Trabajo practico N° 4

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Python Fixed Point

El objetivo es aplicar los conceptos de Aritmética de Punto Fijo usando la clase de Python fixedInt.py.

Ejercicio 1

Aplicar los conceptos de aritmética de punto fijo sobre el filtro rcosine del simulador realizado en python en el archivo tx rcosine procom.py

Actividad 1

Generar tres filtros con rolloff [0.0,0.5,1.0] en punto flotante con NBaud = 16, F Baud = 1G y OS = 8.

In [58]:
```
# coding: utf-8
import numpy as np
import matplotlib.pyplot as plt
from tool._fixedInt import *
## Parametros generales
T     = 1.0/10.0e9    # Periodo de baudio
Nsymb = 1000          # Numero de simbolos
os    = 8             # Over sampling
## Parametros de la respuesta en frecuencia
Nfreqs = 256          # Cantidad de frecuencias

## Parametros del filtro de caida cosenoidal
beta   = [0.0,0.5,1.0] # Roll-Off
Nbauds = 16.0          # Cantidad de baudios del filtro
## Parametros funcionales
Ts = T/os              # Frecuencia de muestreo
```

Funcion para generar el filtro.

In [59]:
```
def rcosine(beta, Tbaud, oversampling, Nbauds, Norm):
    t_vect = np.arange(-0.5*Nbauds*Tbaud, 0.5*Nbauds*Tbaud,float(Tbaud)/oversampling
    y_vect = []
    for t in t_vect:
        y_vect.append(np.sinc(t/Tbaud)*(np.cos(np.pi*beta*t/Tbaud)/(1-(4.0*beta*beta
    y_vect = np.array(y_vect)
    if(Norm):
        return (t_vect, y_vect/np.sqrt(np.sum(y_vect**2)))
    else:
        return (t_vect,y_vect)
```

Calculo de tres filtros RC con diferente roll-off.

In [60]:
```
(t,rc0) = rcosine(beta[0], T,os,Nbauds,Norm=False)
(t,rc1) = rcosine(beta[1], T,os,Nbauds,Norm=False)
```

```
(t,rc2) = rcosine(beta[2], T,os,Nbauds,Norm=False)
```

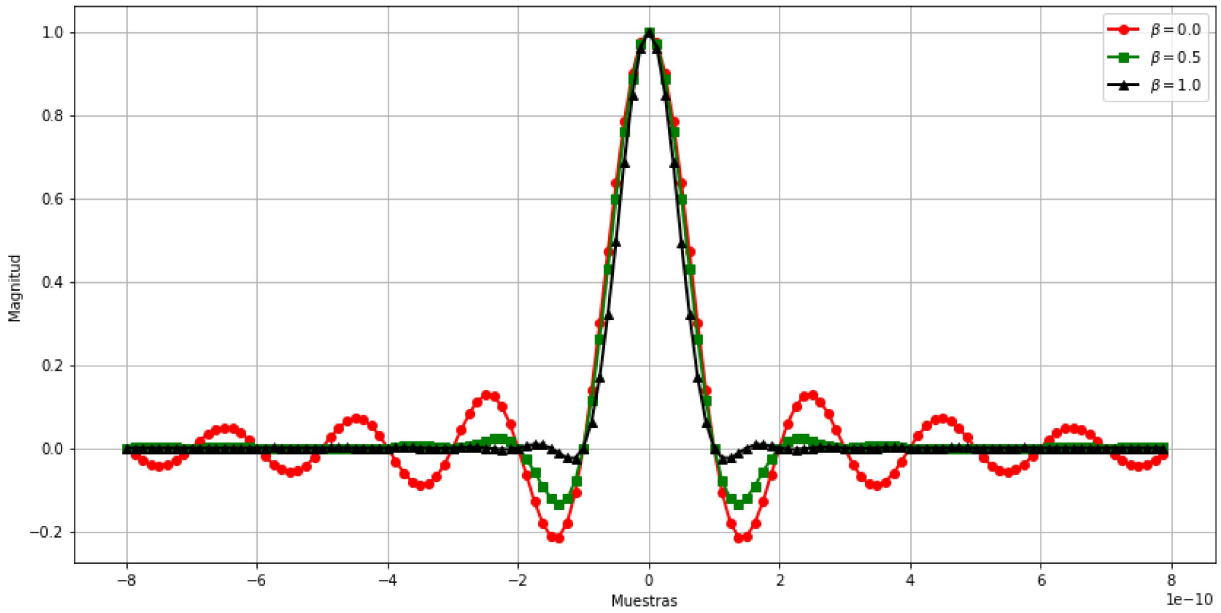
Actividad 2

Graficar la respuesta al impulso y frecuencia.

