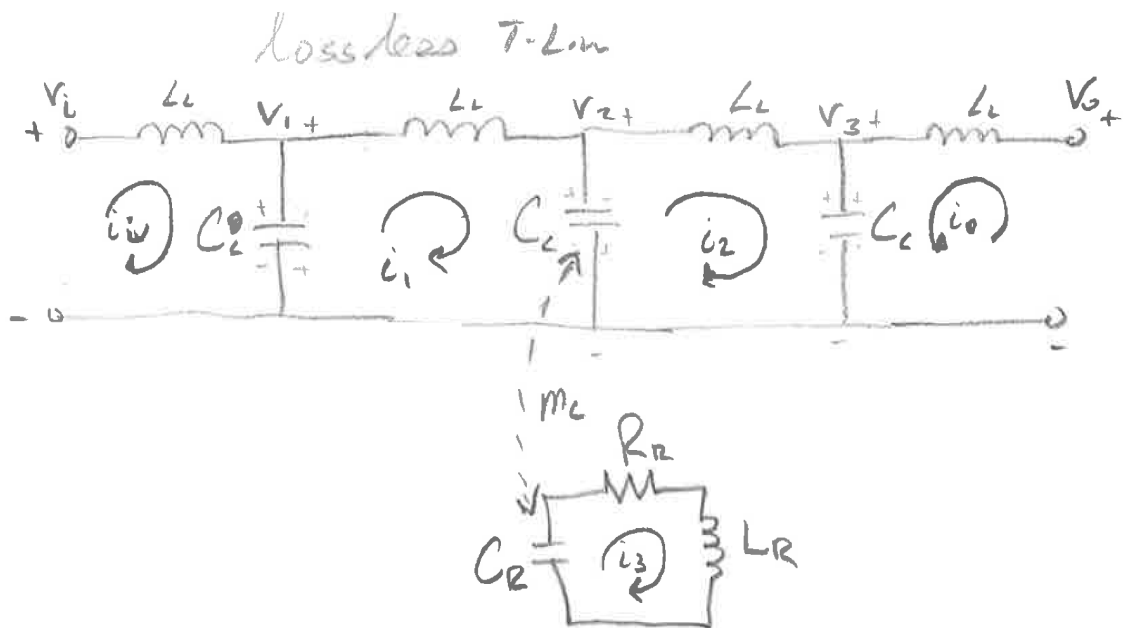


## Lossless T-Line Extension Model



| At port 1                           |  | At port 2                           |  |
|-------------------------------------|--|-------------------------------------|--|
| Open-circuit input impedance        | $z_{11} = \frac{V_1}{I_1} \Big _{I_2=0}$ | Open-circuit forward transimpedance | $z_{21} = \frac{V_2}{I_1} \Big _{I_2=0}$ |
| Open-circuit reverse transimpedance | $z_{12} = \frac{V_1}{I_2} \Big _{I_1=0}$ | Open-circuit output impedance       | $z_{22} = \frac{V_2}{I_2} \Big _{I_1=0}$ |

```

In[ ]:= EqnMatrix =
{ { (I ω (LL/2) + 1/(I ω CL)), -1/(I ω CL), 0, 0, 0 }, { -1/(I ω CL), (2/(I ω CL) + I ω LL), -1/(I ω CL), 0, I ω MC },
  { 0, -1/(I ω CL), (2/(I ω CL) + I ω LL), 1/(I ω CL), I ω MC - I ω ML }, { 0, 0, 1/(I ω CL), (I ω (LL/2) + 1/(I ω CL)), 0 },
  { 0, I ω MC, -(I ω MC - I ω ML), 0, (RR + I ω LR + 1/(I ω CR)) } };

Vector = {vi, 0, 0, vo, 0};
Ans = FullSimplify[
  LinearSolve[EqnMatrix, Vector] /. {Mc -> kc (CR CL)^(1/2), ML -> kL (LR LL)^(1/2)}];
  
