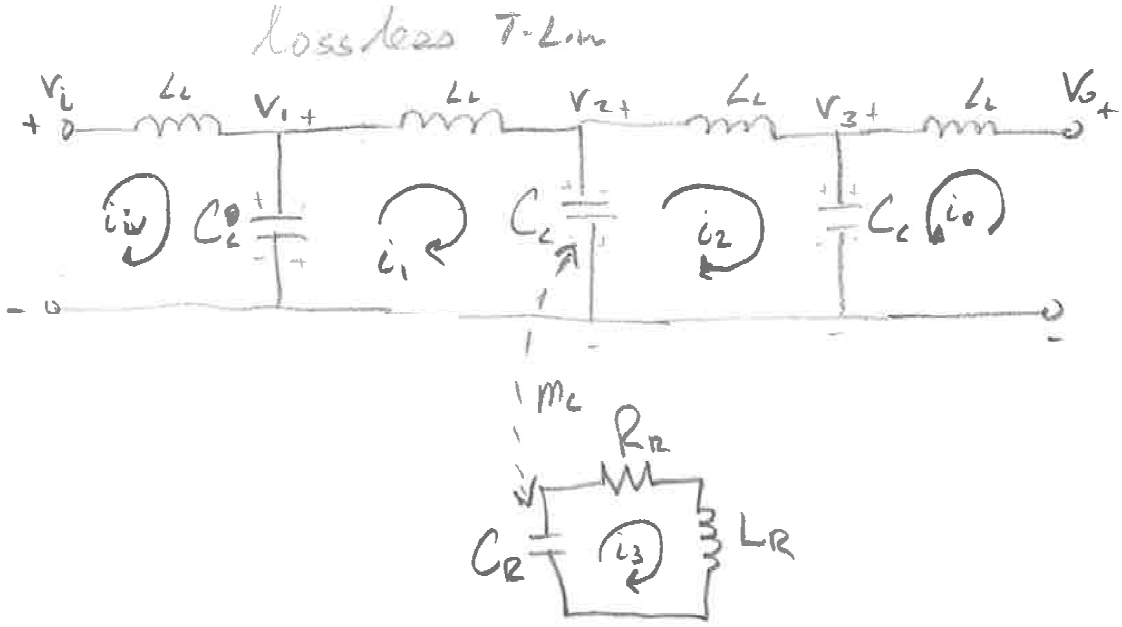
Lossless T-Line Extension Model



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	$z_{22} = \frac{V_2}{I_2}\Big\|_{I_1=0}$

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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}]]
```

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

```
    i CL LL^2 ω^2 (-19 + CR ω (-19 i RR + (19 + 10 kL^2) LR ω + 12 CL √(CL CR) kc kL √(LL LR) ω^3)) +
    2 CL^2 LL^3 ω^4 (-4 i + CR ω (4 RR + i ((4 + 3 kL^2) LR ω + CL √(CL CR) kc kL √(LL LR) ω^3)))) /
  (2 CL ω (2 CR kc (-2 CL CR kc + 3 √(CL CR) kL √(LL LR)) ω^2 +
      CL LL^2 ω^2 (-1 + CR ω (-i RR + (1 + kL^2) LR ω)) +
      LL (3 + CR ω (3 i RR - (3 + 2 kL^2) LR ω + CL kc (2 CL CR kc - 3 √(CL CR) kL √(LL LR)) ω^3))))

Z21a[CL_, LL_, RR_, LR_, CR_, kc_, kL_, ω_] :=
  (-8 i CR √(CL CR) kc kL √(LL LR) ω^2 - i CL^3 LL^4 ω^6 (-1 + CR ω (-i RR + (1 + kL^2) LR ω)) +
    4 LL (-3 i + CR ω (3 RR + i (3 + kL^2) LR ω + 5 i CL √(CL CR) kc kL √(LL LR) ω^3)) -
    i CL LL^2 ω^2 (-19 + CR ω (-19 i RR + (19 + 10 kL^2) LR ω + 12 CL √(CL CR) kc kL √(LL LR) ω^3)) +
    2 CL^2 LL^3 ω^4 (-4 i + CR ω (4 RR + i ((4 + 3 kL^2) LR ω + CL √(CL CR) kc kL √(LL LR) ω^3)))) /
  (2 CL ω (2 CR kc (-2 CL CR kc + 3 √(CL CR) kL √(LL LR)) ω^2 +
      CL LL^2 ω^2 (-1 + CR ω (-i RR + (1 + kL^2) LR ω)) +
      LL (3 + CR ω (3 i RR - (3 + 2 kL^2) LR ω + CL kc (2 CL CR kc - 3 √(CL CR) kL √(LL LR)) ω^3))))

χ[T1_, T2_, ωs0_, ω_, γ_] := (T1 (ωs0 - ω)) / (1 + T2^2 (ωs0 - ω)^2 + γ^2 1 T1 T2) +
  i T1 / (1 + T2^2 (ωs0 - ω)^2 + γ^2 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[Re[
    Sum[(1/qqq^-1 + 1/qqq^-2 + 1/qqq^-3) e^-((f-qqq 150 10^9+6 10^9)^2 / 2 (3000000000)^2), {qqq, 1, 3, .01}]
   ], {f, 50 * 10^9, 750 * 10^9},
  PlotRange → All, AspectRatio → 1 / 4, PlotStyle → Automatic],
 Plot[Re[
    Sum[(1/qqq^-1 + 1/qqq^-2 + 1/qqq^-3) e^-((f-qqq 150 10^9)^2 / 2 (3000000000)^2), {qqq, 1, 3, .01}]
   ], {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 π 10^-7 (1 + gr χ[T1, T2, ωs0, ω, γ]) Dr/2 (Log[8 Dr/dr] - 2)
```

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 × 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[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 × 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, .1 × 10^9}] & /@ 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 × 10^9, 700 × 10^9, .1 × 10^9}][[pos1[[1, 1]]]];
 AppendTo[freq1, {tlist[[i]], freq}];
 If[Length[pos1] == 2,
  freq = Table[f, {f, 255 × 10^9, 700 × 10^9, .1 × 10^9}][[pos1[[2, 1]]]];
  AppendTo[freq2, {tlist[[i]], freq}];
 ];
 If[Length[pos1] == 3,
  freq = Table[f, {f, 255 × 10^9, 700 × 10^9, .1 × 10^9}][[pos1[[2, 1]]]];
  AppendTo[freq2, {tlist[[i]], freq}];
  freq = Table[f, {f, 255 × 10^9, 700 × 10^9, .1 × 10^9}][[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 × 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 × 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, .1 × 10^9}] & /@ 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 × 10^9, 700 × 10^9, .1 × 10^9}][[pos1[[1, 1]]]];
 AppendTo[freq5, {tlist[[i]], freq}];
 If[Length[pos1] == 2,
  freq = Table[f, {f, 255 × 10^9, 700 × 10^9, .1 × 10^9}][[pos1[[2, 1]]]];
  AppendTo[freq6, {tlist[[i]], freq}];
 ];
]
ListLinePlot[freq5, PlotStyle → Green]
```