ECE 546 HOMEWORK No 5 Due Friday, March 13, 2026

Solutions

1. Write a code to simulate the response of a lossy twisted-pair 100-meter cable terminated with linear resistive loads. Test your program using the example shown below. Use $Z_1 = 50\ \Omega$ and $Z_2 = 10\ k\Omega$.

The characteristic impedance of the lossy line is given by $Z_o(f) = \sqrt{\dfrac{Z(f)}{Y(f)}} = \sqrt{\dfrac{R+j\omega L}{G+j\omega C}}$

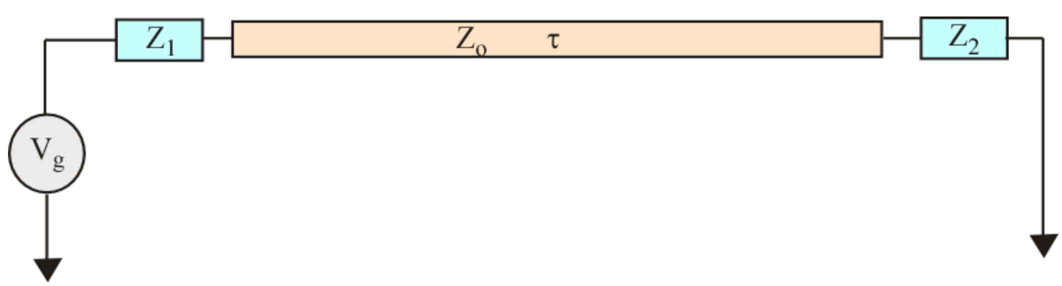
The propagation constant is $\gamma = \sqrt{Z(f)Y(f)} = \sqrt{(R+j\omega L)(G+j\omega C)} = \alpha + j\beta$

The parameters of the cable are L = 145 nH/m, C =14 pf/m. Ignore the dielectric loss (G = 0). The skin effect resistance is: $R_o = 5.0\ \Omega/m - \sqrt{GHz}$. Show near and far end plots for two different loss models:

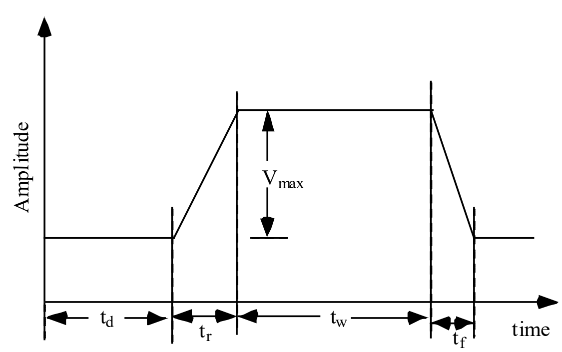
(a) $Z(f) = R_o\sqrt{f} + jL\omega$

(b) $Z(f) = R_o\sqrt{f} + jR_o\sqrt{f} + jL\omega$

Which model is correct? Why?