```

```

In[*]:= FullSimplify[FullSimplify[
$$\frac{\frac{i3}{i \omega CL} + i4 \left( \frac{i \omega LL}{2} + \frac{1}{i \omega CL} \right)}{i1} / .$$

{ i1 → Ans[[2]], i2 → 0, i3 → Ans[[3]], i4 → Ans[[4]]} /. {vo → 1, vi → 1}]]

Out[*]= 
$$\left( -8 i CR \sqrt{CL CR} kc kL \sqrt{LL LR} \omega^2 - i CL^3 LL^4 \omega^6 \left( -1 + CR \omega \left( -i RR + (1 + kL^2) LR \omega \right) \right) + \right.$$


$$4 LL \left( -3 i + CR \omega \left( 3 RR + i (3 + kL^2) LR \omega + 5 i CL \sqrt{CL CR} kc kL \sqrt{LL LR} \omega^3 \right) \right) -$$


$$i CL LL^2 \omega^2 \left( -19 + CR \omega \left( -19 i RR + (19 + 10 kL^2) LR \omega + 12 CL \sqrt{CL CR} kc kL \sqrt{LL LR} \omega^3 \right) \right) +$$


$$2 CL^2 LL^3 \omega^4 \left( -4 i + CR \omega \left( 4 RR + i \left( (4 + 3 kL^2) LR \omega + CL \sqrt{CL CR} kc kL \sqrt{LL LR} \omega^3 \right) \right) \right) \Bigg) /$$


$$\left( 2 CL \omega \left( 2 CR kc \left( -2 CL CR kc + 3 \sqrt{CL CR} kL \sqrt{LL LR} \right) \omega^2 + \right.$$


$$CL LL^2 \omega^2 \left( -1 + CR \omega \left( -i RR + (1 + kL^2) LR \omega \right) \right) +$$


$$LL \left( 3 + CR \omega \left( 3 i RR - (3 + 2 kL^2) LR \omega + CL kc \left( 2 CL CR kc - 3 \sqrt{CL CR} kL \sqrt{LL LR} \right) \omega^3 \right) \right) \Bigg)$$


```

[i1, i2, i3, i4, i5]

[ii, i1, i2, io, i3]

```

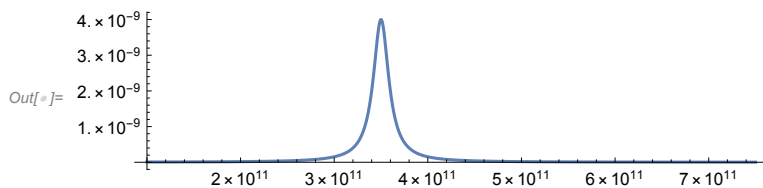
In[ ]:= Z21a[CL_, LL_, RR_, LR_, CR_, kc_, kL_, ω_] :=
  ( - 8 i CR √CL CR kc kL √LL LR ω² - i CL³ LL⁴ ω⁶ ( - 1 + CR ω ( - i RR + ( 1 + kL² ) LR ω ) ) +
    4 LL ( - 3 i + CR ω ( 3 RR + i ( 3 + kL² ) LR ω + 5 i CL √CL CR kc kL √LL LR ω³ ) ) -
    i CL LL² ω² ( - 19 + CR ω ( - 19 i RR + ( 19 + 10 kL² ) LR ω + 12 CL √CL CR kc kL √LL LR ω³ ) ) +
    2 CL² LL³ ω⁴ ( - 4 i + CR ω ( 4 RR + i ( ( 4 + 3 kL² ) LR ω + CL √CL CR kc kL √LL LR ω³ ) ) ) ) /
  ( 2 CL ω ( 2 CR kc ( - 2 CL CR kc + 3 √CL CR kL √LL LR ) ω² +
    CL LL² ω² ( - 1 + CR ω ( - i RR + ( 1 + kL² ) LR ω ) ) +
    LL ( 3 + CR ω ( 3 i RR - ( 3 + 2 kL² ) LR ω + CL kc ( 2 CL CR kc - 3 √CL CR kL √LL LR ) ω³ ) ) ) )

χ[T1_, T2_, ωs0_, ω_, γ_] := ( T1 (ωs0 - ω) / ( 1 + T2² (ωs0 - ω)² + γ² 1 T1 T2 ) + i T1 / ( 1 + T2² (ωs0 - ω)² + γ² 1 T1 T2 ) )

gL = .000025 ;
gR = .007 ;
kkc = 0.01 × 0;
kkL = 0.005 × 0;
RV = .001;
T1 = 4 × 10⁻⁹;
T2 = .1 × 10⁻⁹;
γ = 2.8 ;
Show[Plot[Im[
  χ[T1, T2, 1.4 × 250 × 10⁹, f, γ]
], {f, 100 × 10⁹, 750 × 10⁹}, PlotRange → All, AspectRatio → 1/4, PlotStyle → Automatic]
]
LR[T1_, T2_, ωs0_, ω_, γ_, Dr_, dr_, gr_] :=
  4 π 10⁻⁷ ( 1 + gr χ[T1, T2, ωs0, ω, γ] ) ( Dr / 2 ( Log[ 8 Dr / dr ] - 2 ) )

lineStyle = {Black, Dashed};
line1 = Line[{{398 × 10⁹, -6 × 10¹⁹}, {398 × 10⁹, 6 × 10¹⁹}}];
line2 = Line[{{440 × 10⁹, -6 × 10¹⁹}, {440 × 10⁹, 6 × 10¹⁹}}];

