

Comunicazioni Elettriche L-A

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*Esercitazioni al calcolatore sulla
elaborazione dei segnali*


```
In[441]:=
```

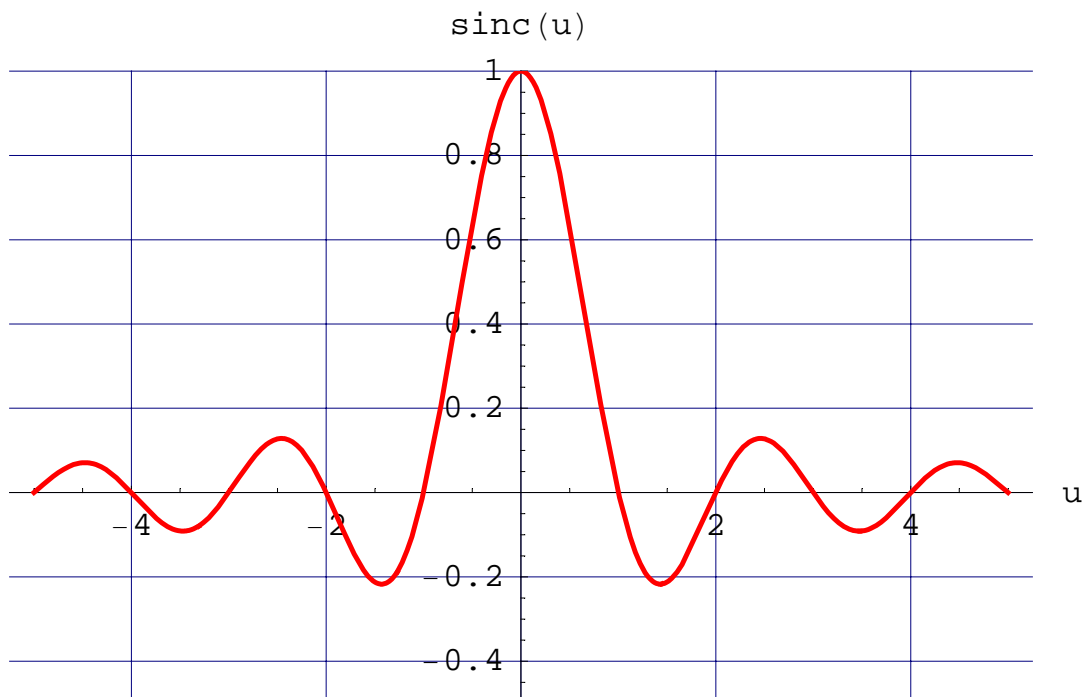
```
ClearAll["Global`*"];  
<< Graphics`Graphics`  
<< Graphics`Colors`  
(*<<Graphics`Legend`*)  
<< Statistics`ContinuousDistributions`
```

```
In[445]:=
```

```
sinc[u_] := If[u == 0, 1, Sin[ $\pi$  u] / ( $\pi$  u)]
```

```
In[446]:=
```

```
plotsinc = Plot[sinc[u], {u, -5, 5}, PlotRange → {-0.5, 1},  
  PlotStyle → {Red, Thickness[.005]}, Frame → False, GridLines → Automatic,  
  AxesLabel → {"u", "sinc(u)"}, TextStyle → {FontSize → 16}];
```



In[447]:=

```
(* impulso rect, es. variare  $\tau$ , A e verifica teor. Rayleigh *)
A := 1
 $\tau$  := 1
x[t_] := If[Abs[t] <  $\tau/2$ , A, 0]
X[f_] := A  $\tau$  sinc[f  $\tau$ ]
Xnum[f_] :=  $\int_{-\infty}^{\infty} x[t] \text{Exp}[-i 2 \pi f t] dt$ 

Energy =  $\int_{-\infty}^{+\infty} \text{Abs}[x[t]]^2 dt$ 
 $\int_{-\infty}^{+\infty} \text{Abs}[X[f]]^2 df$  (* per verifica teor. Rayleigh *)

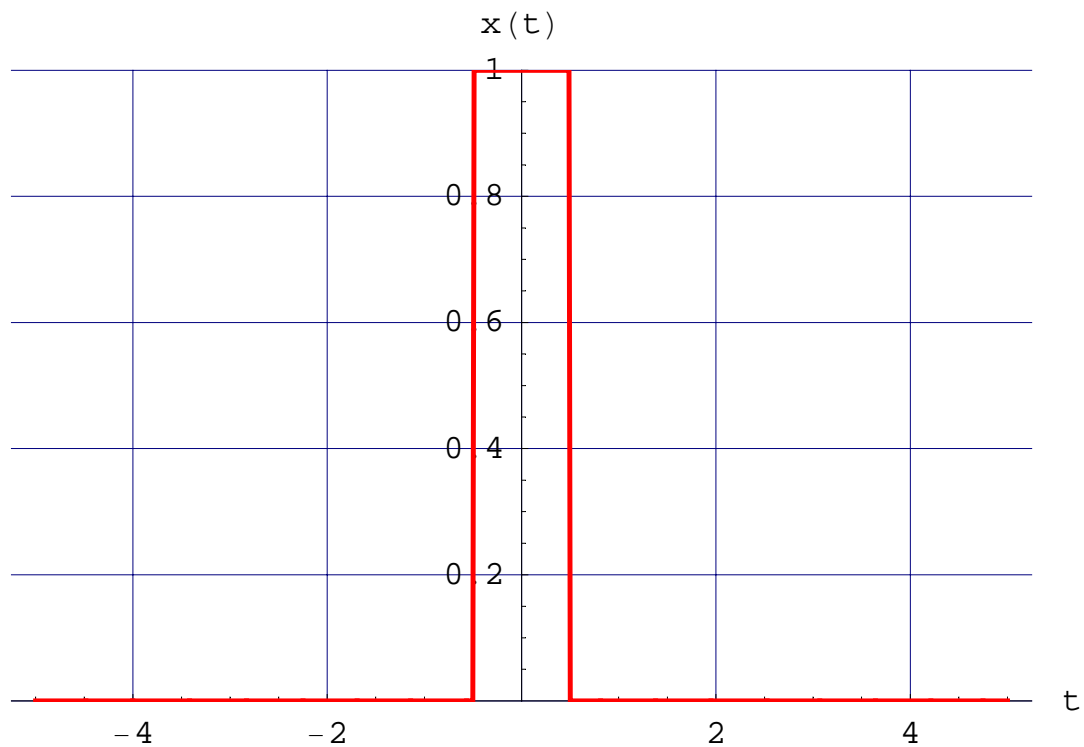
plotx = Plot[x[t], {t, -5  $\tau$ , 5  $\tau$ }, PlotRange -> {0, A},
  PlotStyle -> {Red, Thickness[.005]}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"t", "x(t)", TextStyle -> {FontSize -> 16}}];
plotX = Plot[{X[f], Xnum[f]}, {f, -5 /  $\tau$ , 5 /  $\tau$ }, PlotRange -> {-0.5 A  $\tau$ , A  $\tau$ },
  PlotStyle -> {{Blue, Thickness[.01]}, {Green, Thickness[.005]}},
  Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"f", "X(f), Xnum(f)", TextStyle -> {FontSize -> 16}}];
```

