

Sistemi di Telecomunicazioni

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*Esercitazioni al calcolatore sui sistemi di
trasmissione numerici passa-banda*


```
In[370]:= ClearAll["Global`*"];
<< Graphics`Graphics`
<< Graphics`Colors`
(*<<Graphics`Legend`*)
<< Statistics`ContinuousDistributions`
```

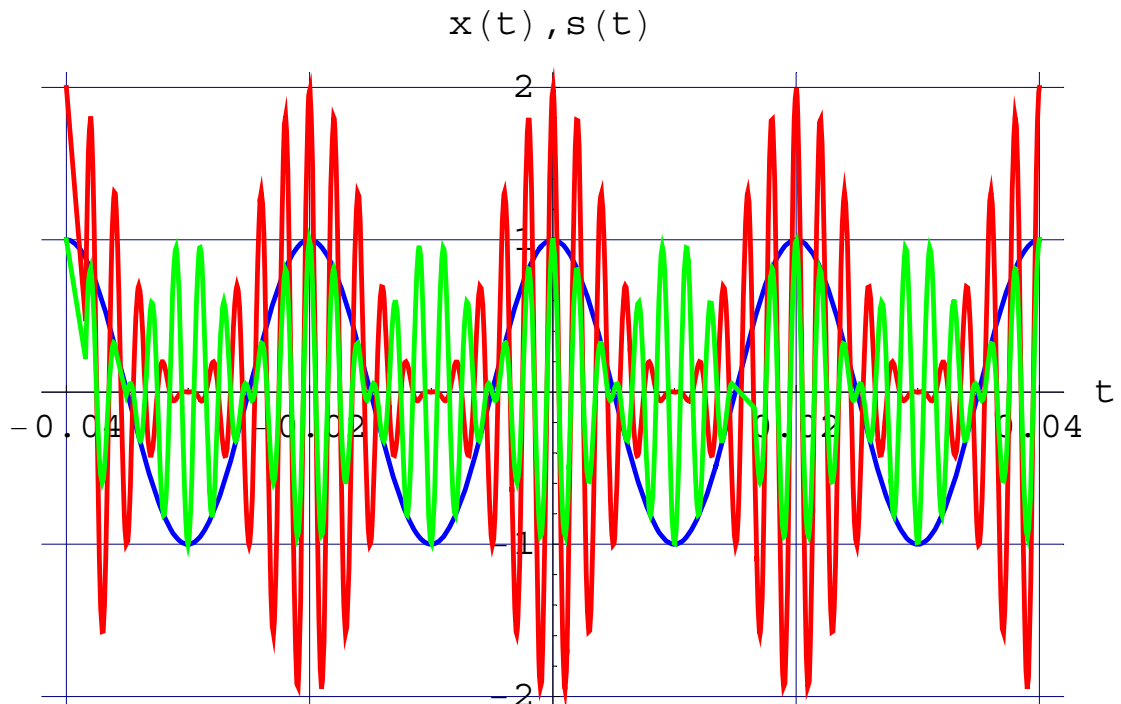
```
In[374]:= sinc[x_] := If[x == 0, 1, Sin[ $\pi$  x] / ( $\pi$  x)]
```

```
In[375]:= (* Modulazione in ampiezza analogica *)
```

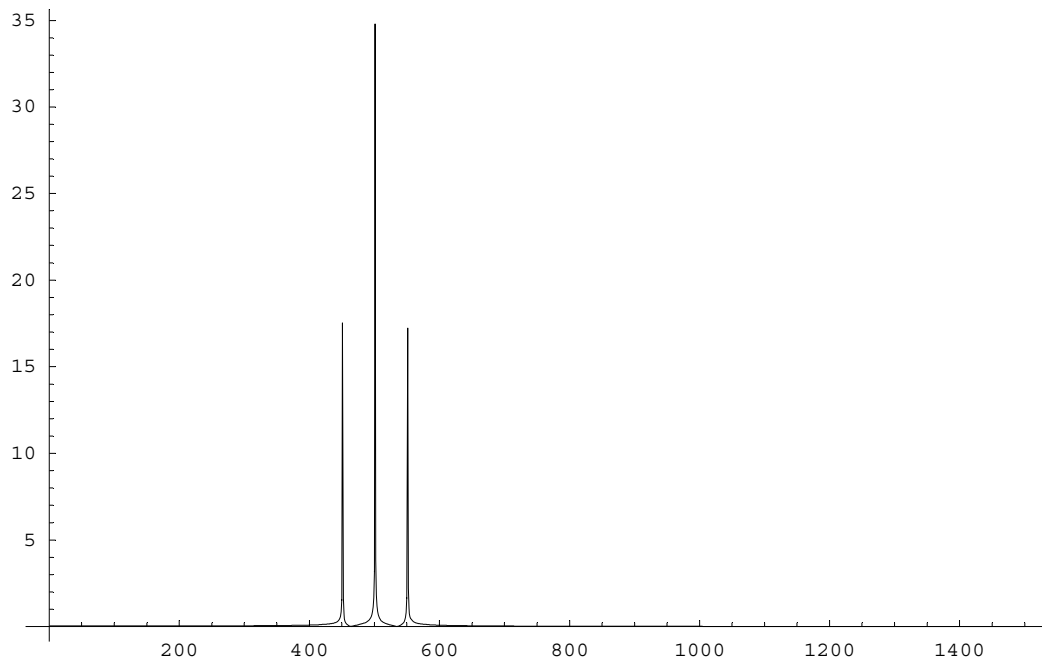
```
VM := 1;
V0 := 1;
 $\phi$ 0 := 0;
ka := 1 / VM;
fm := 50; f0 := 500;
x[t_] := VM Cos[2  $\pi$  fm t]
sAM[t_] := (1 + ka x[t]) V0 Cos[2  $\pi$  f0 t +  $\phi$ 0];
sDSBSC[t_] := ka x[t] V0 Cos[2  $\pi$  f0 t +  $\phi$ 0];
```

```
modulazioneampiezza =
```

```
Plot[{x[t], sAM[t], sDSBSC[t]}, {t, -2 / fm, 2 / fm}, PlotStyle ->
  {{Blue, Thickness[.005]}, {Red, Thickness[.005]}, {Green, Thickness[.005]}},
  Frame -> False, GridLines -> Automatic, AxesLabel -> {"t", "x(t), s(t)"},
  TextStyle -> {FontSize -> 18}];
```

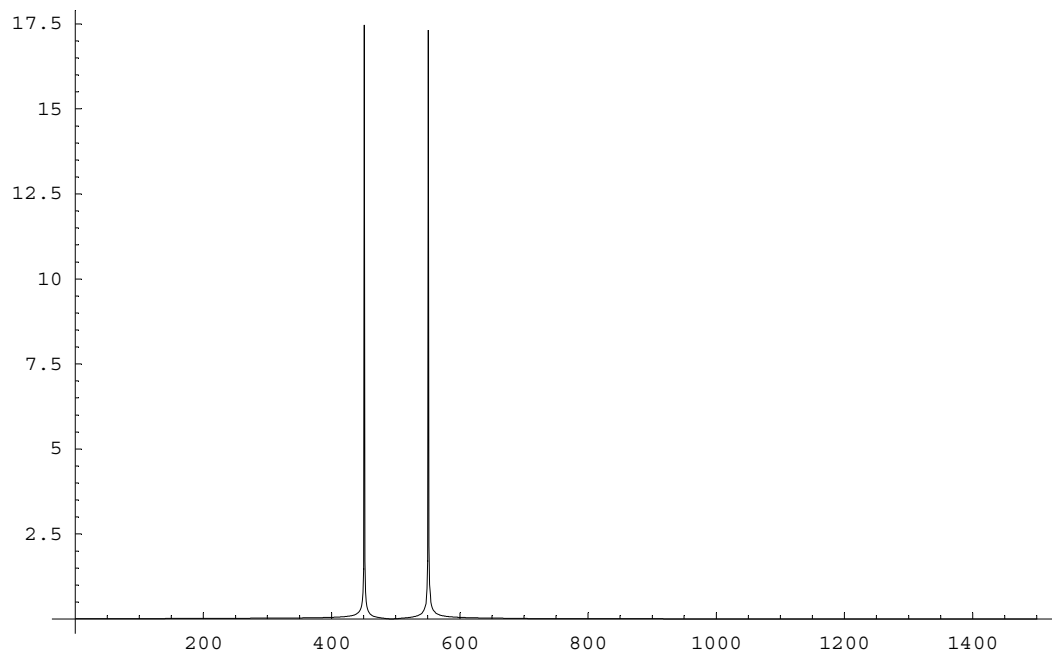


```
In[384]:= campioniAM = Table[sAM[n / (10 f0)], {n, 0, (10 f0)}];  
(* ListPlot[campioniAM, PlotJoined→True] *)  
ListPlot[Take[Abs[Fourier[campioniAM]], 3 f0], PlotJoined→True, PlotRange→All]  
(* ListPlot[InverseFourier[Fourier[campioniAM]],  
PlotJoined→True, PlotRange→All] *)
```



```
Out[385]= - Graphics -
```

```
In[386]:= campioniDSBSC = Table[sDSBSC[n / (10 f0)], {n, 0, (10 f0)}];  
(* ListPlot[campioniDSBSC, PlotJoined→True] *)  
ListPlot[Take[Abs[Fourier[campioniDSBSC]], 3 f0],  
PlotJoined→True, PlotRange→All]  
(* ListPlot[InverseFourier[Fourier[campioniDSBSC]],  
PlotJoined→True, PlotRange→All] *)
```