Respuesta al impulso.

In [63]:

```
plt.figure(figsize=[14,7])
plt.plot(t,rc0,'ro-',linewidth=2.0,label=r'$\beta=0.0$')
plt.plot(t,rc1,'gs-',linewidth=2.0,label=r'$\beta=0.5$')
plt.plot(t,rc2,'k^-',linewidth=2.0,label=r'$\beta=1.0$')
plt.legend()
plt.grid(True)
#plt.xlim(0,len(rc0)-1)
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.show()
```



Calculo de respuesta en frecuencia.

In [64]:

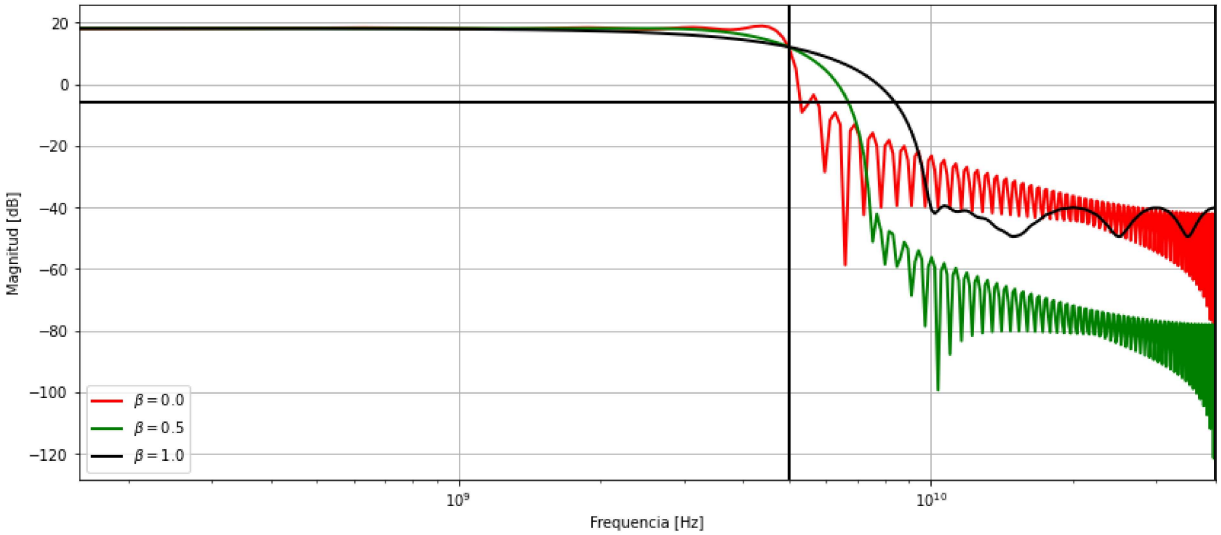
```
def resp_freq(filt, Ts, Nfreqs):
    #Computo de la respuesta en frecuencia de cualquier filtro FIR
    H = [] # Lista de salida de la magnitud
    A = [] # Lista de salida de la fase
    filt_len = len(filt)

    #### Genero el vector de frecuencias
    freqs = np.matrix(np.linspace(0,1.0/(2.0*Ts),Nfreqs))
    #### Calculo cuantas muestras necesito para 20 ciclo de
    #### la mas baja frec diferente de cero
    Lseq = 20.0/(freqs[0,1]*Ts)

    #### Genero el vector tiempo
    t = np.matrix(np.arange(0,Lseq))*Ts

    #### Genero la matriz de 2pifTn
    Omega = 2.0j*np.pi*(t.transpose()*freqs)

    #### Valuacion de la exponencial compleja en todo el
    #### rango de frecuencias
    fin = np.exp(Omega)
```

```
    #### Suma de convolucion con cada una de las exponenciales complejas
    for i in range(0,np.size(fin,1)):
        fout = np.convolve(np.squeeze(np.array(fin[:,i].transpose())),filt)
        mfout = abs(fout[filt_len:len(fout)-filt_len])
        afout = np.angle(fout[filt_len:len(fout)-filt_len])
        H.append(mfout.sum()/len(mfout))
        A.append(afout.sum()/len(afout))

    return [H,A,list(np.squeeze(np.array(freqs)))]
```

Grafico de la respuesta en frecuencia.

