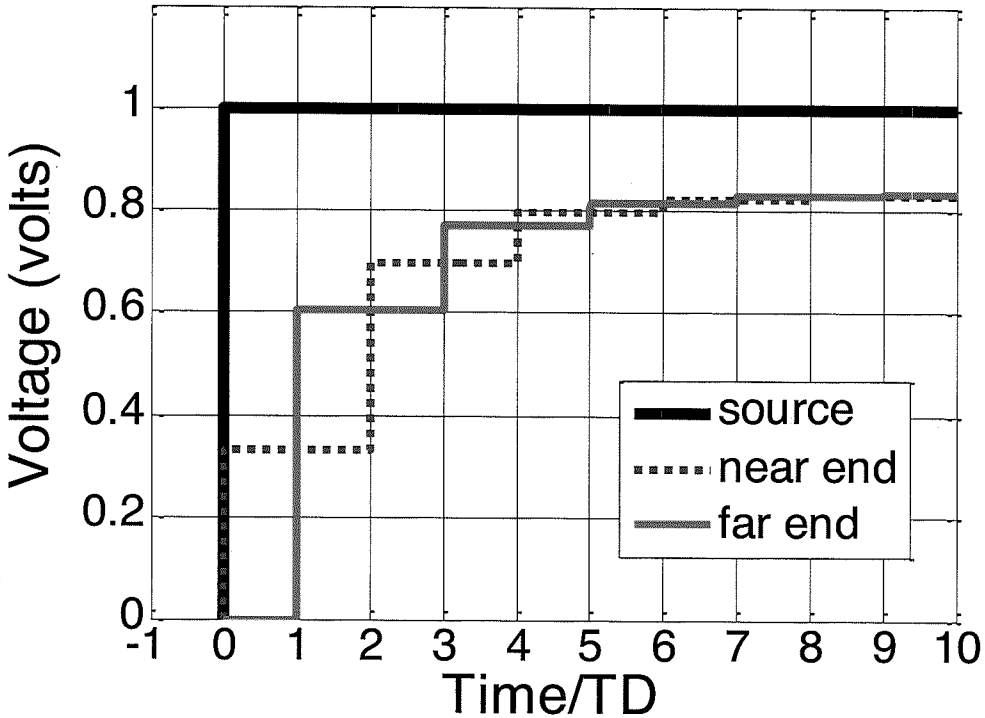
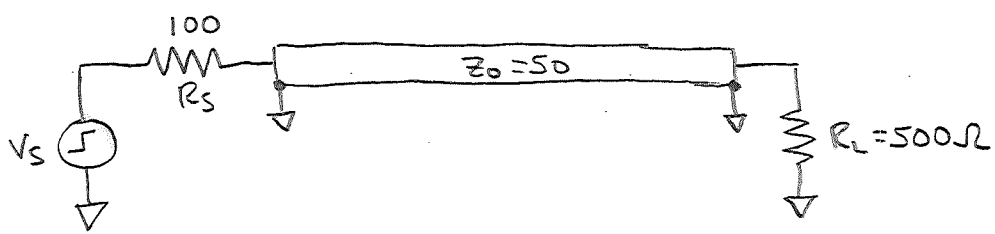
$\rho_s > 0 \quad \rho_L > 0$

$\rho_s = 0.334$
$\rho_L = 0.8182$



Underdriven Line where R_s is too large for the given Z_0. Incident wave is small, only $\frac{1}{3} V_s$



- incident wave less than $\frac{V_s}{2}$ $\therefore R_s > Z_0 \Rightarrow \rho_s > 0$
- reflection from load was positive $\therefore R_L > Z_0 \Rightarrow \rho_L > 0$