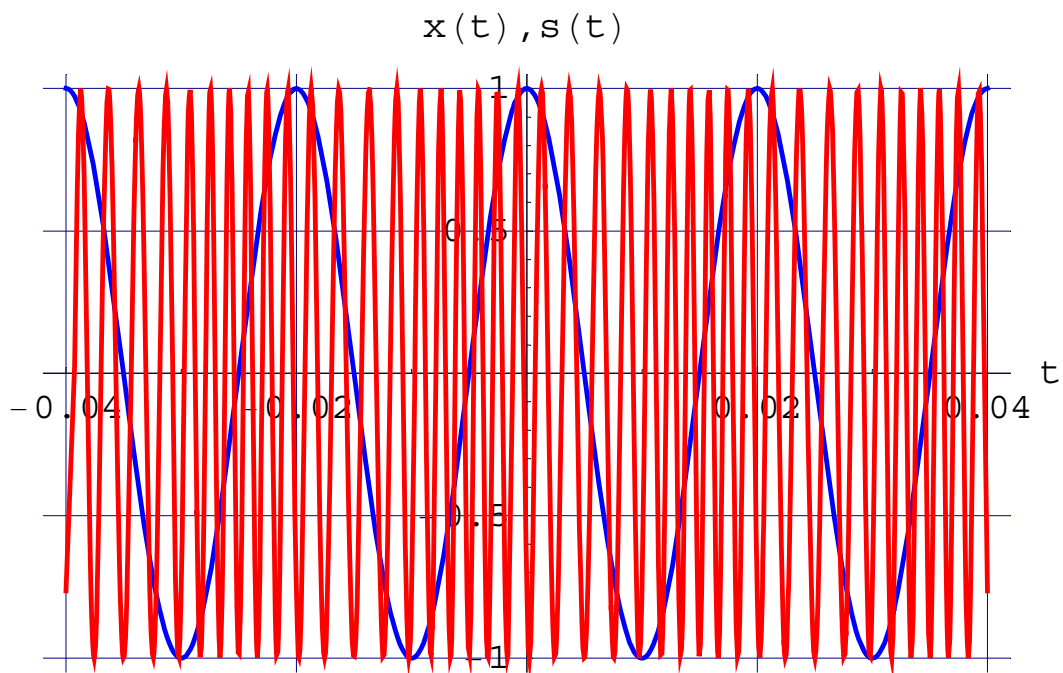


```
Out[387]= - Graphics -
```

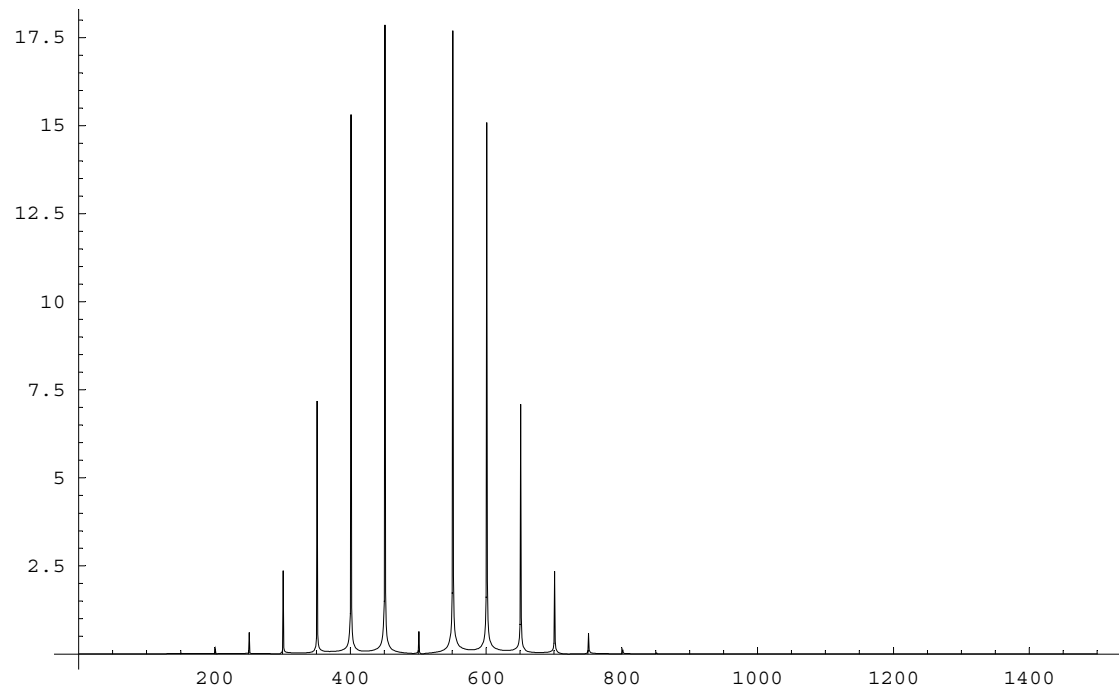
```
In[388]:= (* Modulazione di fase analogica *)
```

```
VM := 1;  
V0 := 1;  
 $\varphi_0 := 0$ ;  
kp := 2.44 / VM;  
fm := 50; f0 := 500;  
x[t_] := VM Cos[2  $\pi$  fm t]  
sPM[t_] := V0 Cos[2  $\pi$  f0 t + kp x[t] +  $\varphi_0$ ];
```

```
modulazionefase = Plot[{x[t], sPM[t]}, {t, -2 / fm, 2 / fm},  
  PlotStyle -> {{Blue, Thickness[.005]}, {Red, Thickness[.005]}},  
  Frame -> False, GridLines -> Automatic,  
  AxesLabel -> {"t", "x(t), s(t)"}, TextStyle -> {FontSize -> 18}];
```



```
In[396]:= campioniPM = Table[sPM[n / (10 f0)], {n, 0, (10 f0)}];  
(* ListPlot[campioniPM, PlotJoined→True] *)  
ListPlot[Take[Abs[Fourier[campioniPM]], 3 f0], PlotJoined→True, PlotRange→All]  
(* ListPlot[InverseFourier[Fourier[campioniPM]],  
PlotJoined→True, PlotRange→All] *)
```

