Lossless T-Line Extension Model
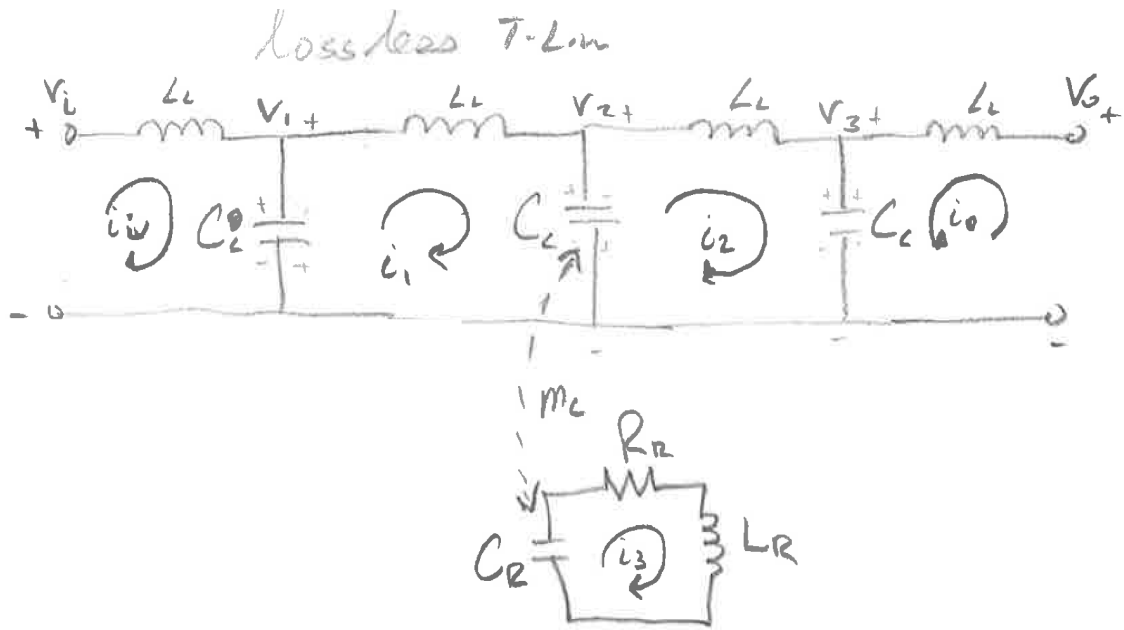
At port 1		At port 2	
Open-circuit input impedance	$z_{11} = \left.\dfrac{V_1}{I_1}\right\|_{I_2=0}$	Open-circuit forward transimpedance	$z_{21} = \left.\dfrac{V_2}{I_1}\right\|_{I_2=0}$
Open-circuit reverse transimpedance	$z_{12} = \left.\dfrac{V_1}{I_2}\right\|_{I_1=0}$	Open-circuit output impedance	$z_{22} = \left.\dfrac{V_2}{I_2}\right\|_{I_1=0}$

```
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))}};

VVector = {vi, 0, 0, vo, 0};
Ans = FullSimplify[
   LinearSolve[EqnMatrix, VVector] /. {Mc → kc (CR CL)^(1/2), ML → kL (LR LL)^(1/2)}];
FullSimplify[FullSimplify[(i3/(i ω CL) + i4 (i ω LL/2 + 1/(i ω CL)))/i1 /.
    {i1 → Ans[[2]], i2 → 0, i3 → Ans[[3]], i4 → Ans[[4]]} /. {vo → 1, vi → 1}]]
```

$$\left(-8\, i\, CR\, \sqrt{CL\, CR}\; kc\, kL\, \sqrt{LL\, LR}\; \omega^2 - i\, CL^3\, LL^4\, \omega^6 \left(-1 + CR\, \omega \left(-i\, RR + \left(1 + kL^2\right) LR\, \omega\right)\right) + \right.$$
$$4\, LL \left(-3\, i + CR\, \omega \left(3\, RR + i \left(3 + kL^2\right) LR\, \omega + 5\, i\, CL\, \sqrt{CL\, CR}\; kc\, kL\, \sqrt{LL\, LR}\; \omega^3\right)\right) -$$
$$i\, CL\, LL^2\, \omega^2 \left(-19 + CR\, \omega \left(-19\, i\, RR + \left(19 + 10\, kL^2\right) LR\, \omega + 12\, CL\, \sqrt{CL\, CR}\; kc\, kL\, \sqrt{LL\, LR}\; \omega^3\right)\right) +$$

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

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

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

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

```
Z21a[CL_, LL_, RR_, LR_, CR_, kc_, kL_, ω_] :=
```
$$\left(-8\,i\,CR\,\sqrt{CL\,CR}\,kc\,kL\,\sqrt{LL\,LR}\,\omega^2 - i\,CL^3\,LL^4\,\omega^6\left(-1 + CR\,\omega\left(-i\,RR + \left(1 + kL^2\right)LR\,\omega\right)\right) +\right.$$