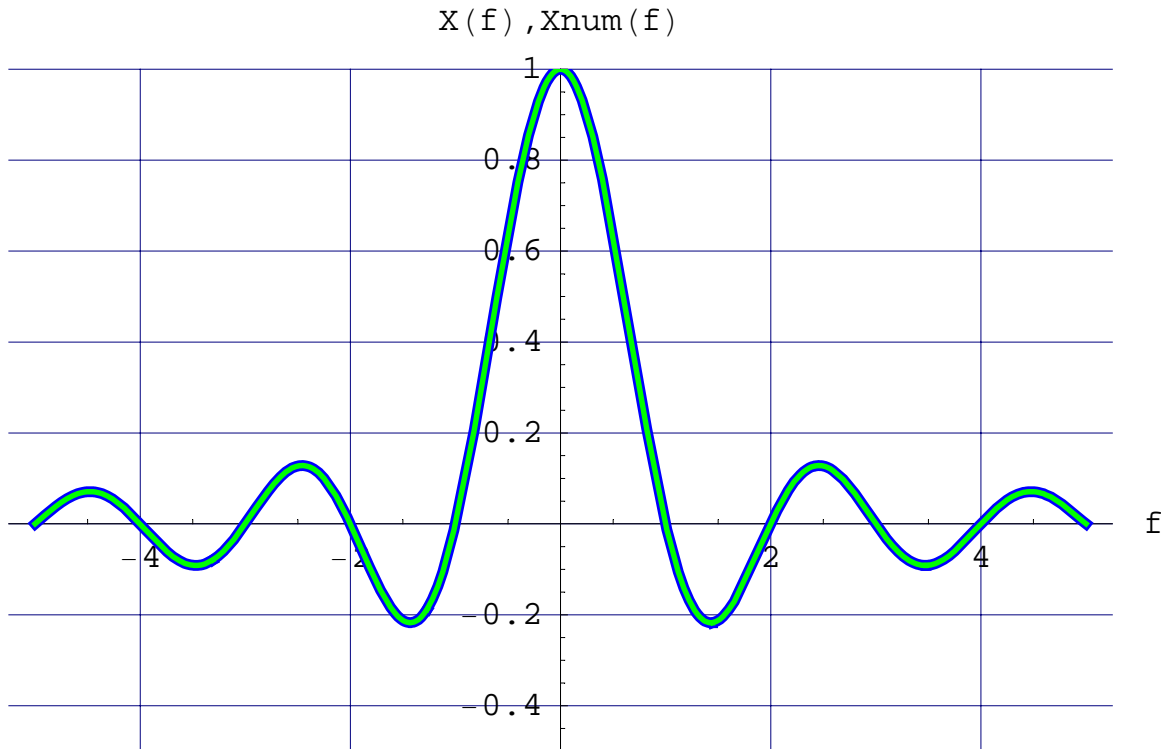
Out[452]=

1

Out[453]=

1





In[456]:=

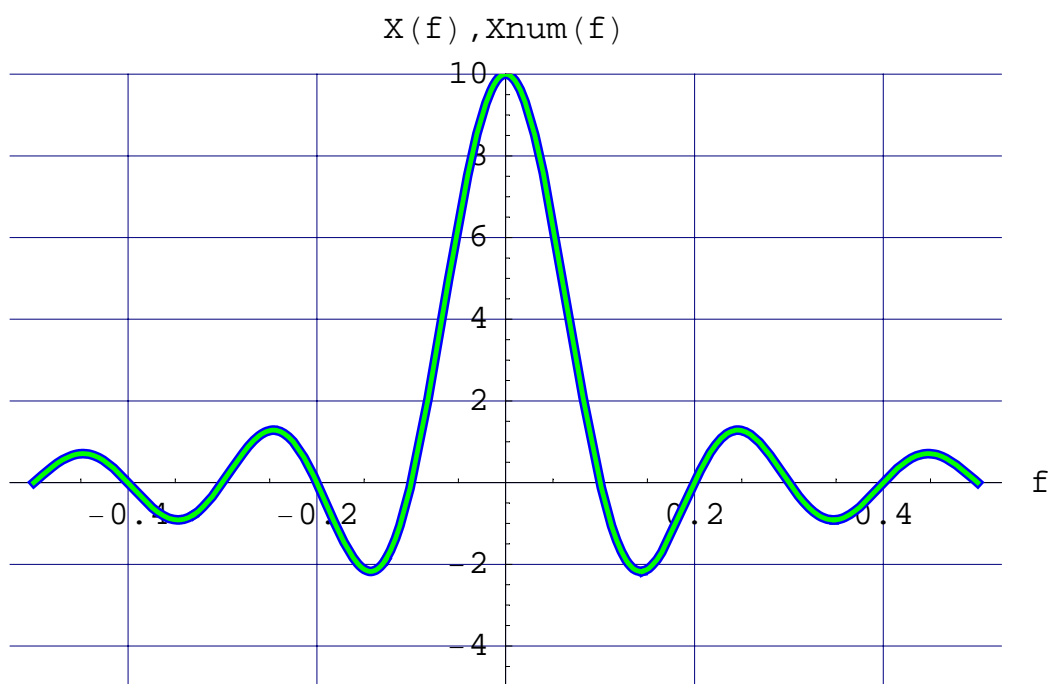
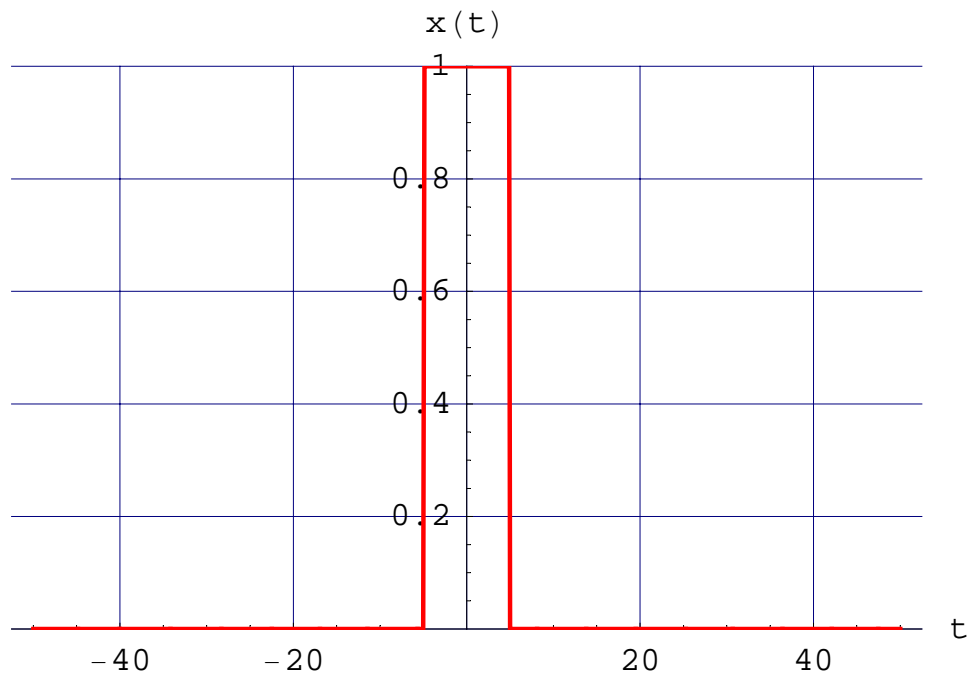
```
(* impulso rect, es. variare  $\tau$ , A e verifica teor. Rayleigh *)
A := 1
 $\tau$  := 10
x[t_] := If[Abs[t] <  $\tau/2$ , A, 0]
X[f_] := A  $\tau$  sinc[f  $\tau$ ]
Xnum[f_] :=  $\int_{-\infty}^{\infty} x[t] \text{Exp}[-i 2 \pi f t] dt$ 

Energy =  $\int_{-\infty}^{\infty} \text{Abs}[x[t]]^2 dt$ 
 $\int_{-\infty}^{\infty} \text{Abs}[X[f]]^2 df$  (* per verifica teor. Rayleigh *)

plotx = Plot[x[t], {t, -5  $\tau$ , 5  $\tau$ }, PlotRange -> {0, A},
  PlotStyle -> {Red, Thickness[.005]}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"t", "x(t)"}, TextStyle -> {FontSize -> 16}];
plotX = Plot[{X[f], Xnum[f]}, {f, -5 /  $\tau$ , 5 /  $\tau$ }, PlotRange -> {-0.5 A  $\tau$ , A  $\tau$ },
  PlotStyle -> {{Blue, Thickness[.01]}, {Green, Thickness[.005]}},
  Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"f", "X(f), Xnum(f)"}, TextStyle -> {FontSize -> 16}];
```