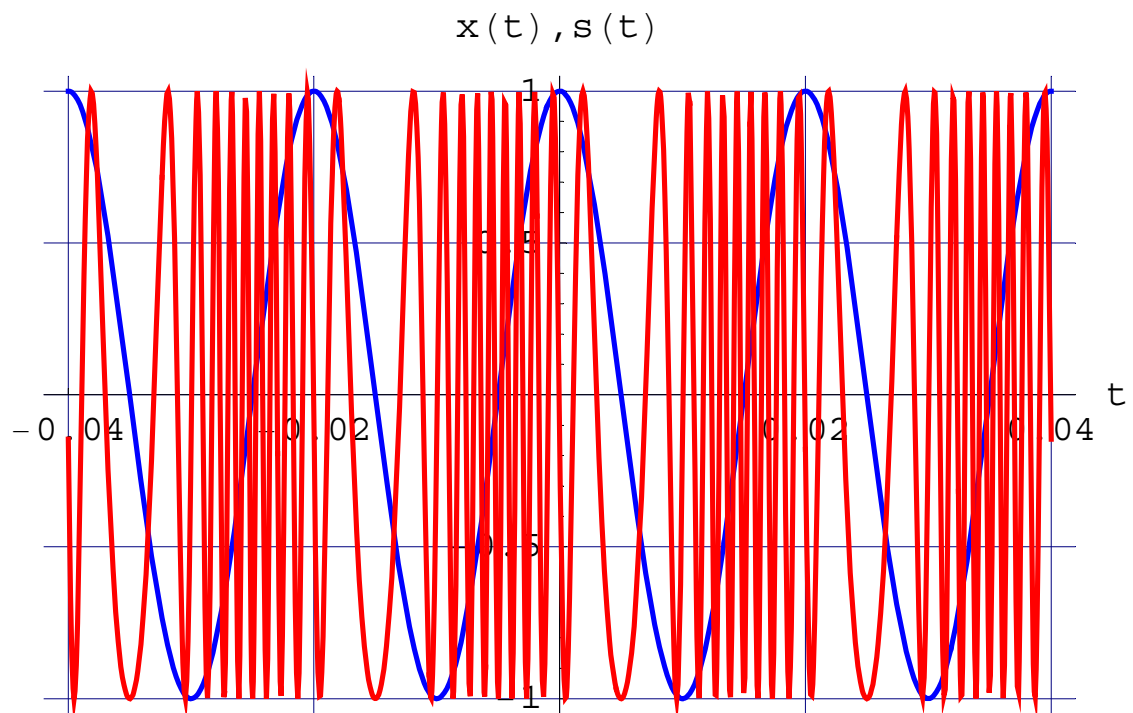


```
Out[397]= - Graphics -
```

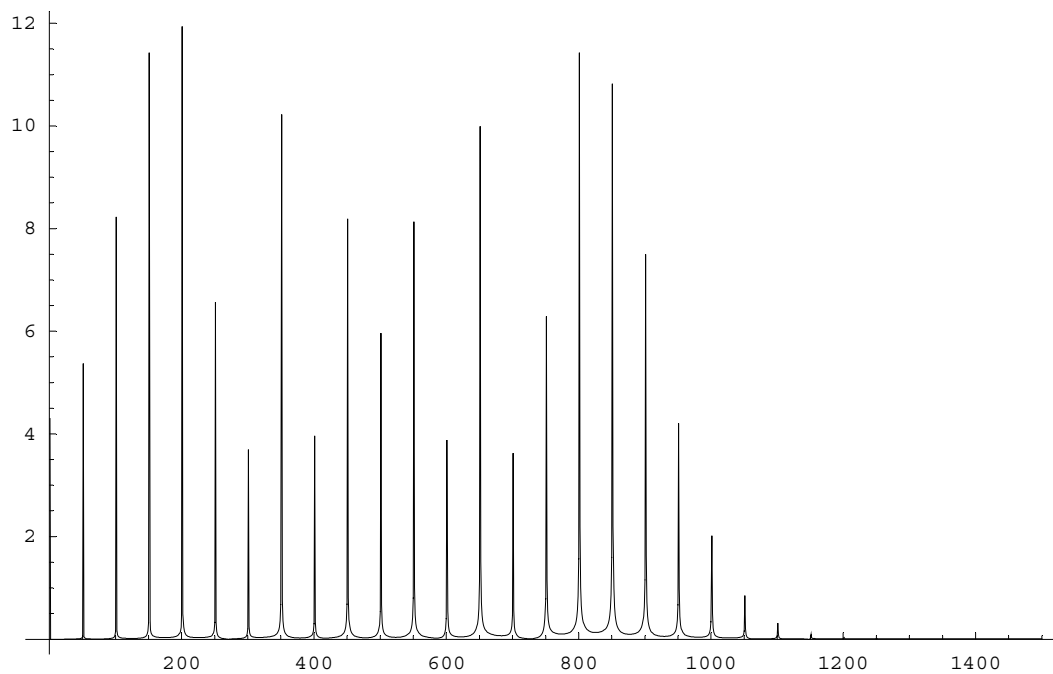
```
In[398]:= (* Modulazione di fase analogica *)

VM := 1;
V0 := 1;
φ0 := 0;
kp := 8 / VM;
fm := 50; f0 := 500;
x[t_] := VM Cos[2 π fm t]
sPM[t_] := V0 Cos[2 π f0 t + kp x[t] + φ0];

modulazionefase = Plot[{x[t], sPM[t]}, {t, -2 / fm, 2 / fm},
  PlotStyle → {{Blue, Thickness[.005]}, {Red, Thickness[.005]}},
  Frame → False, GridLines → Automatic,
  AxesLabel → {"t", "x(t),s(t)"}, TextStyle → {FontSize → 18}];
```



```
In[406]:= campioniPM = Table[sPM[n / (10 f0)], {n, 0, (10 f0)}];  
(* ListPlot[campioniPM, PlotJoined→True] *)  
ListPlot[Take[Abs[Fourier[campioniPM]], 3 f0], PlotJoined→True, PlotRange→All]  
(* ListPlot[InverseFourier[Fourier[campioniPM]],  
PlotJoined→True, PlotRange→All] *)
```



```
Out[407]= - Graphics -
```

```
In[408] := (* Modulazione di frequenza analogica *)
```

```
VM := 1;
```

```
V0 := 1;
```

```
 $\varphi_0 := 0;$ 
```

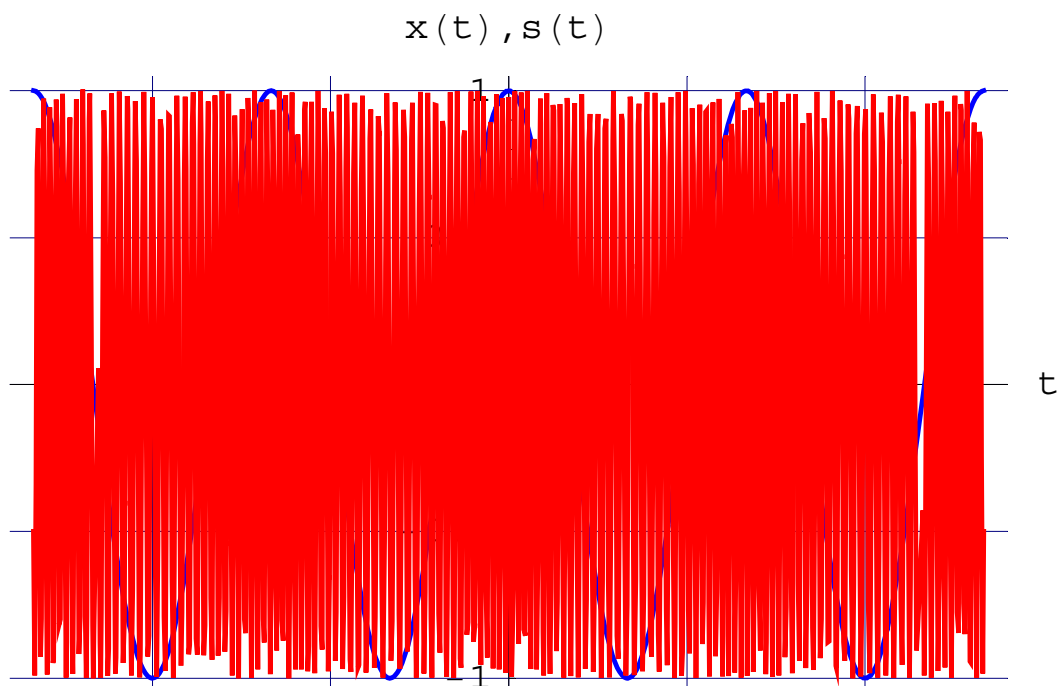
```
kf := 75 / VM;
```

```
fm := 15; f0 := 500;
```