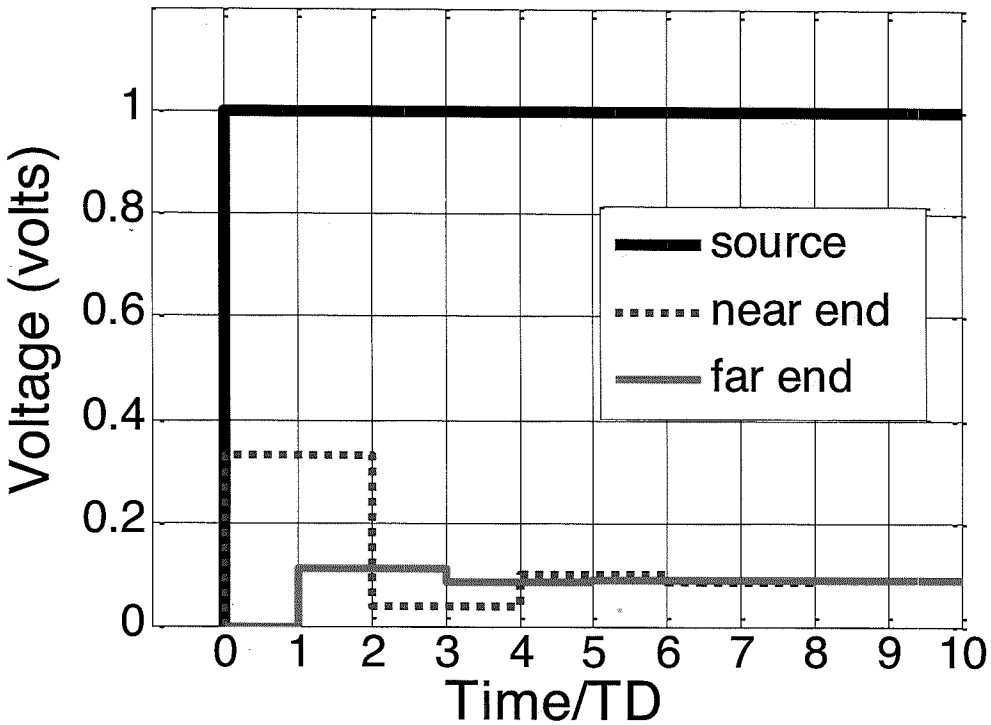
Apr 17, 15 8:41 **case1.sp**

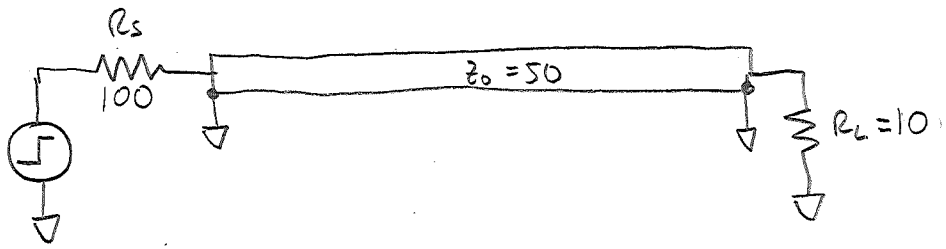
```
The four cases of Rho

*edge source, 0->1v step, delay=0ns, edges=100ps, pulse=20ns
Vin vin 0 PULSE(0 1.0 0e-9 100p 100p 20e-9 100e-9)

t1 tline_input 0 tline_output 0 z0=50 td=1ns ; the t-line

*rho source >0, rho load >0
rsrc vin tline_input 100                    ;source resistor
rload tline_output 0 500                    ;termination resistor

.control
  set color0 = rgb:f/f/f
  set color1 = rgb:0/0/0
  set color2 = rgb:f/0/0
  op
  tran 100ps 10ns
  plot  V(tline_input) V(tline_output) xl 0.11ns 10ns
.endc

.end
```