```



## Coupled Only

```

gL = 0 × 1000 × 10-8 ;
gR = 4700 × 10-8 ;
kkc = 0.255 ;
kkL = 0.065 ;
Rv = .0008;
output = Table[2 Re[
  1 - (Z21a[8.854 × 10-12, 4 π 10-7 (1 + gL χ[T1, T2, 300 × 109 i, f, γ]), Rv, LR[T1, T2,
    300 × 109 i, f, γ, 10 × 10-9, 0.095 × 10-9, gR], 1.93 × 10-10, kkc, kkL, f] /
  Z21a[8.854 × 10-12, 4 π 10-7 (1 + gL χ[T1, T2, 295 × 109 i, f, γ]), Rv, LR[T1,
    T2, 295 × 109 i, f, γ, 10 × 10-9, 0.095 × 10-9, gR], 1.93 × 10-10, kkc, kkL, f])
], {f, 255 × 109, 700 × 109, .5 × 109}, {i, 1.7, 1.2, -.025}];
Export["C:/Users/sidabras/Desktop/CoupledOnly.CSV", output, "CSV"]
Clear[output]

```

## With Transmission

```

gL = 1000 × 10-8 ;
gR = 4000 × 10-8 ;
kkc = 0.255;
kkL = 0.065;
Rv = .0008;
output = Table[2 Re[
  1 - (Z21a[8.854 × 10-12, 4 π 10-7 (1 + gL χ[T1, T2, 300 × 109 i, f, γ]), Rv, LR[T1, T2,
    300 × 109 i, f, γ, 10 × 10-9, 0.095 × 10-9, gR], 1.93 × 10-10, kkc, kkL, f] /
  Z21a[8.854 × 10-12, 4 π 10-7 (1 + gL χ[T1, T2, 295 × 109 i, f, γ]), Rv, LR[T1,
    T2, 295 × 109 i, f, γ, 10 × 10-9, 0.095 × 10-9, gR], 1.93 × 10-10, kkc, kkL, f])
], {f, 255 × 109, 700 × 109, 0.5 × 109}, {i, 1.7, 1.2, -.025}];
Export["~/Desktop/WithTransmission.CSV", output, "CSV"]
Clear[output]

```

## Only Transmission

```

gL = 1000 × 10-8 ;
gR = 4000 × 10-8 ;
kkc = 0.255 × 0;
kkL = 0.065 × 0;
Rv = .0008;
output = Table[2 Re[
  1 - (Z21a[8.854 × 10-12, 4 π 10-7 (1 + gL χ[T1, T2, 300 × 109 i, f, γ]), Rv, LR[T1, T2,
    300 × 109 i, f, γ, 10 × 10-9, 0.095 × 10-9, gR], 1.93 × 10-10, kkc, kkL, f] /
  Z21a[8.854 × 10-12, 4 π 10-7 (1 + gL χ[T1, T2, 295 × 109 i, f, γ]), Rv, LR[T1,
    T2, 295 × 109 i, f, γ, 10 × 10-9, 0.095 × 10-9, gR], 1.93 × 10-10, kkc, kkL, f])
], {f, 255 × 109, 700 × 109, 0.5 × 109}, {i, 1.7, 1.2, -.025}]; *)
(*Export["~/Desktop/OnlyTransmission.CSV",output,"CSV"]
Clear[output]