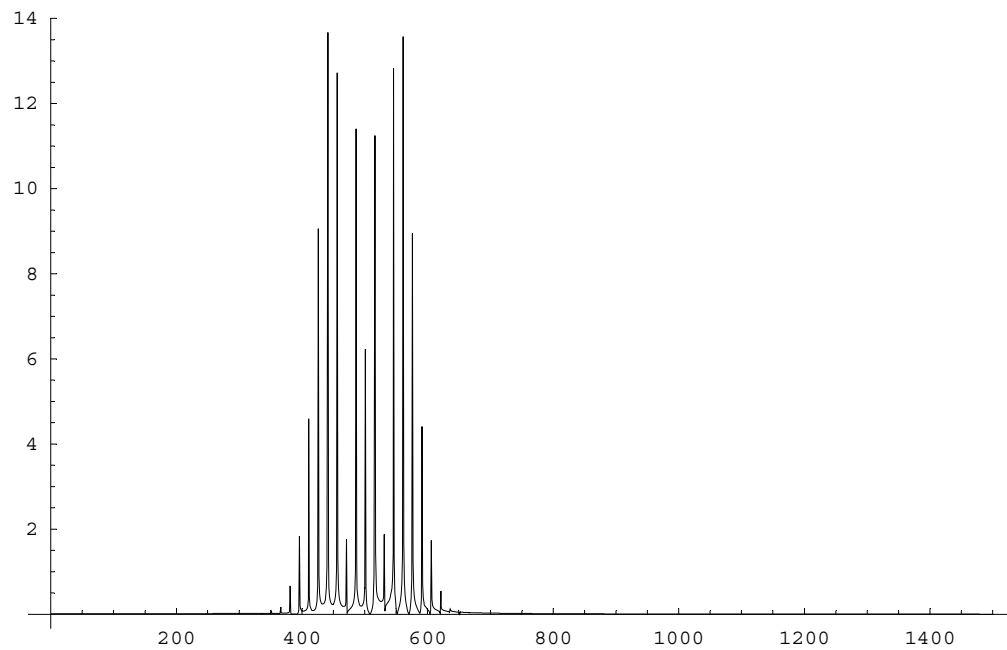
```
x[t_] := VM Cos[2  $\pi$  fm t]
```

```
sFM[t_] := V0 Cos[2  $\pi$  f0 t + 2  $\pi$  kf N[ $\int_{-100/fm}^t x[\xi] d\xi$ ] +  $\varphi_0$ ];
```

```
modulazionefase = Plot[{x[t], sFM[t]}, {t, -2 / fm, 2 / fm},  
  PlotStyle -> {{Blue, Thickness[.005]}, {Red, Thickness[.005]}},  
  Frame -> False, GridLines -> Automatic,  
  AxesLabel -> {"t", "x(t), s(t)"}, TextStyle -> {FontSize -> 18}];
```



```
In[416]:= campioniFM = Table[sFM[n / (10 f0)], {n, 0, (10 f0)}];  
(* ListPlot[campioniFM, PlotJoined→True] *)  
ListPlot[Take[Abs[Fourier[campioniFM]], 3 f0], PlotJoined→True, PlotRange→All]  
(* ListPlot[InverseFourier[Fourier[campioniFM]],  
PlotJoined→True, PlotRange→All] *)
```



```
Out[417]= - Graphics -
```

```

In[418] := (* Modulazione Numerica OOK *)
T := 1;
VM := 1;
φ0 := 0;
f0 := 4 / T; (* nota:sarebbe f0>>1/T,
valore scelto per buona visualizzazione grafica *)
g[t_] := If[Abs[t] < 0.5 T, 1, 0];

(* generazione bit e tx *)
nbit := 12;
b := {0, 1, 0, 1, 0, 0, 1, 0, 1, 1, 0, 1}

va[t_] := VM ∑k=1nbit b[[k]] g[t - k T]

sOOK[t_] := va[t] Cos[2 π f0 t + φ0]

Plot[{sOOK[t], va[t]}, {t, - 2 T, 18 T},
PlotStyle → {{Red, Thickness[.005]}, {Blue, Thickness[.005]}},
Frame → False, GridLines → Automatic,
AxesLabel → {"t/T", "va[t], s[t]"}, TextStyle → {FontSize → 18}]

(* Costellazione OOK *)

φ0 := 0;
iOOK[t_] := va[t] Exp[i φ0];

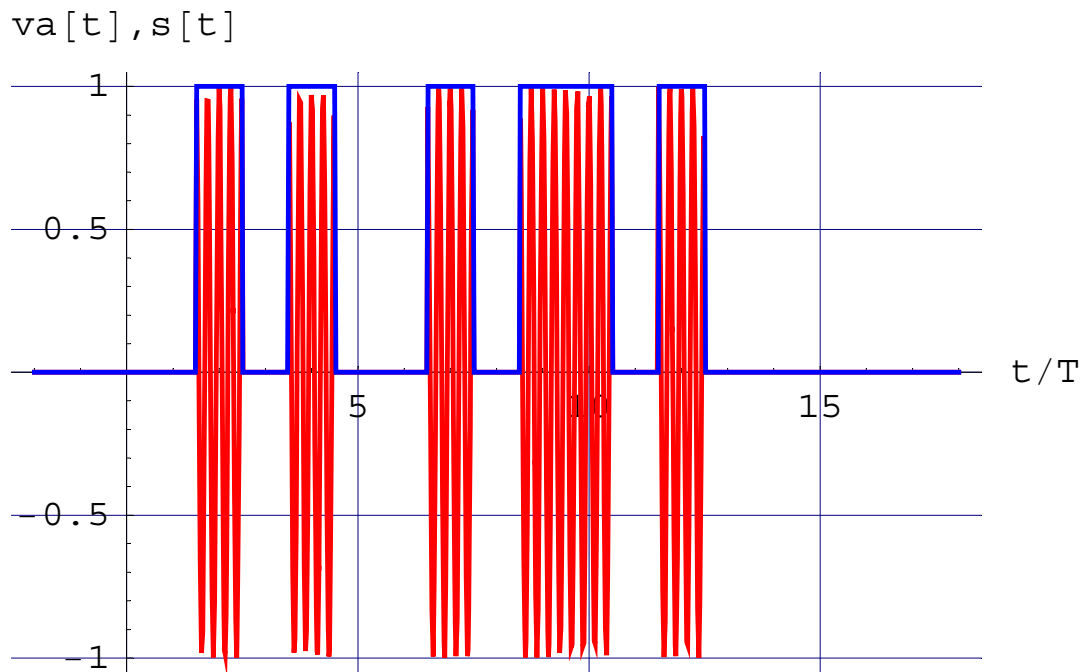
TiOOK = Table[{Re[iOOK[t]], Im[iOOK[t]]}, {t, - 2 T, 18 T, T}];
plotTiOOK = ListPlot[TiOOK, PlotRange → {-1, 1},
PlotStyle → {Blue, PointSize[0.02]}, Frame → False, GridLines → Automatic,
AxesLabel → {"Re", "Im"}, TextStyle → {FontSize → 18}];

(* ParametricPlot[{Re[iOOK[t]],Im[iOOK[t]]},{t,- 2 T,18 T},
PlotStyle → {{Blue,Thickness[.005]}},Frame→False,GridLines→Automatic,
AxesLabel→{"Re", "Im"},TextStyle→{FontSize→18}]*)

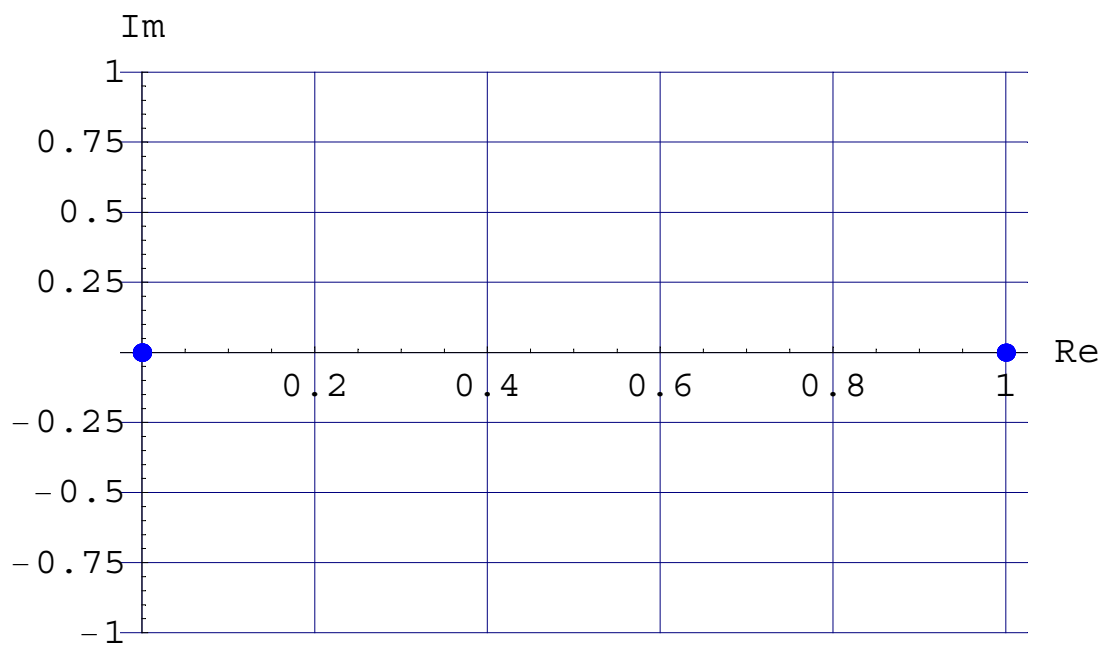
φ0 := π / 8;
iOOK[t_] := va[t] Exp[i φ0];

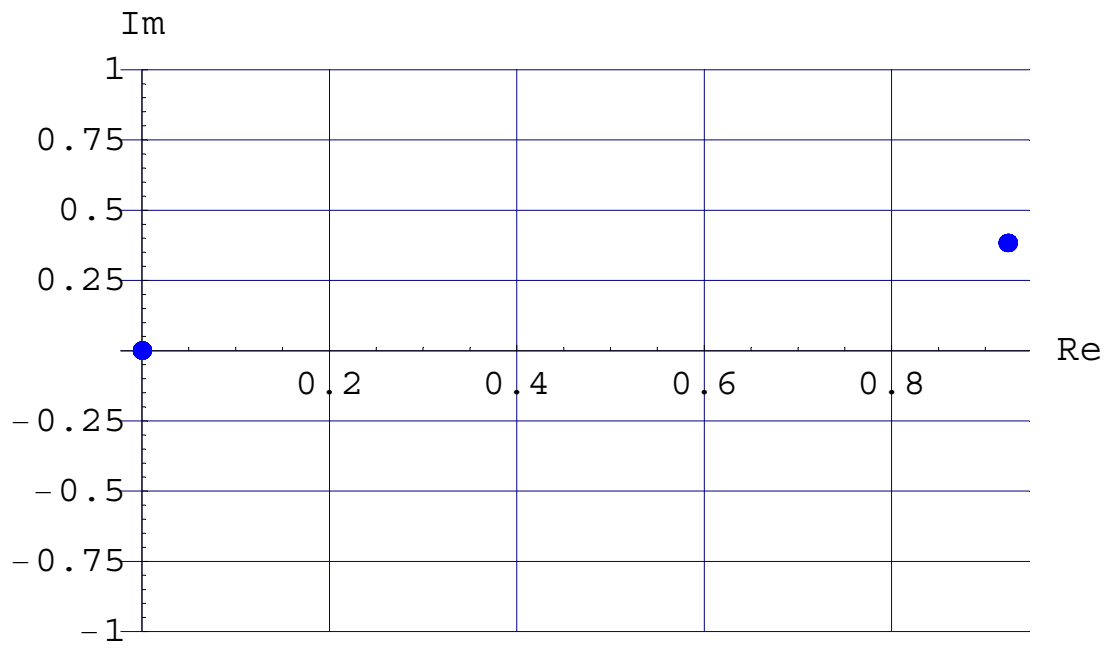
TiOOK = Table[{Re[iOOK[t]], Im[iOOK[t]]}, {t, - 2 T, 18 T, T}];
plotTiOOK = ListPlot[TiOOK, PlotRange → {-1, 1},
PlotStyle → {Blue, PointSize[0.02]}, Frame → False, GridLines → Automatic,
AxesLabel → {"Re", "Im"}, TextStyle → {FontSize → 18}];