Out[461]=
10

Out[462]=
10



In[465]:=

```
(* esponenziale bilatera, es. variare  $\tau$ , A e verifica teor. Rayleigh *)
A := 1
 $\tau$  := 0.1
x[t_] := Exp[-Abs[t] /  $\tau$ ]
X[f_] := 2 A  $\tau$  / (1 + (2  $\pi$  f  $\tau$ ) ^ 2)

Energy =  $\int_{-\infty}^{+\infty}$  Abs[x[t]] ^ 2 dt
 $\int_{-\infty}^{+\infty}$  Abs[X[f]] ^ 2 df (* per verifica teor. Rayleigh *)

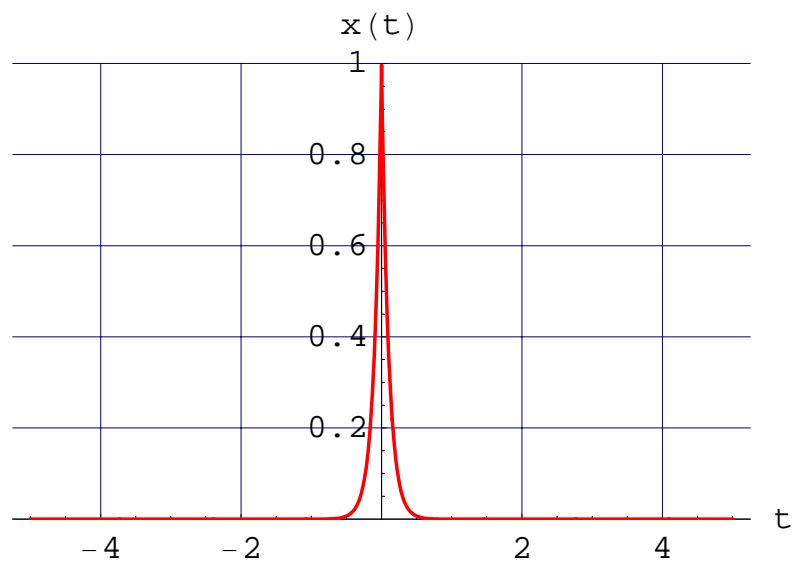
plotx = Plot[x[t], {t, -5, 5}, PlotRange -> {0, A},
  PlotStyle -> {Red, Thickness[.005]}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"t", "x(t)", TextStyle -> {FontSize -> 16}}];
plotX = Plot[{X[f]}, {f, -5, 5}, PlotRange -> {0, 2 A  $\tau$ },
  PlotStyle -> {{Blue, Thickness[.01]}}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"f", "X(f)", TextStyle -> {FontSize -> 16}}];
```