$\rho_s > 0 \quad \rho_L < 0$

$\rho_s = .3334$

$\rho_L = -0.667$





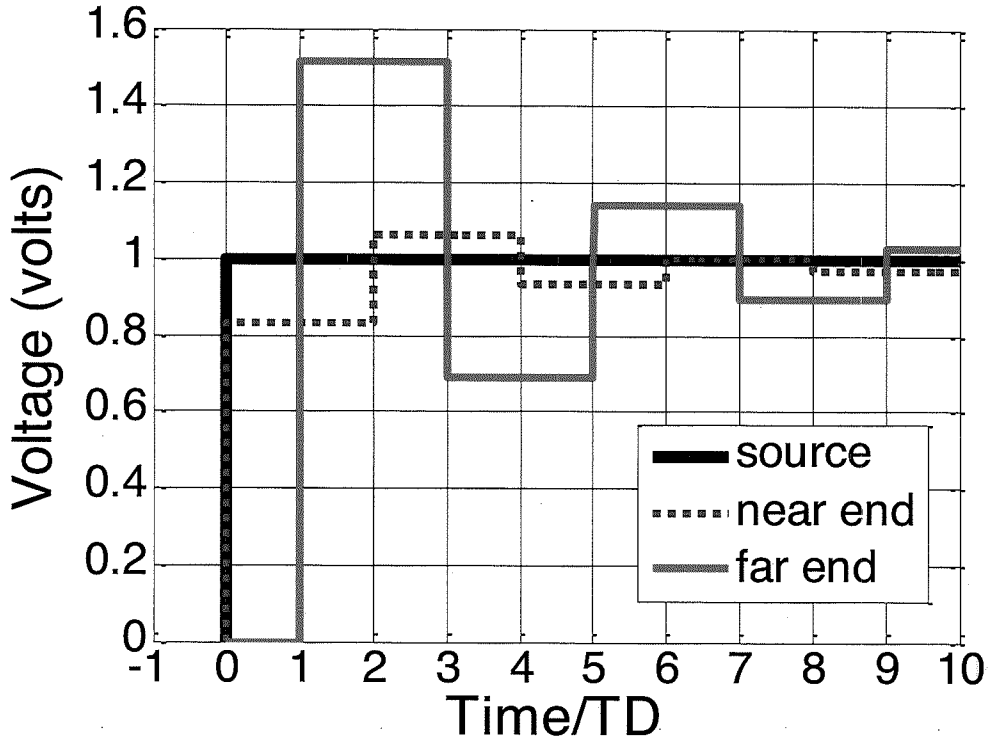
- incident wave less than $\frac{V_s}{2}$ ∴ $R_s > Z_o \rightarrow \rho_s > 0$
- Reflection from load was negative ∴ $R_L < Z_o \rightarrow \rho_L < 0$

Apr 17, 15 8:43 **case2.sp**

```
The four cases of Rho

*edge source, 0->1v step, delay=0ns, edges=100ps, pulse=20ns
Vin vin 0 PULSE(0 1.0 0e-9 100p 100p 20e-9 100e-9)

t1 tline_input 0 tline_output 0 z0=50 td=1ns ; the t-line

*rho source >0, rho load <0
rsrc vin tline_input 100                    ;source resistor
rload tline_output 0 10                     ;termination resistor

.control
  set color0 = rgb:f/f/f
  set color1 = rgb:0/0/0
  set color2 = rgb:f/0/0
  op
  tran 100ps 10ns
  plot  V(tline_input) V(tline_output) xl 0.11ns 10ns
.endc

.end
```

$\rho_s < 0,\ \rho_L > 0$

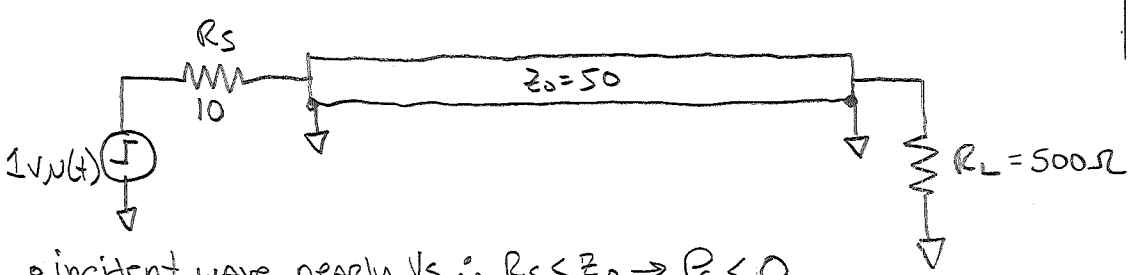
$\rho_s = -0.667$
$\rho_L = 0.8182$



Overdriven Line where R_S is much smaller than Z_0. Incident wave is $5/6 V_S$.