In [65]:

```
### Calculo respuesta en frec para los tres pulsos
[H0,A0,F0] = resp_freq(rc0, Ts, Nfreqs)
[H1,A1,F1] = resp_freq(rc1, Ts, Nfreqs)
[H2,A2,F2] = resp_freq(rc2, Ts, Nfreqs)

### Generacion de los graficos
plt.figure(figsize=[14,6])
plt.semilogx(F0, 20*np.log10(H0),'r', linewidth=2.0, label=r'$\beta=0.0$')
plt.semilogx(F1, 20*np.log10(H1),'g', linewidth=2.0, label=r'$\beta=0.5$')
plt.semilogx(F2, 20*np.log10(H2),'k', linewidth=2.0, label=r'$\beta=1.0$')

plt.axvline(x=(1./Ts)/2.,color='k',linewidth=2.0)
plt.axvline(x=(1./T)/2.,color='k',linewidth=2.0)
plt.axhline(y=20*np.log10(0.5),color='k',linewidth=2.0)
plt.legend(loc=3)
plt.grid(True)
plt.xlim(F2[1],F2[len(F2)-1])
plt.xlabel('Frequencia [Hz]')
plt.ylabel('Magnitud [dB]')
plt.show()
```



Actividad 3

Graficar la convolución de los tres filtros con los símbolos a transmitir y la constelación buscado la fase óptima.

Grafico para rolloff 0.0

In [66]:

```
symbolsI = 2*(np.random.uniform(-1,1,Nsymb)>0.0)-1;
symbolsQ = 2*(np.random.uniform(-1,1,Nsymb)>0.0)-1;
zsymbI = np.zeros(os*Nsymb); zsymbI[1:len(zsymbI):int(os)]=symbolsI
```

```
zsymbQ = np.zeros(os*Nsymb); zsymbQ[1:len(zsymbQ):int(os)]=symbolsQ

symb_out0I = np.convolve(rc0,zsymbI,'same');
symb_out0Q = np.convolve(rc0,zsymbQ,'same')
plt.figure(figsize=[10,6])
plt.subplot(2,1,1)
plt.plot(symb_out0I,'r-',linewidth=2.0,label=r'$\beta=%2.2f$'%beta[0])
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')

plt.subplot(2,1,2)
plt.plot(symb_out0Q,'r-',linewidth=2.0,label=r'$\beta=%2.2f$'%beta[0])
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')

plt.show()
```