```



Out [427]= - Graphics -





- Graphics -

```

In[436]:= (* Modulazione Numerica L-ASK *)

T := 1;
VM := 1;
φ0 := 0;
f0 := 4 / T; (* nota:sarebbe f0>>1/T,
  valore scelto per buona visualizzazione grafica *)
g[t_] := If[Abs[t] < 0.5 T, 1, 0];

(* Generazione simboli *)
L := 4;
nsimb := 12;
a := {-3, 1, 3, -1, -3, -1, 1, 3, 1, 3, 1, -1}

va[t_] := VM  $\sum_{k=1}^{nsimb} a_{[k]} g[t - k T]$ 

sASK[t_] := va[t] Cos[2 π f0 t + φ0]

Plot[{sASK[t], va[t]}, {t, 0, 12 T},
  PlotStyle → {{Red, Thickness[.005]}, {Blue, Thickness[.005]}},
  Frame → False, GridLines → Automatic,
  AxesLabel → {"t/T", "va[t],s[t]"}, TextStyle → {FontSize → 18}]

(* Costellazione L-ASK *)

φ0 := 0;
iASK[t_] := va[t] Exp[i φ0];

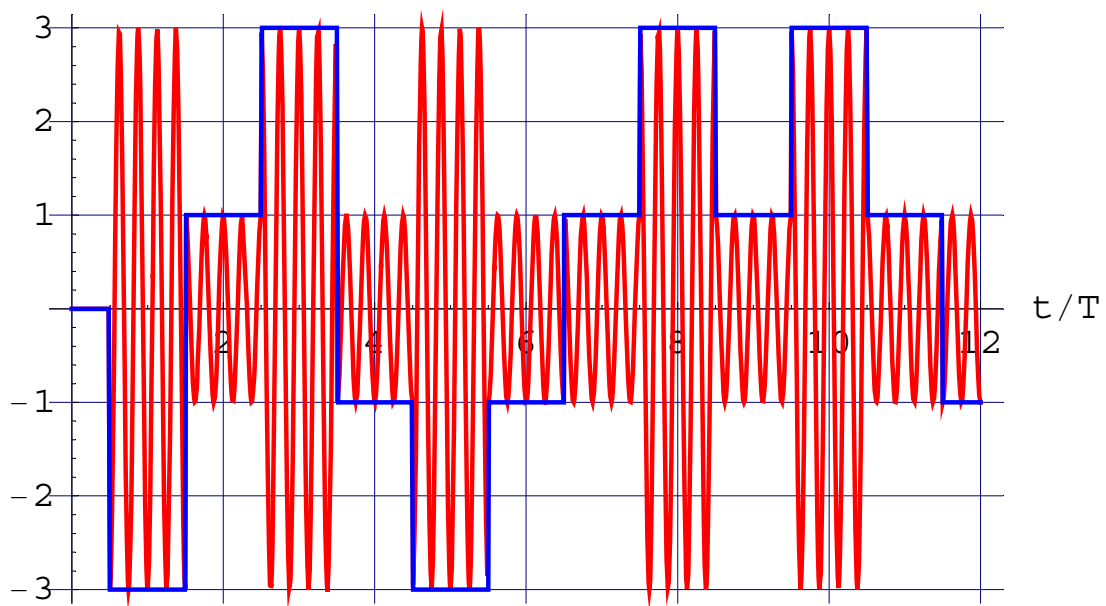
TiASK = Table[{Re[iASK[t]], Im[iASK[t]]}, {t, T, 12 T, T}];
plotTiASK = ListPlot[TiASK, PlotRange → {-L, L},
  PlotStyle → {Blue, PointSize[0.02]}, Frame → False, GridLines → Automatic,
  AxesLabel → {"Re", "Im"}, TextStyle → {FontSize → 18}];

φ0 := π / 8;
iASK[t_] := va[t] Exp[i φ0];

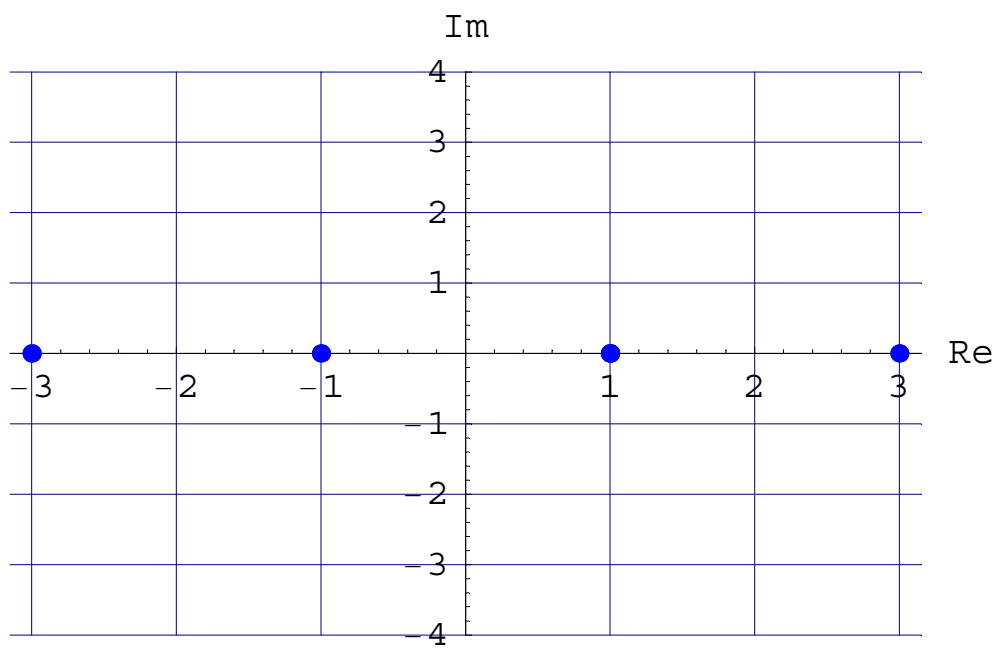
TiASK = Table[{Re[iASK[t]], Im[iASK[t]]}, {t, T, 12 T, T}];
plotTiASK = ListPlot[TiASK, PlotRange → {-L, L},
  PlotStyle → {Blue, PointSize[0.02]}, Frame → False, GridLines → Automatic,
  AxesLabel → {"Re", "Im"}, TextStyle → {FontSize → 18}];

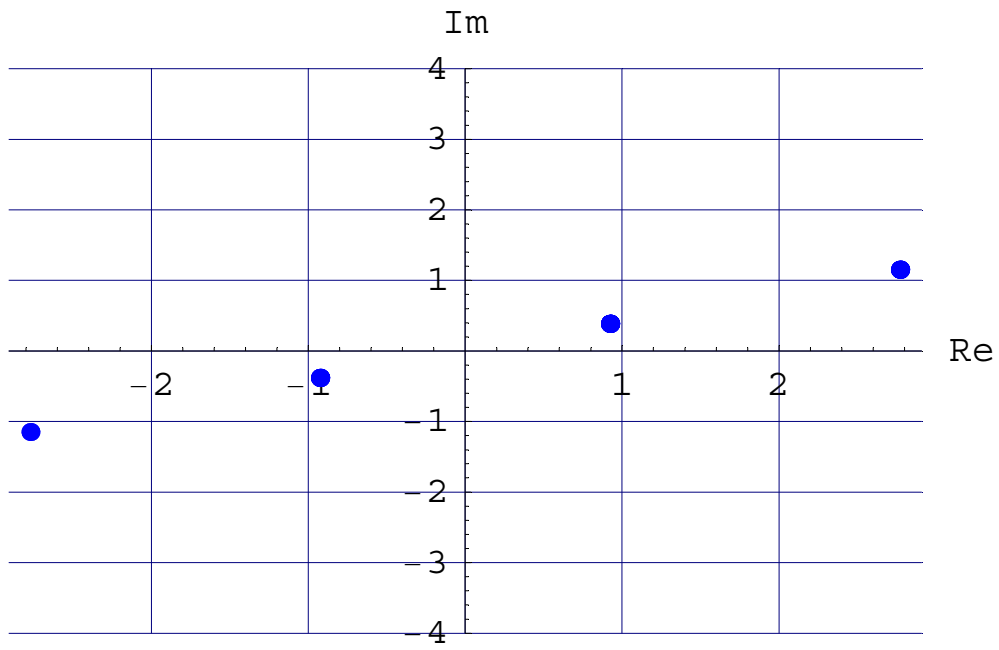
```

va[t],s[t]