The pulse characteristics for $V_g(t)$ are as shown in the figure below, with time delay: t_d = 5 ns, rise time: t_r = 2 ns, fall time: t_f = 2 ns, pulse width: t_w = 20 ns, pulse amplitude: V_{max} = 1 volt



```
all;
%TL-1
l=100.0;
lind=145.0;
cap=0.014;
rdc=0.000000001;
ro=5.00000000003;
gond=0.0000000001;
fstart=0.00001;
fstop=.5;
ax=5.0;
ris=2.0;
fal=2.0;
wid=20.0;
%------
% %TL-2
% l=.335;
% lind=418.0;
% cap=0.093;
% rdc=200.0000000001;
% ro=0.00000000003;
% gond=0.0000000001;
% fstart=0.00001;
% fstop=5;
% ax=5;
% ris=2;
% fal=2;
% wid=20.0;
%------
pi=3.14159;
m=3201;
z1=50.0;
z2=10000.0;
fstep=(fstop-fstart)/(m-1);
tstep=1.0/(fstep*(m-1));
mag=1.0;
for c=1:m
        tim=(c-1)*tstep;
        tme(c)=tim;
  zet=Sub_timecomp(tim,ax,ris,fal,wid);
       vst(c)=zet;
 end
%plot(tme,vst,'r');
vss=fft(vst);
vsr=real(vss);
vsi=imag(vss);
for c=1:m
    fre(c)=(c-1)*fstep;
end
%plot(fre,vsr,'r',fre,vsi,'r');
for p=1:m
freq=fstart+(p-1)*fstep;
sincx=Sub_pulf(ax,ris,fal,wid,mag,freq);
omeg=2*pi*freq;
rskin=ro*sqrt(freq);
res=rdc+rskin;
xskin=rskin;
```

```
%xskin=0.0;
zmat=res+i*(xskin+omeg*lind);
ymat=gond*freq+i*omeg*cap;
g=sqrt(ymat*zmat);
zc=sqrt(zmat/ymat);
ef=exp(-g*l);
ef2=ef*ef;
t1=zc/(zc+z1);
g1=(z1-zc)/(z1+zc);
g2=(z2-zc)/(z2+zc);
vs=sincx;
a=t1*vs/(1-g1*g2*ef2);
b=a*g2*ef2;
%near end
z=0.0;
wpl=exp(-g*z);
wmn=exp(+g*z);
vnearf(p)=a*wpl+b*wmn;
%far end
z=l;
wpl=exp(-g*z);
wmn=exp(+g*z);
vfarf(p)=a*wpl+b*wmn;
end
[vnr,vni]=Sub_iffget(vnearf);
[vfr,vfi]=Sub_iffget(vfarf);
lgt=length(vnr);
for col=1:lgt/16
    timet(col)=tstep*(col-1);
    vlt(col)=2.0*vnr(col)/(tstep);
    vll(col)=2.0*vfr(col)/(tstep);
end
plot(timet,vlt,'b',timet,vll,'r');

function [w]=Sub_pulf(ax,ris,fal,wid,mag,f)
% This subroutine calculates the transform of a pulse  */
% C- version Feb 27, 2004
% Matlab version 2/7/2009
small=1.0e-29;
pi=3.14159;
a=ax;
b=ax+ris;
c=b+wid;
d=c+fal;
om=2.0*pi*f+small;
vp=mag;
pa=-i*om*a;
pb=-i*om*b;
pc=-i*om*c;
pd=-i*om*d;
ca=exp(pa);
cb=exp(pb);
cc=exp(pc);
cd=exp(pd);
d1=cb-ca;
d2=cd-cc;
a1=vp/(om*om*(b-a));
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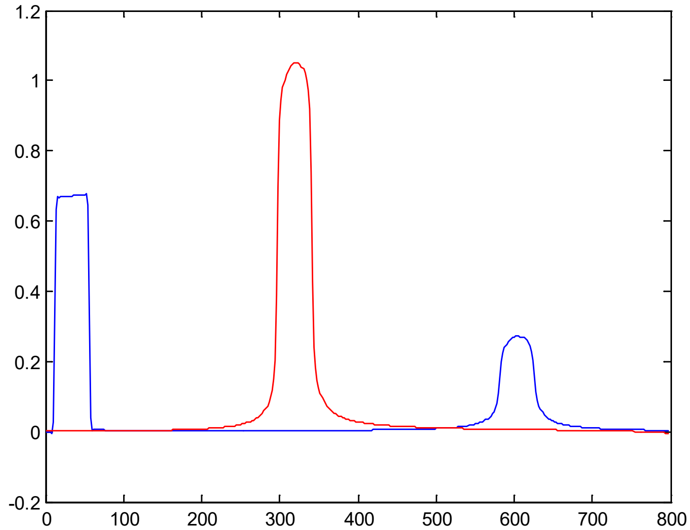
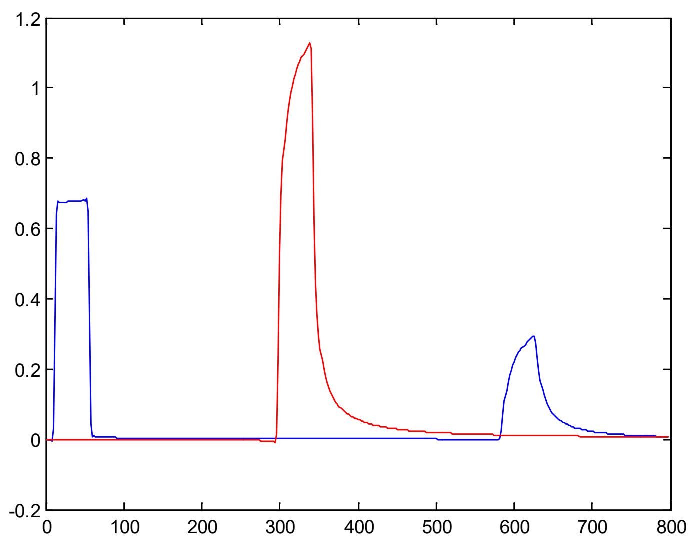
```
a2=vp/(om*om*(c-d));
w1=a1*d1;
w2=a2*d2;
w=w1+w2;
```

(a)



(b)



(b) is correct since it accounts for proximity effect. Plots show no causality violation