die Leitung ergibt die mechanische Leitungslänge in mm

- `ll:=float(300/(2000*8*sqrt(3.6))*1000);`

9.882117688026185

Betrag der Eingangsimpedanz am Leitungseingang

- `plot(plot::PointList2d([[op(f,k),abs(op(op(ZIn1t,k),2))]] $ k=1..16],PointSize=2,Color=RGB::Blue,TitlePosition=[400,200],Title="abs{ZIn1t}",TicksNumber=High)):`

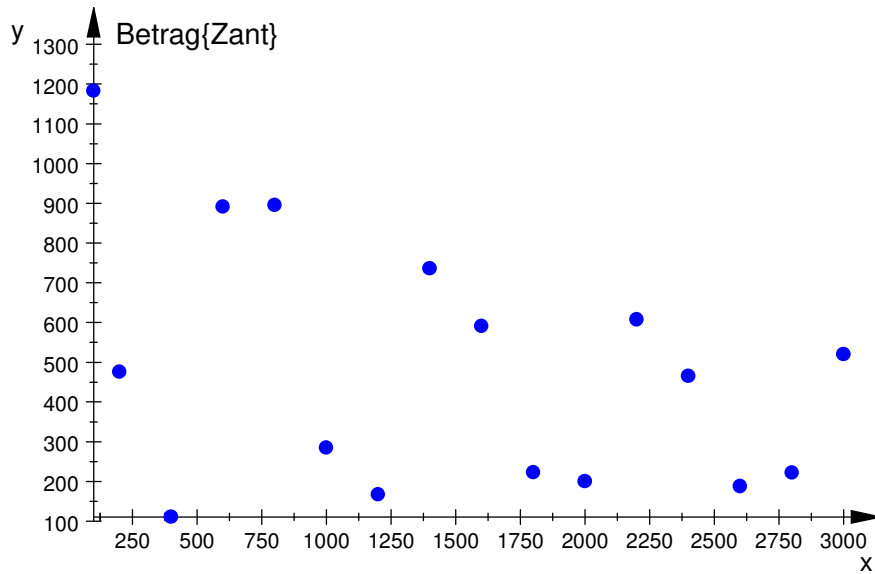


Impedanzen der Antenne berechnet mit 4NEC2 (l=0.15 m, h=10 m)

- `Zant0:=[0.73-3188*I,2.85-1540*I,11.5-663*I,26.9-321*I,50.5-112*I,84.3+46.8*I,132+182*I,201+305*I,304+420*I,469+518*I,747+544*I,1109+256*I,924-354*I,404-361*I,203-131*I,156+50.7*I]:`

Impedanzen der Antenne berechnet mit 4NEC2 (l=0.38 m, h=10 m)

- `Zant:=[3.04-1183*I,13.5-476*I,92.1+62.3*I,720+526*I,509-737*I,88.7-271*I,147+80.8*I,724+132*I,365-465*I,101-199*I,182+83.6*I,607-21.3*I,301-355*I,106-155*I,208+78.9*I,514-79.3*I]:`
- `plot(plot::PointList2d([[op(f,k),abs(Zant[k])]] $ k=1..16],PointSize=2,Color=RGB::Blue,TitlePosition=[500,1300],Title="Betrag{Zant}",TicksNumber=High)):`



U2/U0 komplex inklusive Verstärkung

- `for k from 1 to 16 do`
`h:=float(ZIn1t[k]/Zant[k]*v):u2u0[k]:=h:`
`end_for:u2u0;`

$$\begin{aligned}
 1 &= -0.4108763334976034 + 0.5403808200827502 \cdot i \\
 2 &= 1.063709679323069 + 0.5406296393781368 \cdot i \\
 3 &= 2.254472393631618 + 1.955182429359124 \cdot i \\
 4 &= 1.04420674148191 - 1.091490784454877 \cdot i \\
 5 &= -0.1165042959834376 + 1.041473352668192 \cdot i \\
 6 &= -0.3157479360272215 + 0.5239151830356798 \cdot i \\
 7 &= 3.498573290521702 - 3.575151600204024 \cdot i \\
 8 &= 0.1926480971865827 - 0.05974657590143295 \cdot i \\
 9 &= 0.4249161315959565 + 1.050965491115475 \cdot i \\
 10 &= 0.6821814385328305 + 0.6187889816127114 \cdot i \\
 11 &= 1.963773815448878 + 0.2389828700480675 \cdot i \\
 12 &= 0.8587594973584545 - 0.2329819381566352 \cdot i \\
 13 &= 0.8984052590673068 + 0.3895054203072939 \cdot i \\
 14 &= 1.489896981718605 + 0.6384683659693466 \cdot i \\
 15 &= 2.280959023045316 - 1.347133955431651 \cdot i \\
 16 &= 0.8041809860214111 + 0.4823485919452521 \cdot i
 \end{aligned}$$