Out[446]= - Graphics -





```

(* Modulazione Numerica M-QASK *)

T := 1;
VM := 1;
φ0 := 0;
f0 := 4/T; (* nota:sarebbe f0>>1/T,
  valore scelto per buona visualizzazione grafica *)
g[t_] := If[Abs[t] < 0.5 T, 1, 0];

(* Generazione simboli *)
L := 4;
nsimbvia := 24;
ap := {-3, 1, 3, -1, -3, -1, 1, 3, 1, 3, 1, -1, -3, -1, 1, 3, -3, 1, -3, 1, -3, 3, -1, 3}
aq := {1, -1, 3, 1, -3, 1, 3, -1, 1, -1, -3, 3, -1, -3, -1, 1, 3, 1, 3, 1, 3, -3, -1, 1}

vap[t_] := VM ∑k=1nsimbvia ap[[k]] g[t - k T]
vaq[t_] := VM ∑k=1nsimbvia aq[[k]] g[t - k T]

sQASK[t_] := vap[t] Cos[2 π f0 t + φ0] - vaq[t] Sin[2 π f0 t + φ0]

Plot[{sQASK[t], vap[t], vaq[t]}, {t, 0, 12 T}, PlotStyle →
  {{Red, Thickness[.005]}, {Blue, Thickness[.005]}, {Green, Thickness[.005]}},
  Frame → False, GridLines → Automatic, AxesLabel → {"t/T", "va[t],s[t]"},
  TextStyle → {FontSize → 18}]

(* Costellazione M-QASK *)

φ0 := 0;
iQASK[t_] := (vap[t] + i vaq[t]) Exp[i φ0];

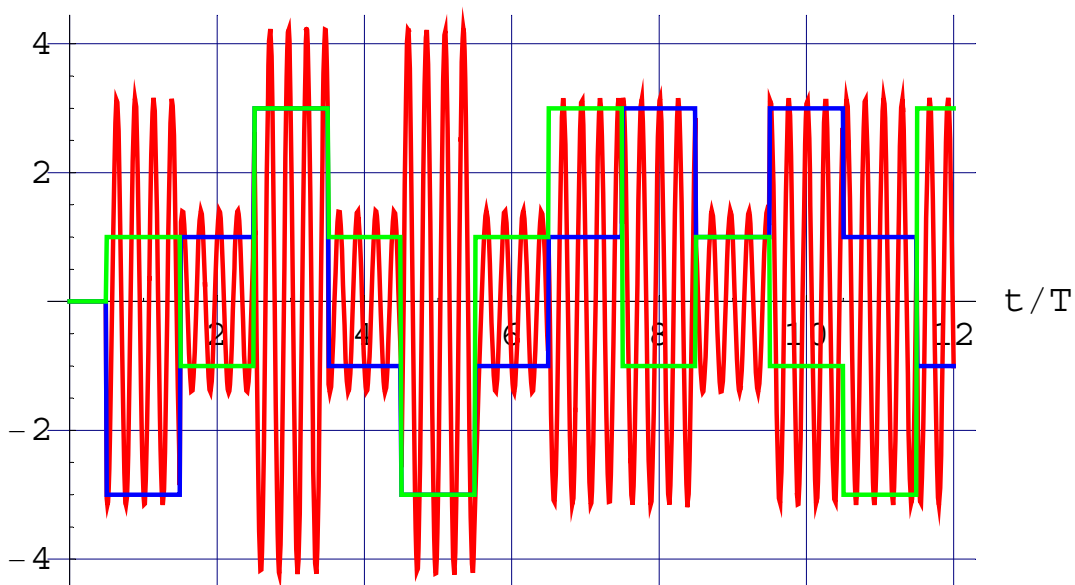
TiQASK = Table[{Re[iQASK[t]], Im[iQASK[t]]}, {t, T, 24 T, T}];
plotTiQASK = ListPlot[TiQASK, PlotRange → {-3, 3},
  PlotStyle → {Blue, PointSize[0.02]}, Frame → False, GridLines → Automatic,
  AxesLabel → {"Re", "Im"}, TextStyle → {FontSize → 18}];

φ0 := π/8;
iQASK[t_] := (vap[t] + i vaq[t]) Exp[i φ0];

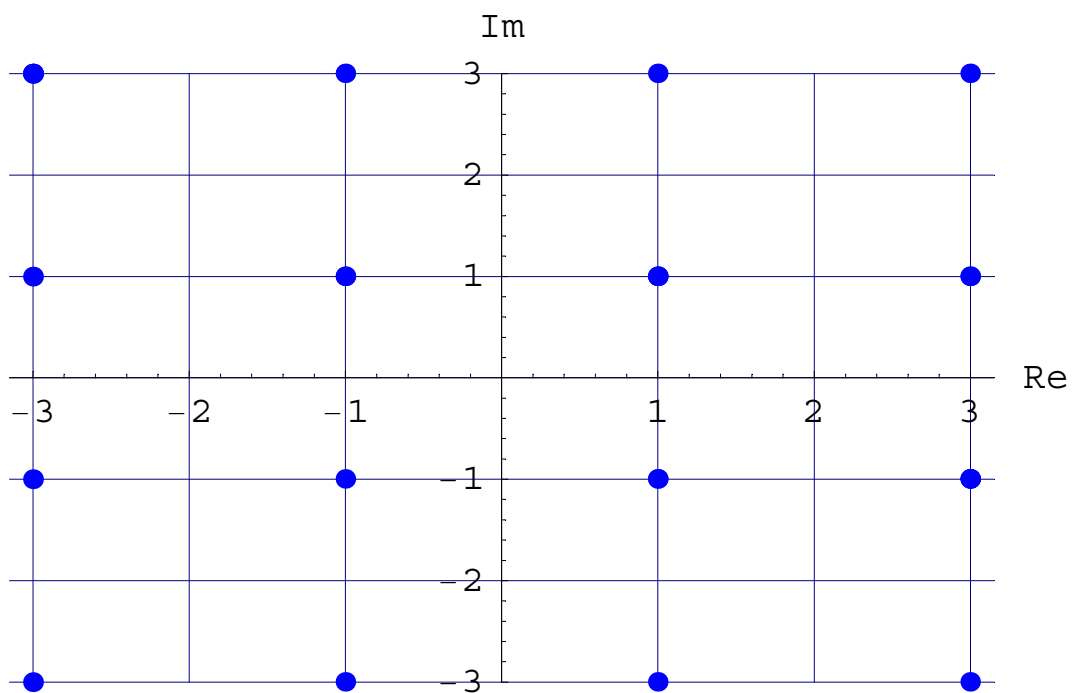
TiQASK = Table[{Re[iQASK[t]], Im[iQASK[t]]}, {t, T, 24 T, T}];
plotTiQASK = ListPlot[TiQASK, PlotRange → {-4, 4},
  PlotStyle → {Blue, PointSize[0.02]}, Frame → False, GridLines → Automatic,
  AxesLabel → {"Re", "Im"}, TextStyle → {FontSize → 18}];

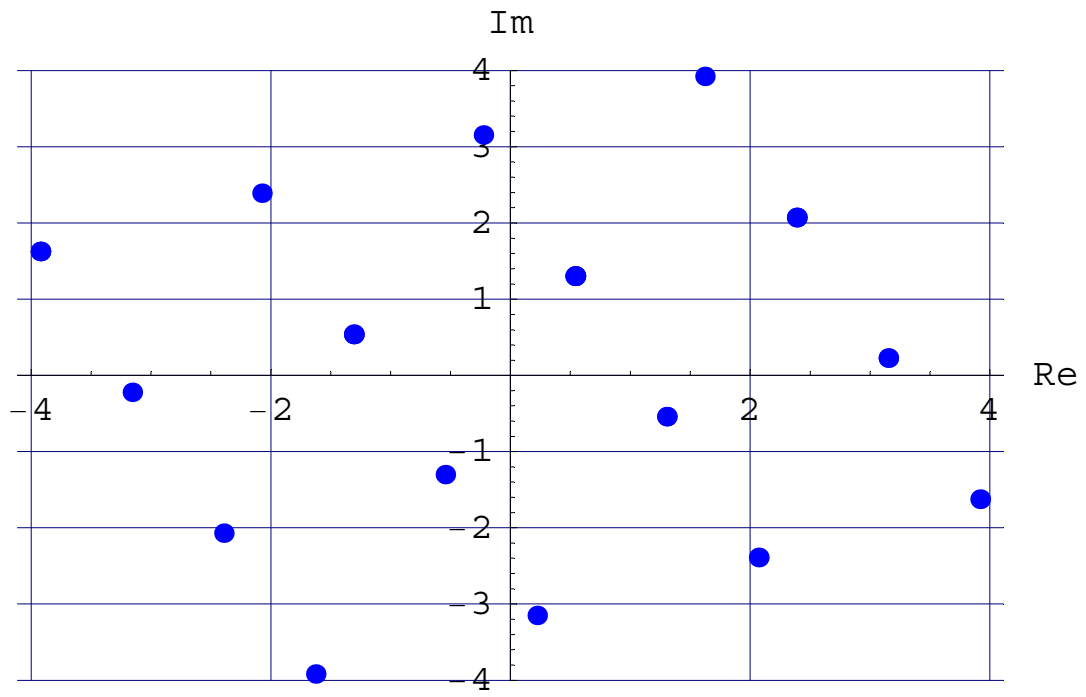
```

va[t],s[t]