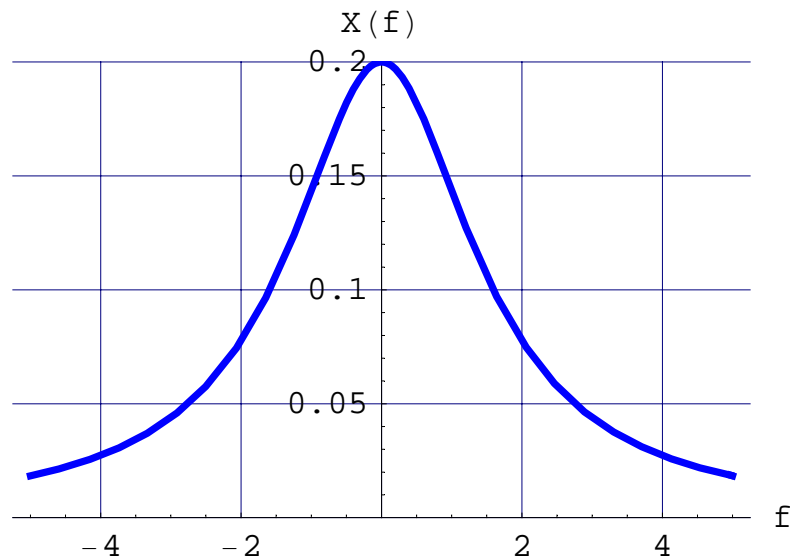
Out[469]=

0.1

Out[470]=

0.1





In[473]:=

```
(* esponenziale bilatera, es. variare  $\tau$ , A e verifica teor. Rayleigh *)
A := 1
 $\tau$  := 1
x[t_] := Exp[-Abs[t] /  $\tau$ ]
X[f_] := 2 A  $\tau$  / (1 + (2  $\pi$  f  $\tau$ ) ^ 2)

Energy =  $\int_{-\infty}^{+\infty}$  Abs[x[t]] ^ 2 dt
 $\int_{-\infty}^{+\infty}$  Abs[X[f]] ^ 2 df (* per verifica teor. Rayleigh *)

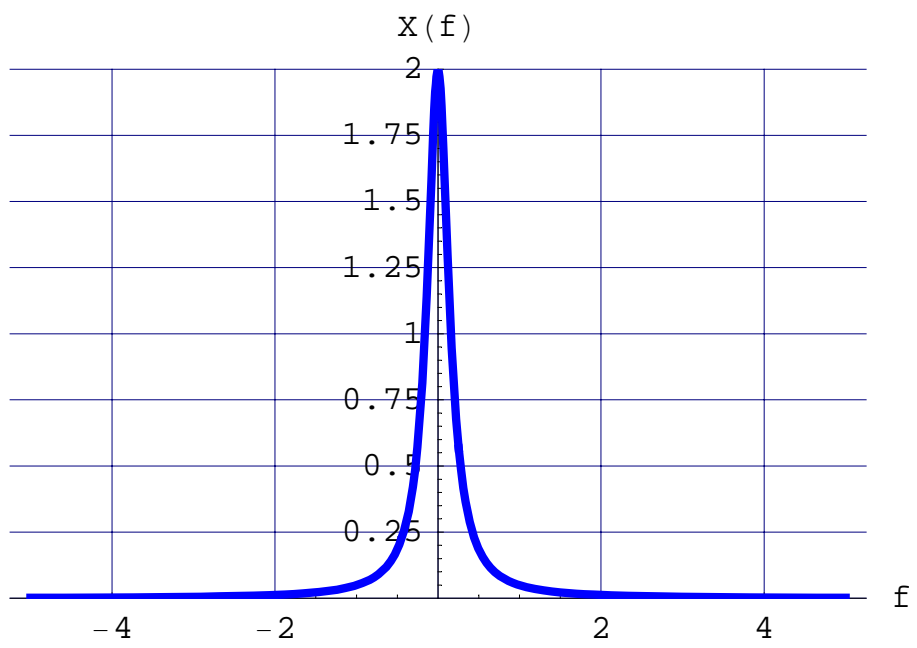
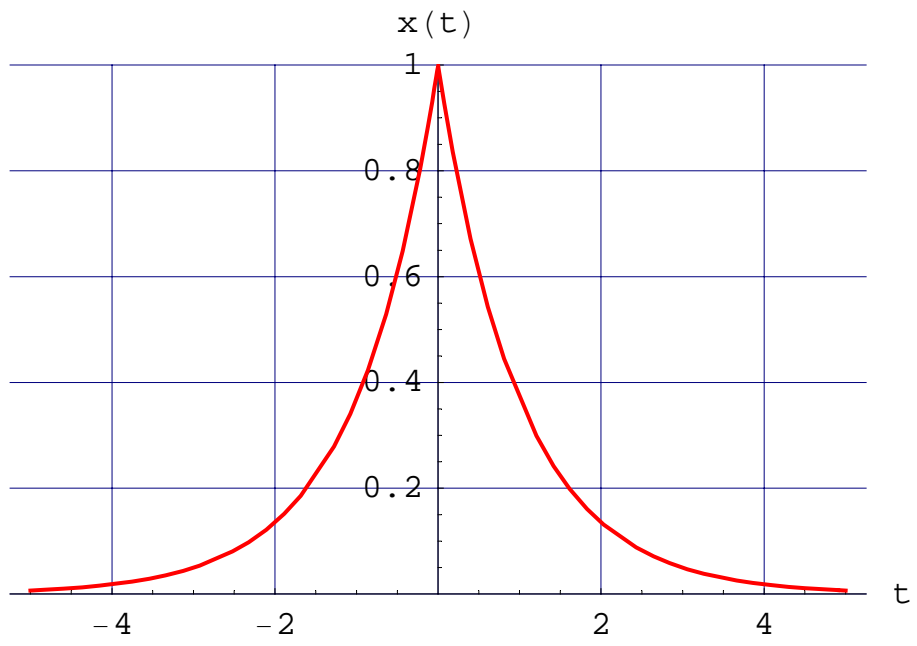
plotx = Plot[x[t], {t, -5  $\tau$ , 5  $\tau$ }, PlotRange -> {0, A},
  PlotStyle -> {Red, Thickness[.005]}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"t", "x(t)"}, TextStyle -> {FontSize -> 16}];
plotX = Plot[{X[f]}, {f, -5 /  $\tau$ , 5 /  $\tau$ }, PlotRange -> {0, 2 A  $\tau$ },
  PlotStyle -> {{Blue, Thickness[.01]}}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"f", "X(f)"}, TextStyle -> {FontSize -> 16}];
```

Out[477]=

1

Out[478]=

1



In[481]:=

```
(* esponenziale monolaterale, es. variare  $\tau$ , A e verifica teor. Rayleigh *)
A := 1
 $\tau := 0.1$ 
x[t_] := If[t < 0, 0, Exp[-t /  $\tau$ ]]
X[f_] := A  $\tau$  / (1 + i 2  $\pi$  f  $\tau$ )
Xamplitude[f_] := A  $\tau$  /  $\sqrt{1 + (2 \pi f \tau)^2}$ 
Xphase[f_] := -ArcTan[2  $\pi$  f  $\tau$ ]

Energy =  $\int_{-\infty}^{+\infty}$  Abs[x[t]] ^ 2 dt
 $\int_{-\infty}^{+\infty}$  Abs[X[f]] ^ 2 df (* per verifica teor. Rayleigh *)

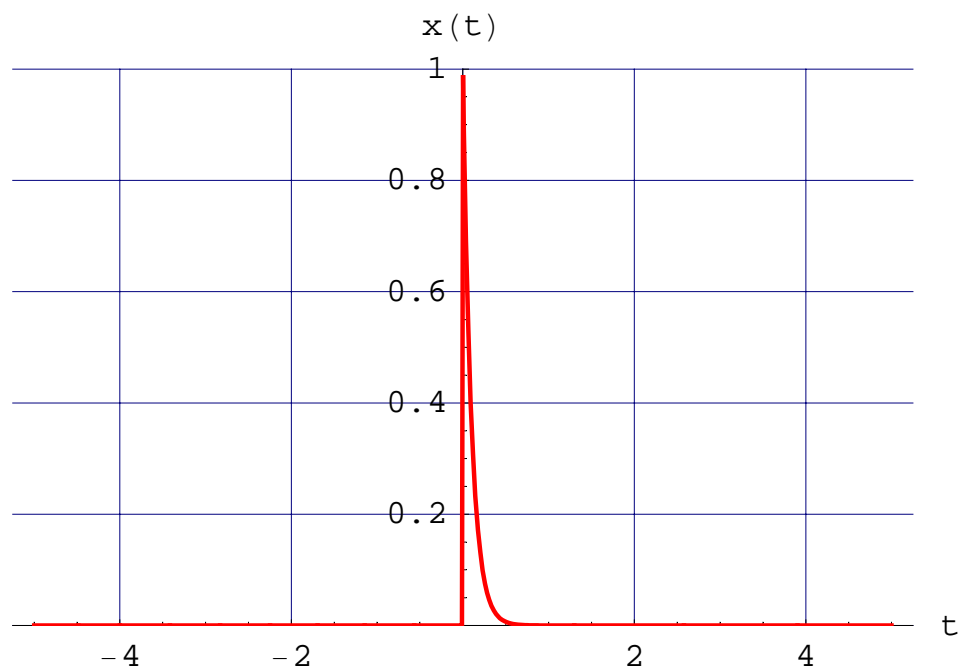
plotx = Plot[x[t], {t, -5, 5}, PlotRange -> {0, A},
  PlotStyle -> {Red, Thickness[.005]}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"t", "x(t)"}, TextStyle -> {FontSize -> 16}];
plotXamp = Plot[{Xamplitude[f]}, {f, -5, 5}, PlotRange -> {0, A  $\tau$ },
  PlotStyle -> {{Blue, Thickness[.01]}}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"f", "|X(f)|"}, TextStyle -> {FontSize -> 16}];
plotXphase = Plot[{Xphase[f]}, {f, -5, 5}, PlotRange -> {- $\pi/2$ ,  $\pi/2$ },
  PlotStyle -> {{Green, Thickness[.01]}}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"f", "arg X(f)"}, TextStyle -> {FontSize -> 16}];
```