Apr 17, 15 8:44 **case3.sp**

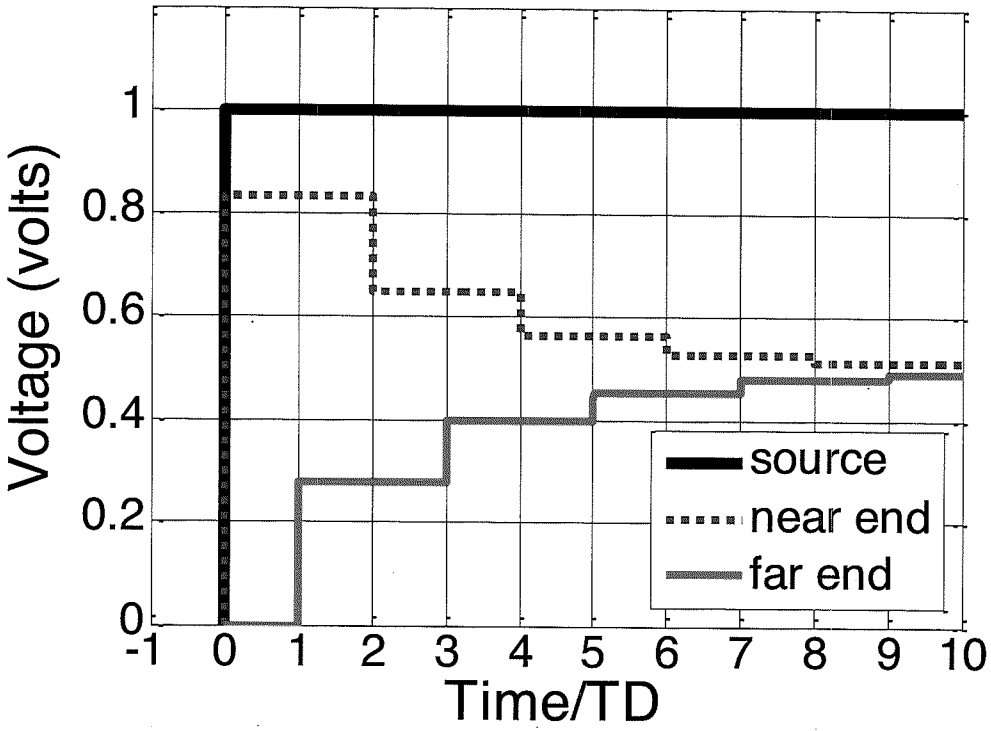
```
The four cases of Rho

*edge source, 0->1v step, delay=0ns, edges=100ps, pulse=20ns
Vin vin 0 PULSE(0 1.0 0e-9 100p 100p 20e-9 100e-9)

t1 tline_input 0 tline_output 0 z0=50 td=1ns ; the t-line

*rho source <0, rho load >0
rsrc vin tline_input 10          ;source resistor
rload tline_output 0 500         ;termination resistor

.control
  set color0 = rgb:f/f/f
  set color1 = rgb:0/0/0
  set color2 = rgb:f/0/0
  op
  tran 100ps 10ns
  plot  V(tline_input) V(tline_output) xl 0.11ns 10ns
.endc

.end
```



- incident wave nearly V_S ∴ $R_S < Z_0 \rightarrow \rho_S < 0$
- reflection from load was positive ∴ $R_L > Z_0 \rightarrow \rho_L > 0$

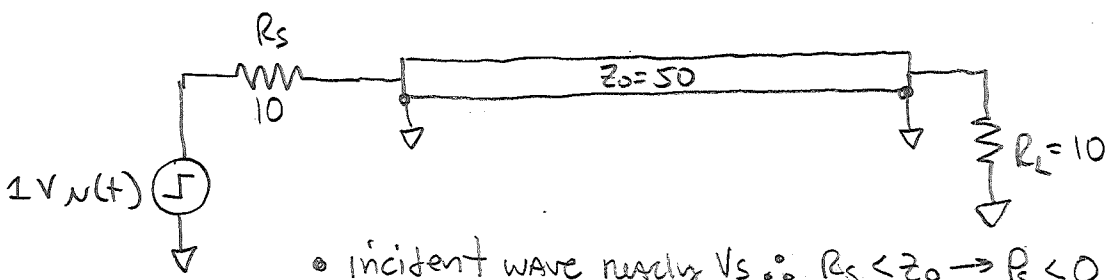
$\rho_s < 0$, $\rho_L < 0$

$\rho_s = -0.667$
$\rho_L = -0.667$



Apr 17, 15 8:46 **case4.sp**

```
The four cases of Rho

*edge source, 0->1v step, delay=0ns, edges=100ps, pulse=20ns
Vin vin 0 PULSE(0 1.0 0e-9 100p 100p 20e-9 100e-9)

t1 tline_input 0 tline_output 0 z0=50 td=1ns ; the t-line

*rho source <0, rho load <0
rsrc vin tline_input 10                ;source resistor
rload tline_output 0 10                ;termination resistor

.control
  set color0 = rgb:f/f/f
  set color1 = rgb:0/0/0
  set color2 = rgb:f/0/0
  op
  tran 100ps 10ns
  plot  V(tline_input) V(tline_output) xl 0.11ns 10ns
.endc

.end
```



- incident wave nearly Vs ∴ $R_s < Z_0 \rightarrow \rho_s < 0$
- reflection from load is negative ∴ $R_L < Z_0 \rightarrow \rho_L < 0$