Out[467]= - Graphics -





In[481] :=

```
(* Modulazione Numerica L-PSK *)
L := 8;
T := 1;
VM := π / L; (* NOTA: per garantire uniformità su angolo giro *)
V0 := 1;
φ0 := 0;
f0 := 4 / T; (* nota:sarebbe f0>>1/T,
  valore scelto per buona visualizzazione grafica *)
g[t_] := If[Abs[t] < 0.5 T, 1, 0];

(* Generazione simboli *)

nsimb := 24;
a := {-3, 1, 7, -1, 5, -1, -5, -7, 1,
  3, 7, 5, -3, -1, 1, 3, -5, -7, -3, 1, -3, -5, -7, 3}

va[t_] := VM ∑k=1nsimb a[[k]] g[t - k T]

sPSK[t_] := V0 Cos[2 π f0 t + va[t] + φ0]

Plot[{sPSK[t], va[t]}, {t, 0, 24 T}, PlotRange → {-L, L},
  PlotStyle → {{Red, Thickness[.005]}, {Blue, Thickness[.005]}},
  Frame → False, GridLines → Automatic,
  AxesLabel → {"t/T", "va[t],s[t]"}, TextStyle → {FontSize → 18}]

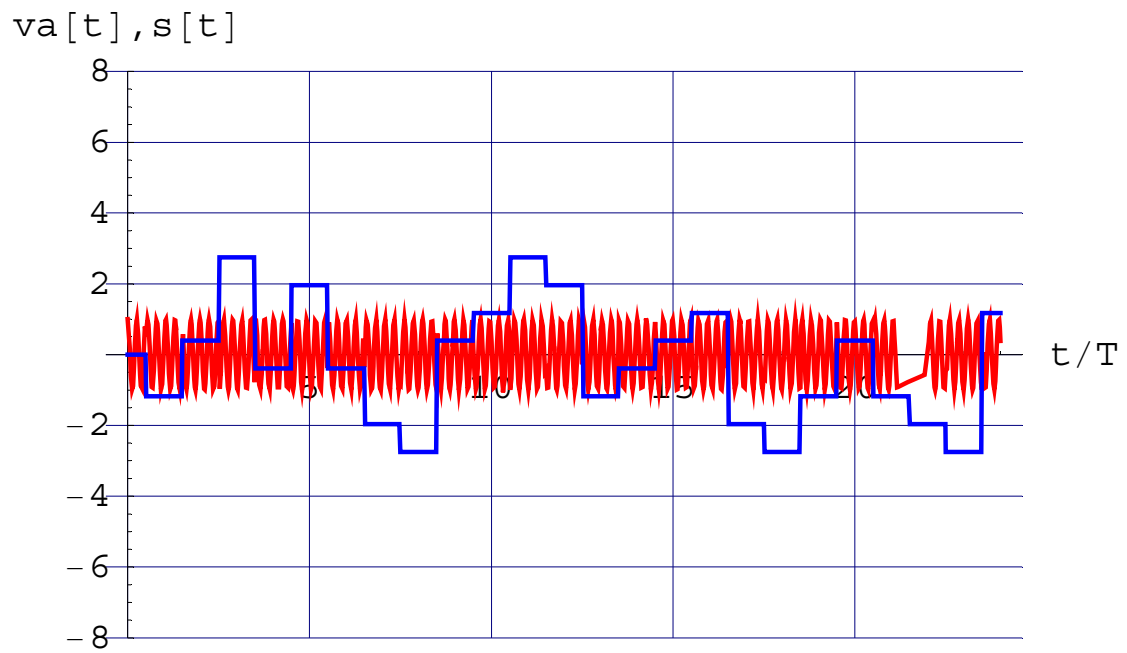
(* Costellazione L-PSK *)

φ0 := 0;
iPSK[t_] := V0 Exp[i (va[t] + φ0)];

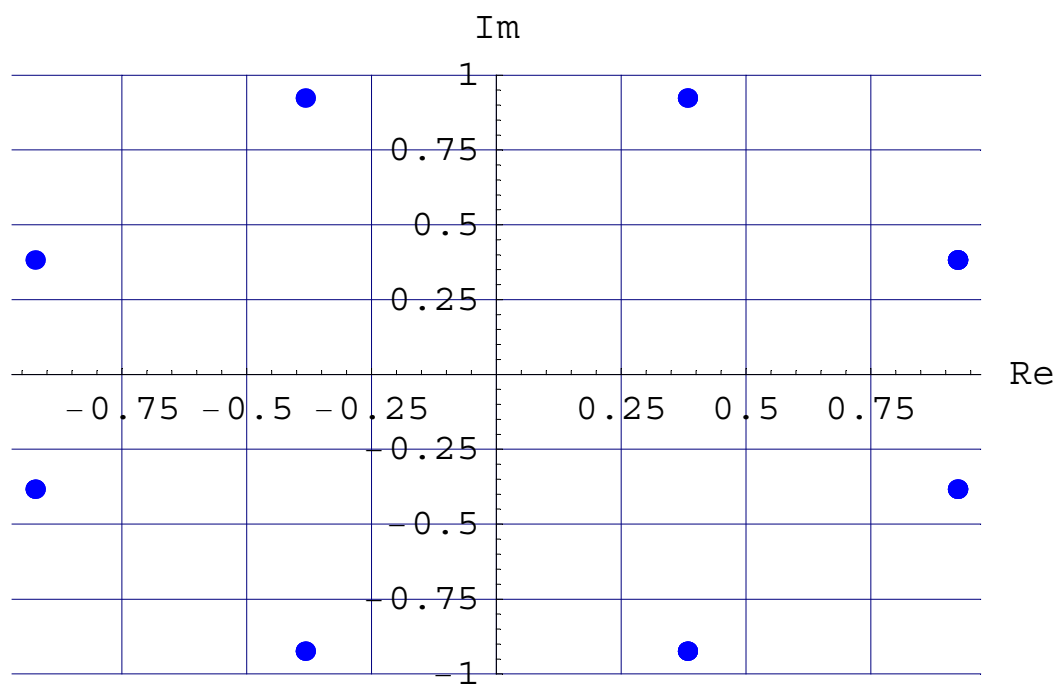
TiPSK = Table[{Re[iPSK[t]], Im[iPSK[t]]}, {t, T, 24 T, T}];
plotTiPSK = ListPlot[TiPSK, PlotRange → {-1., 1.},
  PlotStyle → {Blue, PointSize[0.02]}, Frame → False, GridLines → Automatic,
  AxesLabel → {"Re", "Im"}, TextStyle → {FontSize → 18}];

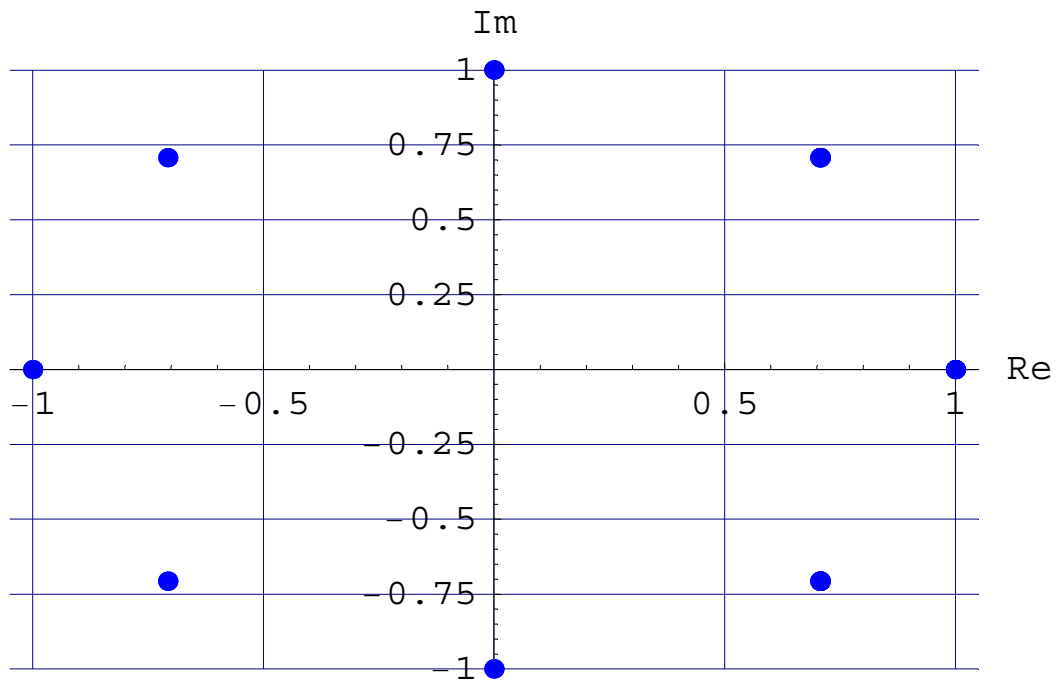
φ0 := π / 8;
iPSK[t_] := V0 Exp[i (va[t] + φ0)];

TiPSK = Table[{Re[iPSK[t]], Im[iPSK[t]]}, {t, T, 24 T, T}];
plotTiPSK = ListPlot[TiPSK, PlotRange → {-1., 1.},
  PlotStyle → {Blue, PointSize[0.02]}, Frame → False, GridLines → Automatic,
  AxesLabel → {"Re", "Im"}, TextStyle → {FontSize → 18}];
```