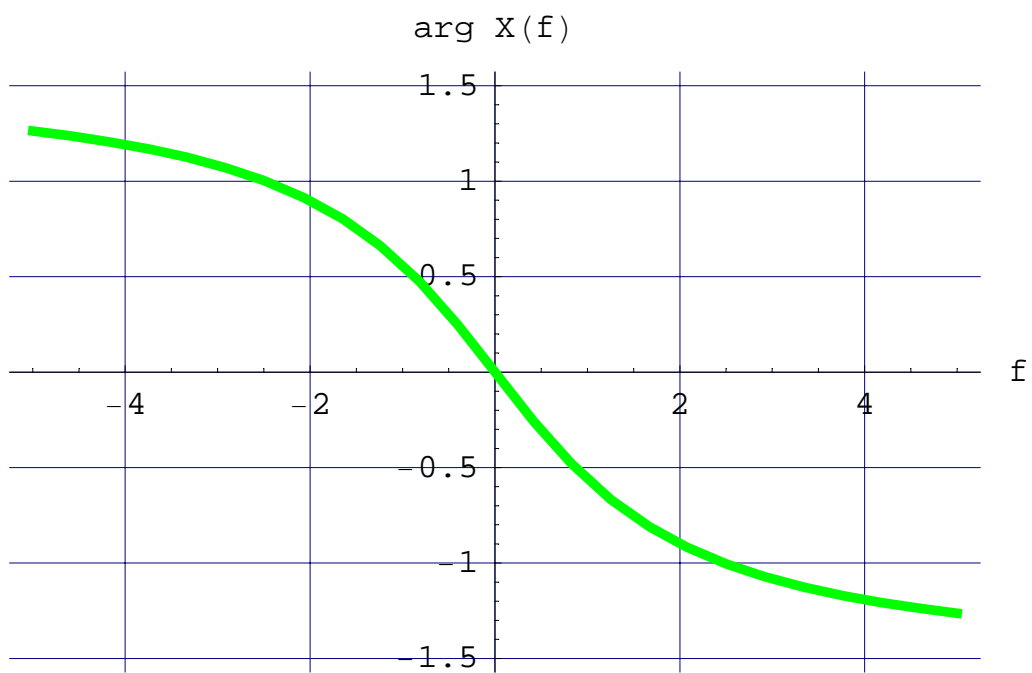
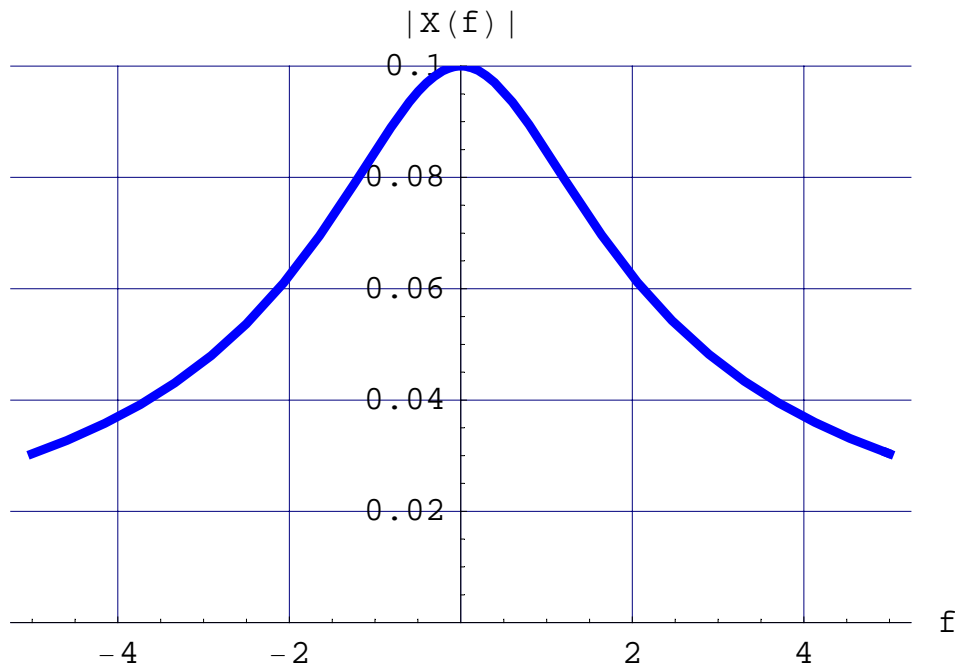
Out[487]=

0.05

Out[488]=

0.05





In[492]:=

```
(* esponenziale monolaterale, es. variare  $\tau$ , A e verifica teor. Rayleigh *)
A := 1
 $\tau$  := 1
x[t_] := If[t < 0, 0, Exp[-t /  $\tau$ ]]
X[f_] := A  $\tau$  / (1 + i 2  $\pi$  f  $\tau$ )
Xamplitude[f_] := A  $\tau$  /  $\sqrt{1 + (2 \pi f \tau)^2}$ 
Xphase[f_] := -ArcTan[2  $\pi$  f  $\tau$ ]

Energy =  $\int_{-\infty}^{+\infty}$  Abs[x[t]] ^ 2 dt
 $\int_{-\infty}^{+\infty}$  Abs[X[f]] ^ 2 df (* per verifica teor. Rayleigh *)

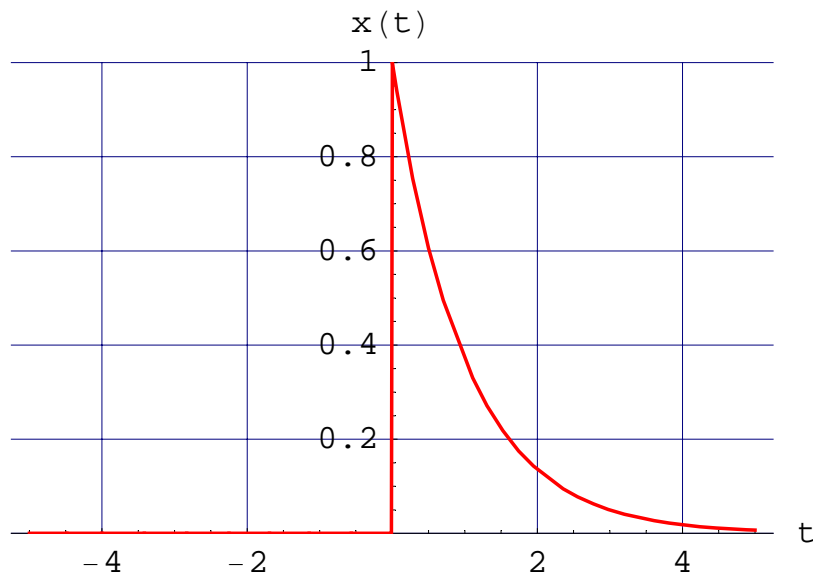
plotx = Plot[x[t], {t, -5, 5}, PlotRange -> {0, A},
  PlotStyle -> {Red, Thickness[.005]}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"t", "x(t)", TextStyle -> {FontSize -> 16}}];
plotXamp = Plot[{Xamplitude[f]}, {f, -5, 5}, PlotRange -> {0, A  $\tau$ },
  PlotStyle -> {{Blue, Thickness[.01]}}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"f", "|X| (f)", TextStyle -> {FontSize -> 16}}];
plotXphase = Plot[{Xphase[f]}, {f, -5, 5}, PlotRange -> {- $\pi/2$ ,  $\pi/2$ },
  PlotStyle -> {{Green, Thickness[.01]}}, Frame -> False, GridLines -> Automatic,
  AxesLabel -> {"f", "arg X(f)", TextStyle -> {FontSize -> 16}}];
```