```

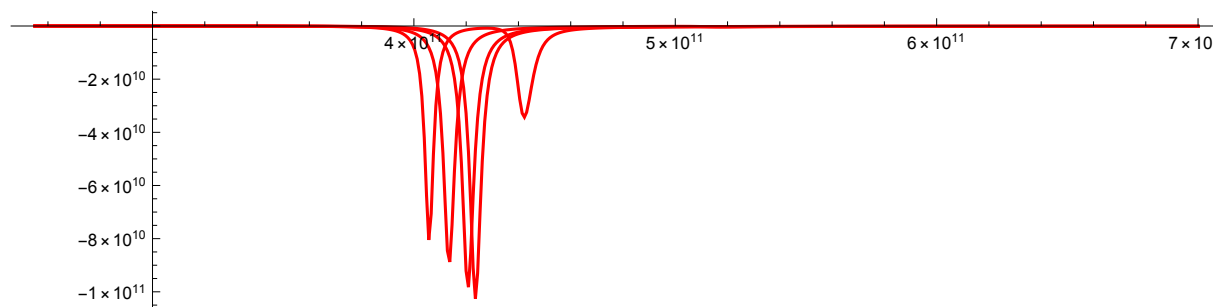
## Strong and Weak Coupling Studies

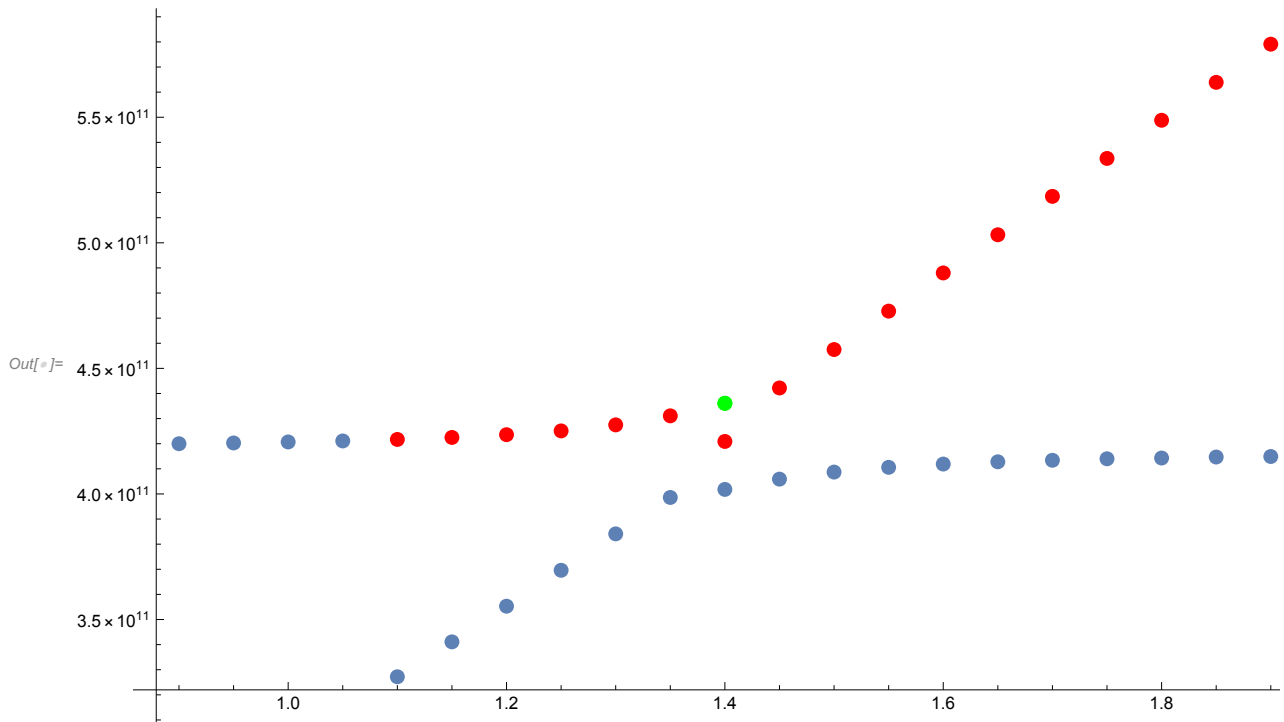
```

gL = 0 × 1000 × 10-8;
gR = 100 × 4700 × 10-8;
kkc = 0.255;
kkL = 0.065;
RV = .0008/5;
Show[Plot[Re[
  Z21a[8.854 × 10-12, 4 π 10-7 (1 + gL χ[T1, T2, 300 × 109 #, f, γ]), RV,
  LR[T1, T2, 300 × 109 #, f, γ, 10 × 10-9, 0.095 × 10-9, gR], 1.93 × 10-10, kkc, kkL, f]
], {f, 255 × 109, 700 × 109}, PlotRange → All, PlotPoints → 500, MaxRecursion → 0,
AspectRatio → 1/4, PlotStyle → Red] & /@ {1.7`, 1.45`, 1.2`, 1}, PlotRange → All]
tab1 = Table[Re[
  Z21a[8.854 × 10-12, 4 π 10-7 (1 + gL χ[T1, T2, 300 × 109 #, f, γ]), RV,
  LR[T1, T2, 300 × 109 #, f, γ, 10 × 10-9, 0.095 × 10-9, gR], 1.93 × 10-10, kkc, kkL, f]
], {f, 255 × 109, 700 × 109, .1 × 109}] & /@ Table[i, {i, 0.9, 1.9, .05}];
freq1 = {};
freq2 = {};
freq3 = {};
posout = {};
For[i = 1, i ≤ Length[tab1], i++,
  tlist = Table[i, {i, 0.9, 1.9, .05}];
  pos1 = FindPeaks[-tab1[[i]]];
  freq = Table[f, {f, 255 × 109, 700 × 109, .1 × 109}] [[pos1[[1, 1]]]];
  AppendTo[freq1, {tlist[[i]], freq}];
  If[Length[pos1] == 2,
    freq = Table[f, {f, 255 × 109, 700 × 109, .1 × 109}] [[pos1[[2, 1]]]];
    AppendTo[freq2, {tlist[[i]], freq}];
  ];
  If[Length[pos1] == 3,
    freq = Table[f, {f, 255 × 109, 700 × 109, .1 × 109}] [[pos1[[2, 1]]]];
    AppendTo[freq2, {tlist[[i]], freq}];
    freq = Table[f, {f, 255 × 109, 700 × 109, .1 × 109}] [[pos1[[3, 1]]]];
    AppendTo[freq3, {tlist[[i]], freq}];
  ];
  If[Length[pos1] == 4,
    Print["you missed!"];
  ];
];
Show[ListPlot[freq1],
  ListPlot[freq2, PlotStyle → Red],
  ListPlot[freq3, PlotStyle → Green], PlotRange → All]