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

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

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

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

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

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

```
χ[T1_, T2_, ωs0_, ω_, γ_] :=
```
$$\left(\frac{T1\left(\omega s0 - \omega\right)}{1 + T2^2\left(\omega s0 - \omega\right)^2 + \gamma^2\,1\,T1\,T2} + i\,\frac{T1}{1 + T2^2\left(\omega s0 - \omega\right)^2 + \gamma^2\,1\,T1\,T2}\right)$$

```
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[Re[
```
$$Sum\left[\left(\frac{1}{qqq^{-1}} + \frac{1}{qqq^{-2}} + \frac{1}{qqq^{-3}}\right)e^{-\frac{\left(f - qqq\,150\cdot10^9 + 6\cdot10^9\right)^2}{2\left(3\,000\,000\,000\right)^2}}, \{qqq, 1, 3, .01\}\right]$$
```
   ], {f, 50 × 10^9, 750 × 10^9},
  PlotRange → All, AspectRatio → 1/4, PlotStyle → Automatic],
 Plot[Re[
```
$$Sum\left[\left(\frac{1}{qqq^{-1}} + \frac{1}{qqq^{-2}} + \frac{1}{qqq^{-3}}\right)e^{-\frac{\left(f - qqq\,150\cdot10^9\right)^2}{2\left(3\,000\,000\,000\right)^2}}, \{qqq, 1, 3, .01\}\right]$$
```
   ], {f, 50 × 10^9, 750 × 10^9}, PlotRange → All,
  AspectRatio → 1/4, PlotStyle → {Automatic, Red}]
]
LR[T1_, T2_, ωs0_, ω_, γ_, Dr_, dr_, gr_] :=
```
$$4\,\pi\,10^{-7}\left(1 + gr\,\chi[T1, T2, \omega s0, \omega, \gamma]\right)\frac{Dr}{2}\left(Log\left[\frac{8\,Dr}{dr}\right] - 2\right)$$

Coupled Only

```
gL = 0 × 1000 × 10^-8 ;
gR = 4700 × 10^-8 ;
kkc = 0.255 ;
kkL = 0.065 ;
Rv = .0008;
output = Table[2 Re[
```
$$1 - \left(Z21a\left[8.854 \times 10^{-12}, 4\,\pi\,10^{-7}\left(1 + gL\,\chi[T1, T2, 300 \times 10^9\,i, f, \gamma]\right), Rv, LR[T1, T2, \right.\right.$$

```
        300 × 10^9 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 × 10^9 i, f, γ]), Rv, LR[T1,
        T2, 295 × 10^9 i, f, γ, 10 × 10^-9, 0.095 × 10^-9, gR], 1.93 × 10^-10, kkc, kkL, f])
   ], {f, 255 × 10^9, 700 × 10^9, .5 × 10^9}, {i, 2.0, 1.0, -.025}];
Export[C:/Users/sidabras/Desktop/CoupledOnly.CSV, output, CSV]
Clear[output]
```

With Transmission

```
gL = 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 × 10^9 i, f, γ]), Rv, LR[T1, T2,
          300 × 10^9 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 × 10^9 i, f, γ]), Rv, LR[T1,
          T2, 295 × 10^9 i, f, γ, 10 × 10^-9, 0.095 × 10^-9, gR], 1.93 × 10^-10, kkc, kkL, f])
     ], {f, 255 × 10^9, 700 × 10^9, .5 × 10^9}, {i, 2.0, 1.0, -.025}];
Export[~/Desktop/WithTransmission.CSV, output, CSV]
Clear[output]
```