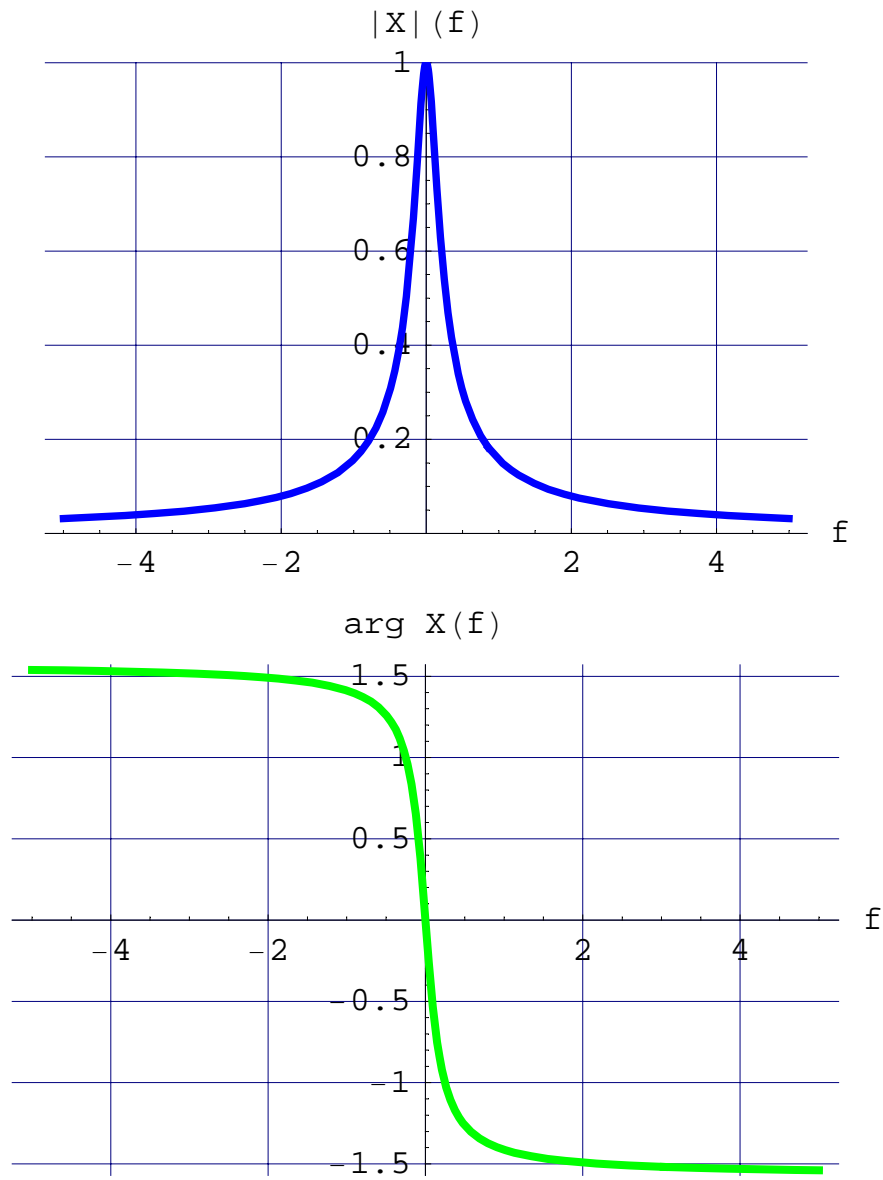
Out[498]=

$$\frac{1}{2}$$

Out[499]=

$$\frac{1}{2}$$





In[503]:=

(* Convoluzione *)

A := 1

B := 1

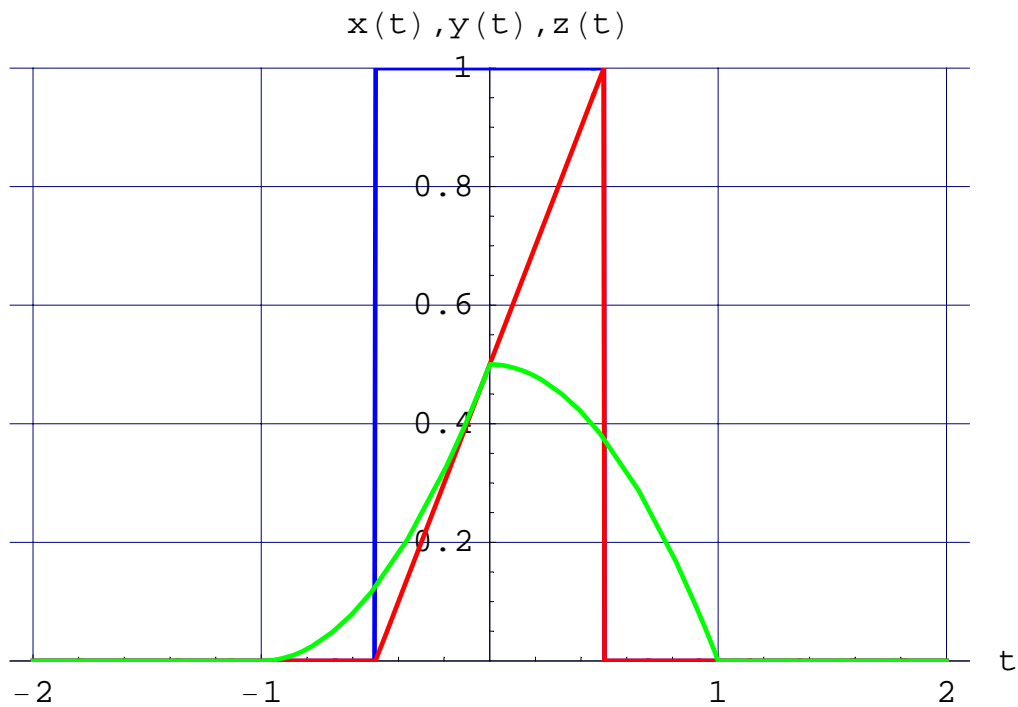
T := 1

x[t_] := If[Abs[t] < T/2, A, 0]