```

Out[ ]=





```

In[ ]:= gL = 1 × 10-8 ;
gR = 4.7 × 10-8 ;
kkc = 0.255 ;
kkL = 0.065 ;
RV = .0008;
Show[Plot[Re[
  Z21a[8.854 × 10-12, 4 π 10-7 (1 + gL χ[T1, T2, 300 × 109 #, f, γ]), Rv,
  LR[T1, T2, 300 × 109 #, f, γ, 10 × 10-9, 0.095 × 10-9, gR], 1.93 × 10-10, kkc, kkL, f]
], {f, 255 × 109, 700 × 109}, PlotRange → All, PlotPoints → 500, MaxRecursion → 0,
  AspectRatio → 1/4, PlotStyle → Red] & /@ {1.7`, 1.45`, 1.2`, 1}, PlotRange → All]
tab1 = Table[Re[
  Z21a[8.854 × 10-12, 4 π 10-7 (1 + gL χ[T1, T2, 300 × 109 #, f, γ]), Rv,
  LR[T1, T2, 300 × 109 #, f, γ, 10 × 10-9, 0.095 × 10-9, gR], 1.93 × 10-10, kkc, kkL, f]
], {f, 255 × 109, 700 × 109, .1 × 109}] & /@ Table[i, {i, 0.9, 1.9, .005}];
freq5 = {};
freq6 = {};
For[i = 1, i ≤ Length[tab1], i++,
  tlist = Table[i, {i, 0.9, 1.9, .005}];
  pos1 = FindPeaks[-tab1[[i]]];
  freq = Table[f, {f, 255 × 109, 700 × 109, .1 × 109}] [[pos1[[1, 1]]]];
  AppendTo[freq5, {tlist[[i]], freq}];
  If[Length[pos1] == 2,
    freq = Table[f, {f, 255 × 109, 700 × 109, .1 × 109}] [[pos1[[2, 1]]]];
    AppendTo[freq6, {tlist[[i]], freq}];
  ];
]

```

Out[ ]:= \$Aborted

```
Show[ListPlot[freq1],  
ListPlot[freq2, PlotStyle -> Red],  
ListPlot[freq3, PlotStyle -> Red],  
ListLinePlot[freq5, PlotStyle -> Green], PlotRange -> All]
```