U2/U0 Betrag inklusive Verstärkung

- `for k from 1 to 16 do`
`h:=float(ZIn1t[k]/Zant[k]*v):u2u0abs[k]:=abs(h):`
`end_for:u2u0abs;`

```

1 = 0.6788451901146088
2 = 1.193213597332732
3 = 2.984189019770987
4 = 1.510536279440581
5 = 1.047969462961837
6 = 0.6117057120223418
7 = 5.002171931630623
8 = 0.2017001305938018
9 = 1.133614653401262
10 = 0.921016459594517
11 = 1.978261967086022
12 = 0.8898024824704456
13 = 0.9792070679731414
14 = 1.620936417777631
15 = 2.64906473282341
16 = 0.937745819734717

```

$20 \cdot \log(\text{abs}(U2/U0)) / \text{dB}$

- `for k from 1 to 16 do`
`h:=float(ZIn1t[k]/Zant[k]*v):u2u0abslog[k]:=20*log(10,abs(h)):`
`end_for:u2u0abslog;`

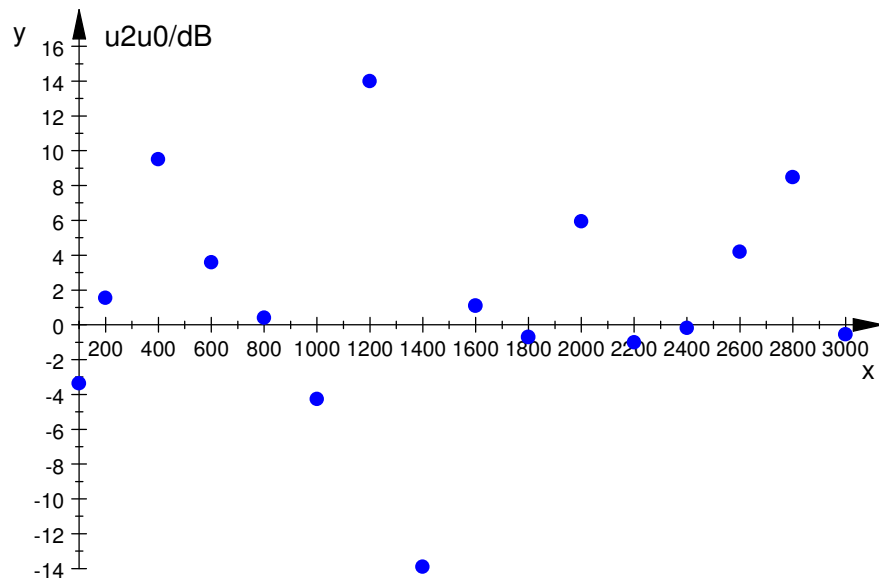
```

1 = -3.364585095968787
2 = 1.534363874908905
3 = 9.496526561291715
4 = 3.582623208824704
5 = 0.4069725563818417
6 = -4.269149282043254
7 = 13.98317229916993
8 = -13.90587641193218
9 = 1.089309021608445
10 = -0.7146521681108271
11 = 5.925676031640162
12 = -1.014127738859687
13 = -0.1825092084912097
14 = 4.195319594318953
15 = 8.461851417847338
16 = -0.5582972632502957

```

$20 \cdot \log(\text{abs}(U2/U0)) / \text{dB}$

- `plot(plot::PointList2d([[op(f,k),op(op(u2u0abslog,k),2)] $`
`k=1..16],PointSize=2,Color=RGB::Blue,TitlePosition=[400,16],Title="u`
`2u0/dB",TicksNumber=High)):`



durch Variation der Transformationsleitungslänge optimierte Summe

- `h:=0:for k from 1 to 16 do`
`h:=h+u2u0abslog[k]:`
`end_for:h;`

24.66661739733575

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