y[t_] := If[Abs[t] < T/2, B/T (t + T/2), 0]

z[t_] := $\int_{-\infty}^{\infty} x[\xi] y[t - \xi] d\xi$

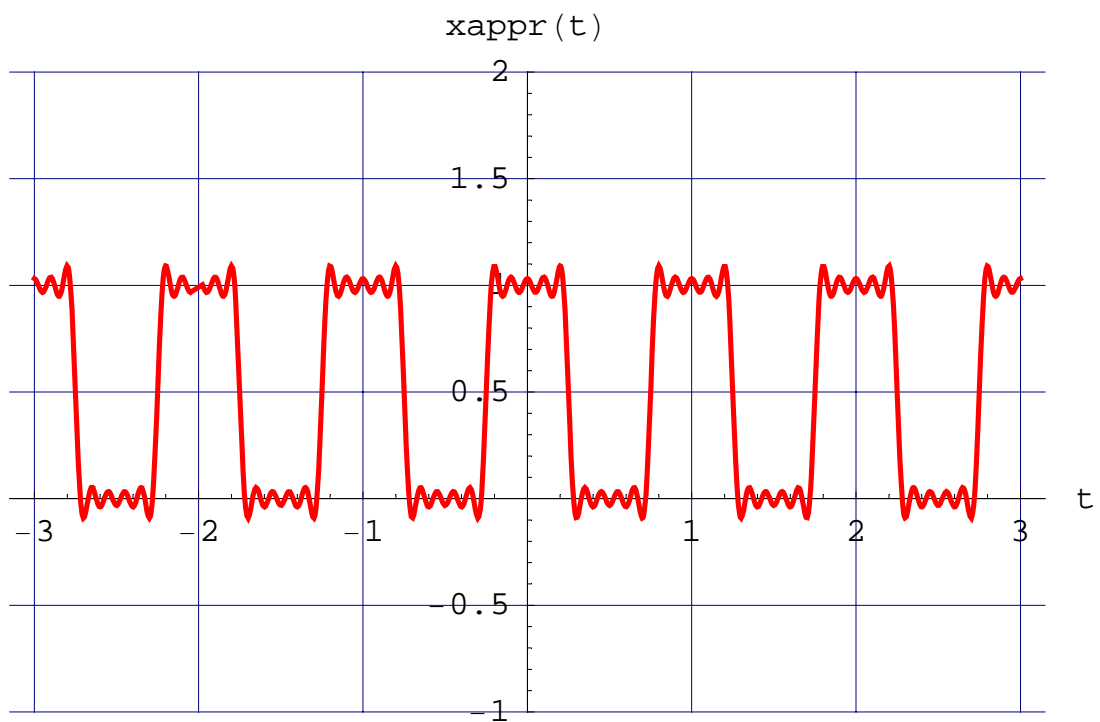
plotconv = Plot[{x[t], y[t], z[t]}, {t, -2 T, 2 T}, PlotRange -> {0, A B T}, PlotStyle -> {{Blue, Thickness[.005]}, {Red, Thickness[.005]}, {Green, Thickness[.005]}}, Frame -> False, GridLines -> Automatic, AxesLabel -> {"t", "x(t), y(t), z(t)"}, TextStyle -> {FontSize -> 16}];



```
In[510]:=
(* treno impulsi rect, A ampiezza, d duty cycle *)

A := 1
T := 1
d := 0.5
Ncoeff := 10

c[n_] := A d sinc[n d]
xappr[t_] :=  $\sum_{n=-Ncoeff}^{Ncoeff} c[n] \text{Exp}[i 2 \pi n t / T]$ 
plotxappr = Plot[xappr[t], {t, -3 T, 3 T}, PlotRange → {-A, 2 A},
  PlotStyle → {Red, Thickness[.005]}, Frame → False, GridLines → Automatic,
  AxesLabel → {"t", "xappr(t)"}, TextStyle → {FontSize → 16}];
```



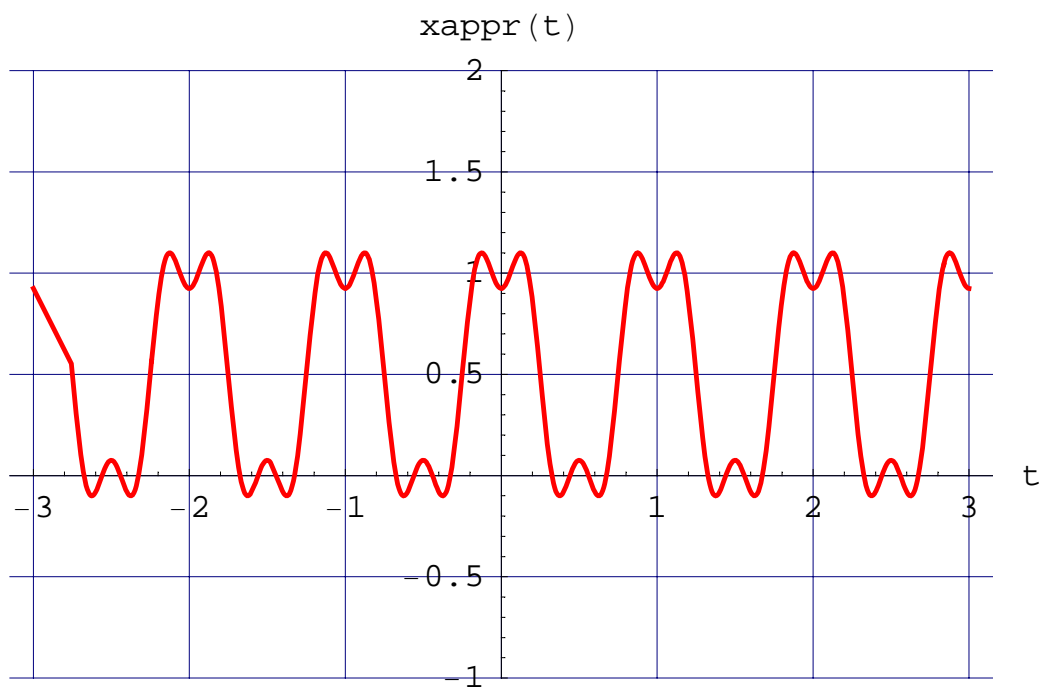
```

In[517]:=
(* treno impulsi rect, A ampiezza, d duty cycle *)

A := 1
T := 1
d := 0.5
Ncoeff := 3

c[n_] := A d sinc[n d]
xappr[t_] :=  $\sum_{n=-Ncoeff}^{Ncoeff} c[n] \text{Exp}[i 2 \pi n t / T]$ 
plotxappr = Plot[xappr[t], {t, -3 T, 3 T}, PlotRange → {-A, 2 A},
  PlotStyle → {Red, Thickness[.005]}, Frame → False, GridLines → Automatic,
  AxesLabel → {"t", "xappr(t)"}, TextStyle → {FontSize → 16}];