Out[492]= - Graphics -





```

CR[α_, f_, r0_, Rs_] := If[Abs[f] < (1 - α) Rs / 2, r0 / Rs,
  If[Abs[f] > (1 + α) Rs / 2, 0, r0 / (2 Rs) (1 + Cos[π / (α Rs) (Abs[f] - (1 - α) Rs / 2)]])]

(* Calcolo potenza esterna L-ASK *)

r0 := 1;
Rb := 1;
V := 1;
(* impulso rect G (f) *)
G[f_, Rs_] := (V / Rs) sinc[f / Rs];

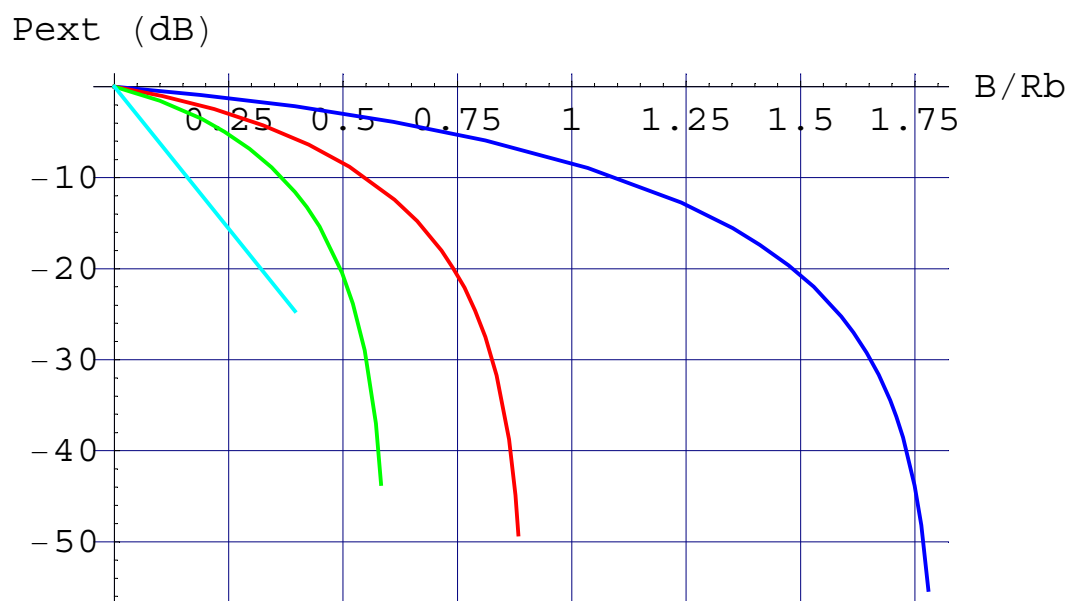
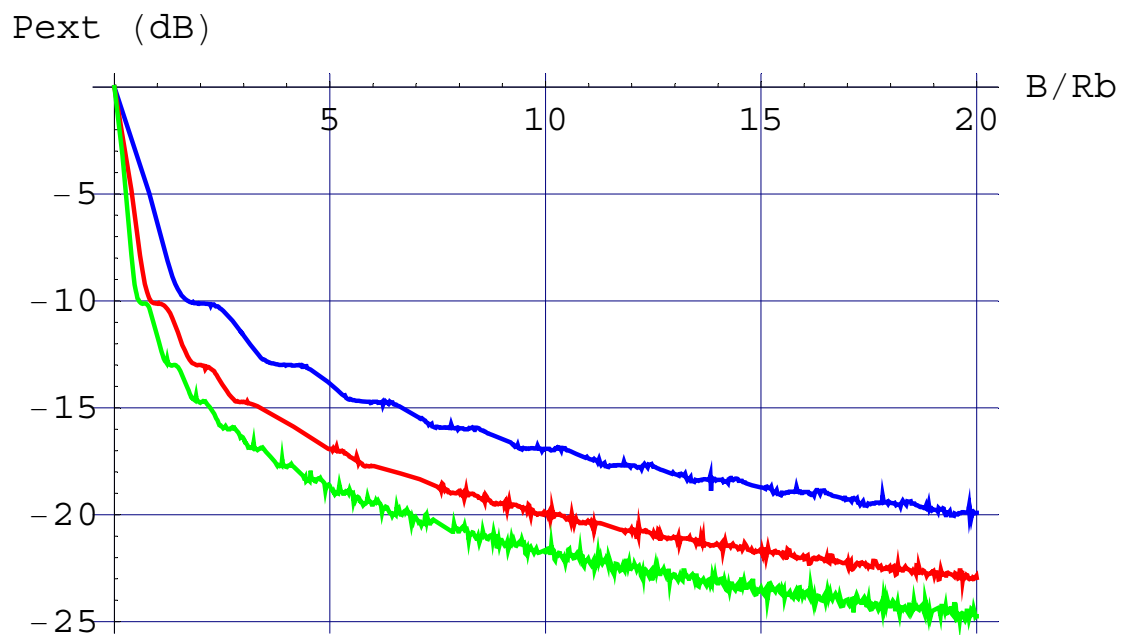
PextrectdB[B_, L_] :=
  10 Log[10, N[∫B/2+∞ G[f, Rb / Log[2, L]]2 df] / N[∫0+∞ G[f, Rb / Log[2, L]]2 df]]

(* impulso √CRα(f) / G(f) *)
CR[α_, f_, r0_, Rs_] := If[Abs[f] < (1 - α) Rs / 2, r0 / Rs,
  If[Abs[f] > (1 + α) Rs / 2, 0, r0 / (2 Rs) (1 + Cos[π / (α Rs) (Abs[f] - (1 - α) Rs / 2)]])]
PextsqrtdB[B_, L_, α_] :=
  10 Log[10, N[∫B/2+∞ CR[α, f, r0, Rb / Log[2, L]] df] / N[∫0+∞ CR[α, f, r0, Rb / Log[2, L]] df]]

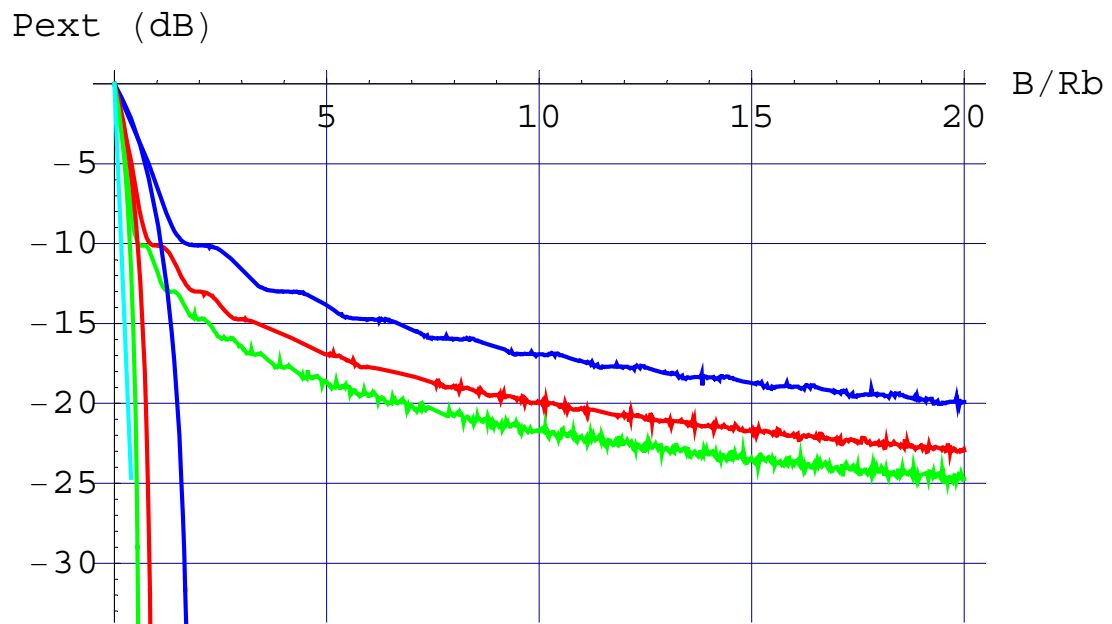
potextrect =
  Plot[{PextrectdB[B, 2], PextrectdB[B, 4], PextrectdB[B, 8]}, {B, 0, 20}, PlotStyle →
    {{Blue, Thickness[.005]}, {Red, Thickness[.005]}, {Green, Thickness[.005]}},
    Frame → False, GridLines → Automatic, AxesLabel → {"B/Rb", "Pext (dB)"},
    TextStyle → {FontSize → 18}];

potextsqrtdB =
  Plot[{PextsqrtdB[B, 2, 0.8], PextsqrtdB[B, 4, 0.8], PextsqrtdB[B, 8, 0.8],
    PextsqrtdB[B, 8, 0.3]}, {B, 0, 20}, PlotStyle → {{Blue, Thickness[.005]},
    {Red, Thickness[.005]}, {Green, Thickness[.005]}, {Cyan, Thickness[.005]}},
    Frame → False, GridLines → Automatic, AxesLabel → {"B/Rb", "Pext (dB)"},
    TextStyle → {FontSize → 18}];

```



```
In[511]:= Show[potextrect, potextsqrtcr]
```



```
Out[511]= - Graphics -
```

```
In[512]:= PextrectdB[20, 8]
```

```
Out[512]= -24.7438
```