Only Transmission

```
gL = 1000 × 10^-8;
gR = 4700 × 10^-8 ;
kkc = 0.255 × 0;
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 × 10^9 i, f, γ]), Rv, LR[T1, T2,
          300 × 10^9 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 × 10^9 i, f, γ]), Rv, LR[T1,
          T2, 295 × 10^9 i, f, γ, 10 × 10^-9, 0.095 × 10^-9, gR], 1.93 × 10^-10, kkc, kkL, f])
     ], {f, 255 × 10^9, 700 × 10^9, .5 × 10^9}, {i, 2.0, 1.0, -.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 × 10^9 ♯, f, γ]), Rv,
      LR[T1, T2, 300 × 10^9 ♯, f, γ, 10 × 10^-9, 0.095 × 10^-9, gR], 1.93 × 10^-10, kkc, kkL, f]
     ], {f, 255 × 10^9, 700 × 10^9}, PlotRange → All, PlotPoints → 500, MaxRecursion → 0,
    AspectRatio → 1 / 4, PlotStyle → Red] & /@ {1.7`, 1.45`, 1.2`, 1}, PlotRange → All]
tab1 = Table[Re[
```
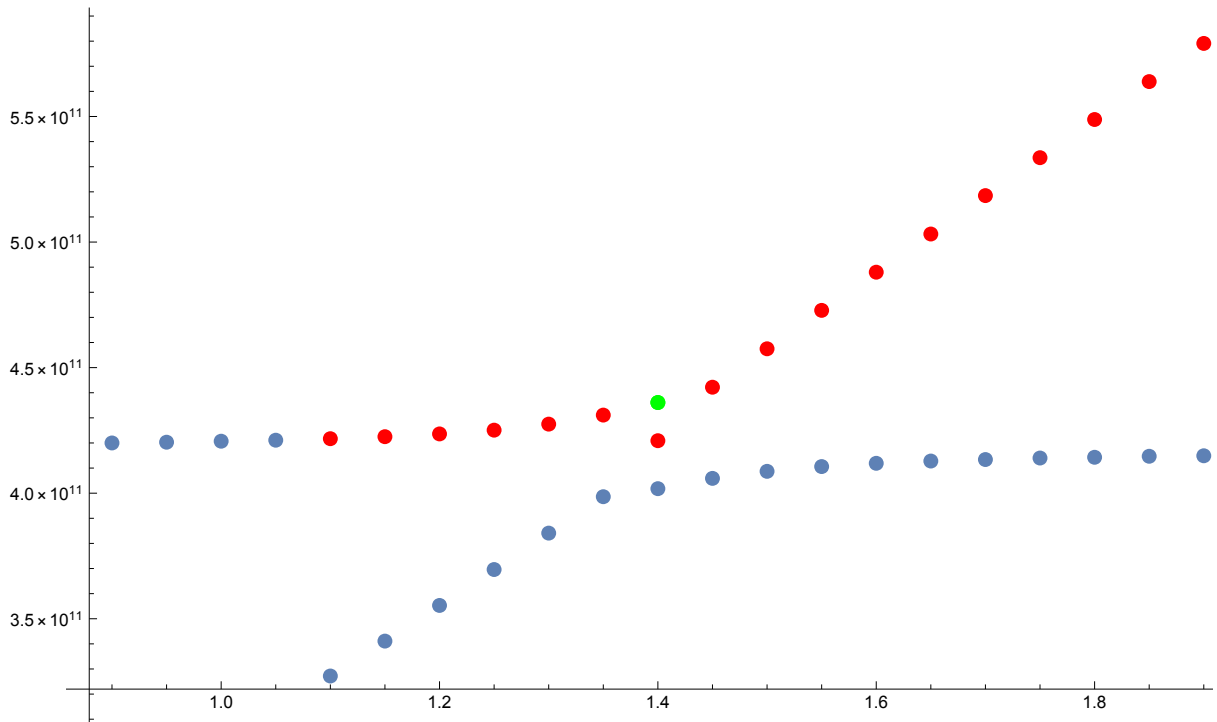
```
      Z21a[8.854 × 10⁻¹², 4 π 10⁻⁷ (1 + gL χ[T1, T2, 300 × 10⁹ ♯, f, γ]), Rv,
        LR[T1, T2, 300 × 10⁹ ♯, f, γ, 10 × 10⁻⁹, 0.095 × 10⁻⁹, gR], 1.93 × 10⁻¹⁰, kkc, kkL, f]
     ], {f, 255 × 10⁹, 700 × 10⁹, .1 × 10⁹}] & /@ Table[i, {i, 0.9, 1.9, .05}];
freq1 = {};
freq2 = {};
freq3 = {};
posout = {};
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]
```
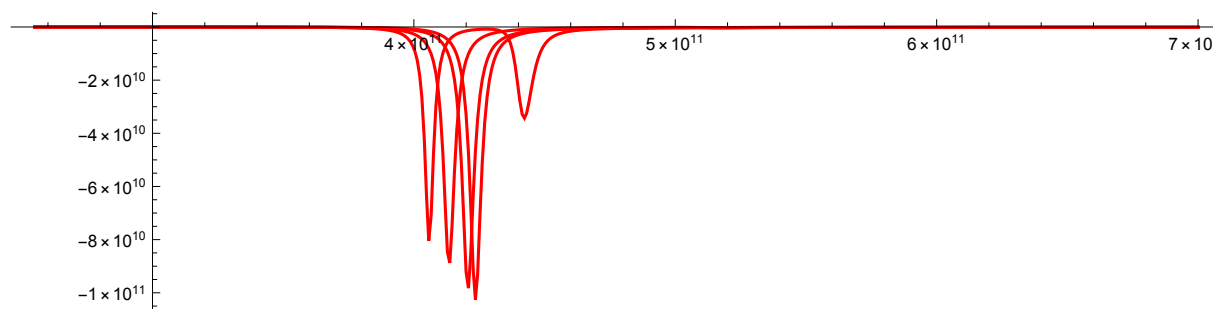
```
gL = 1 × 10⁻⁸ ;
gR = 4.7 × 10⁻⁸ ;
kkc = 0.255 ;
kkL = 0.065 ;
Rv = .0008;
Show[Plot[Re[
      Z21a[8.854 × 10⁻¹², 4 π 10⁻⁷ (1 + gL χ[T1, T2, 300 × 10⁹ ♯, f, γ]), Rv,
        LR[T1, T2, 300 × 10⁹ ♯, f, γ, 10 × 10⁻⁹, 0.095 × 10⁻⁹, gR], 1.93 × 10⁻¹⁰, kkc, kkL, f]
      ], {f, 255 × 10⁹, 700 × 10⁹}, 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}];
 ];
]

ListLinePlot[freq5, PlotStyle → Green]
```