```



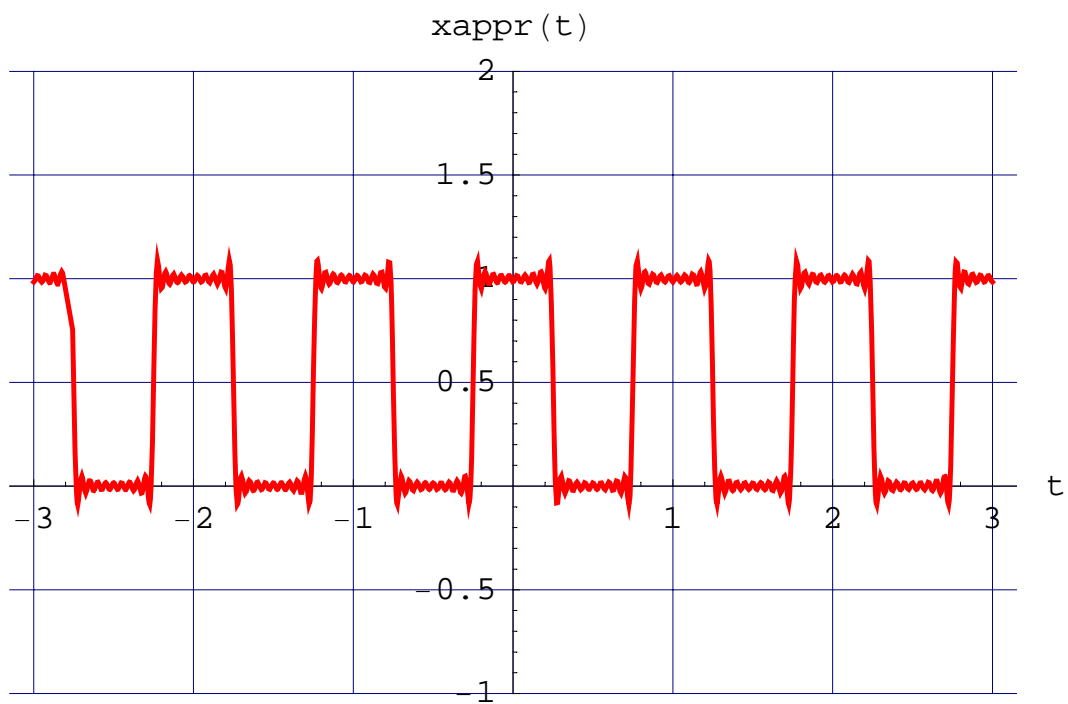
```

In[524]:=
(* treno impulsi rect, A ampiezza, d duty cycle *)

A := 1
T := 1
d := 0.5
Ncoeff := 20

c[n_] := A d sinc[n d]
xappr[t_] :=  $\sum_{n=-Ncoeff}^{Ncoeff} c[n] \text{Exp}[i 2 \pi n t / T]$ 
plotxappr = Plot[xappr[t], {t, -3 T, 3 T}, PlotRange → {-A, 2 A},
  PlotStyle → {Red, Thickness[.005]}, Frame → False, GridLines → Automatic,
  AxesLabel → {"t", "xappr(t)"}, TextStyle → {FontSize → 16}];

```



In[531]:=

(* sinusoide raddrizzata a semionda *)

A := 1

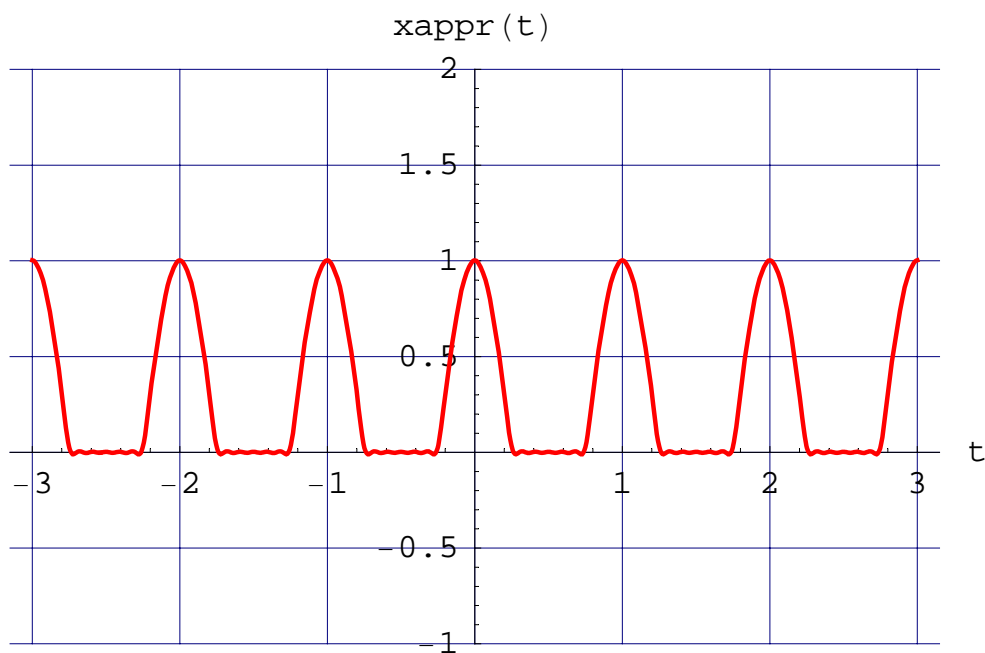
T := 1

c[n_] := If[Abs[n] == 1, A/4, A/π Cos[π n/2] / (1 - n^2)]

Ncoeff := 10

xappr[t_] := $\sum_{n=-Ncoeff}^{Ncoeff} c[n] \text{Exp}[i 2 \pi n t / T]$

plotxappr = Plot[xappr[t], {t, -3 T, 3 T}, PlotRange → {-A, 2 A},
 PlotStyle → {Red, Thickness[.005]}, Frame → False, GridLines → Automatic,
 AxesLabel → {"t", "xappr(t)"}, TextStyle → {FontSize → 16}];



In[537]:=

(* sinusoide raddrizzata a semionda *)

A := 1

T := 1

c[n_] := If[Abs[n] == 1, A/4, A/π Cos[π n/2] / (1 - n^2)]

Ncoeff := 3

xappr[t_] := $\sum_{n=-Ncoeff}^{Ncoeff} c[n] \text{Exp}[i 2 \pi n t / T]$

plotxappr = Plot[xappr[t], {t, -3 T, 3 T}, PlotRange → {-A, 2 A},
 PlotStyle → {Red, Thickness[.005]}, Frame → False, GridLines → Automatic,
 AxesLabel → {"t", "xappr(t)"}, TextStyle → {FontSize → 16}];