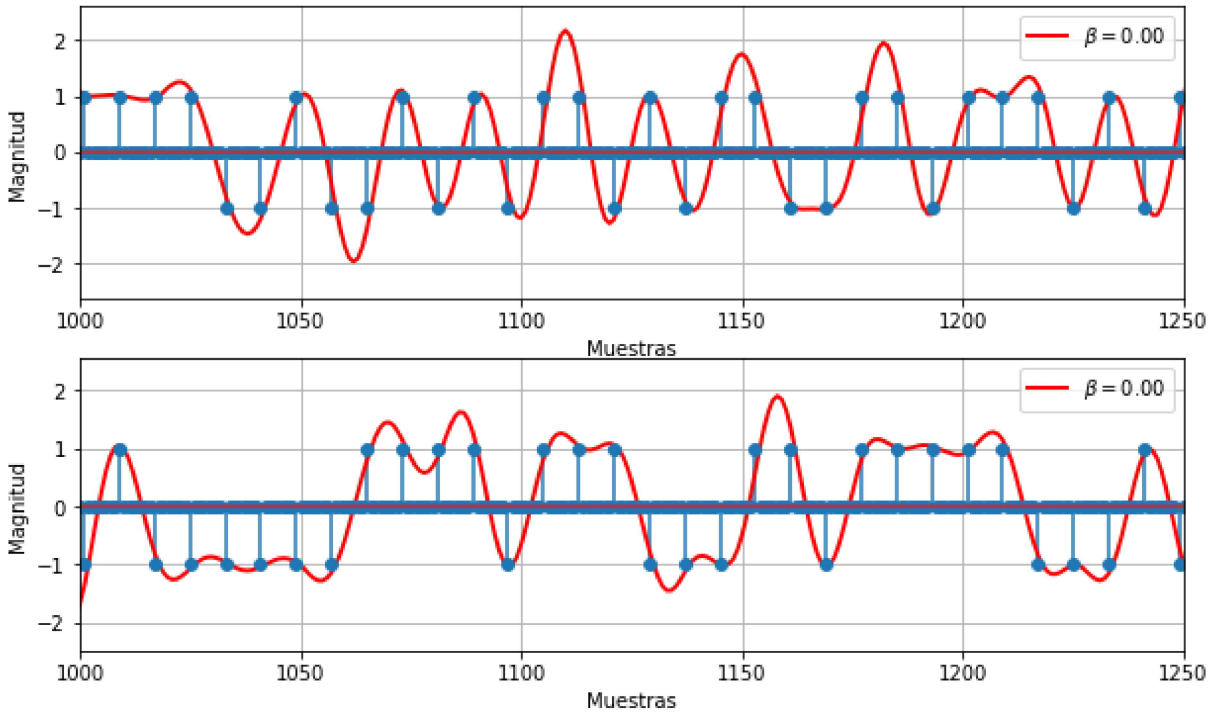


Grafico para rolloff 0.5

In [67]:

```
symb_out1I = np.convolve(rc1,zsymbI,'same'); symb_out1Q = np.convolve(rc1,zsymbQ,'sa

plt.figure(figsize=[10,6])
plt.subplot(2,1,1)
plt.plot(symb_out1I,'g-',linewidth=2.0,label=r'$\beta=%2.2f$'%beta[1])
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')

plt.subplot(2,1,2)
```

```
plt.plot(symb_out1Q,'g-',linewidth=2.0,label=r'$\beta=%2.2f$'%beta[1])
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')

plt.show()
```

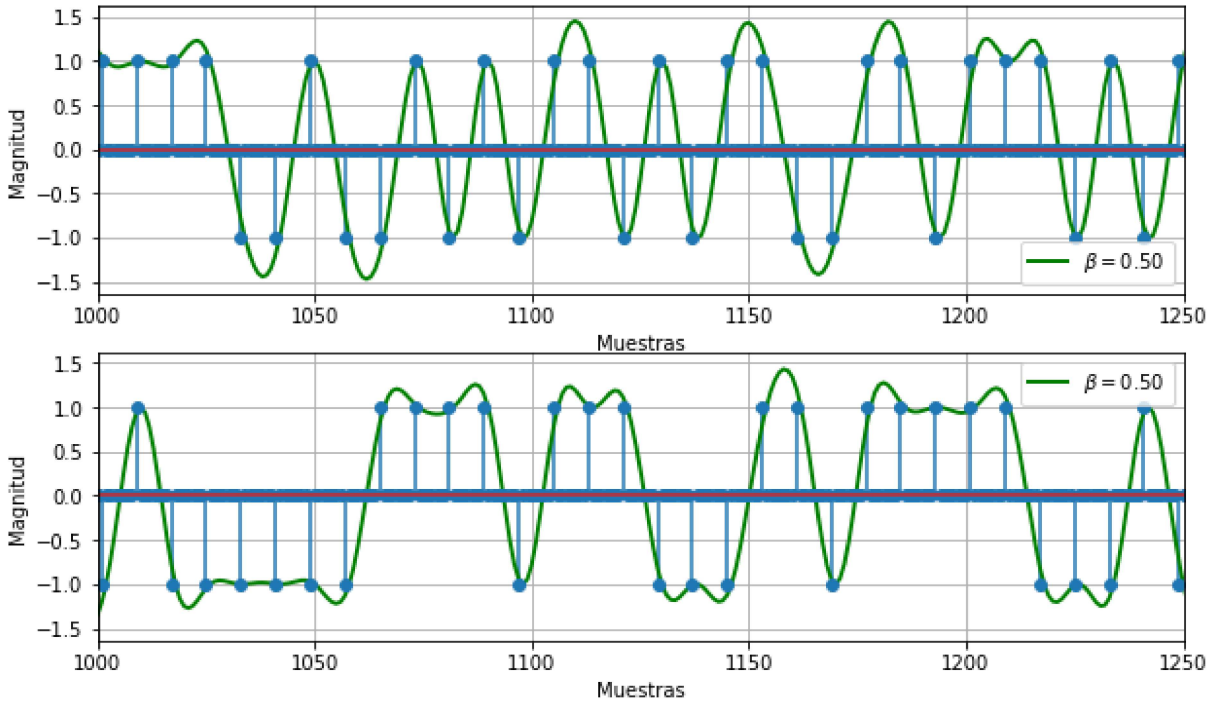
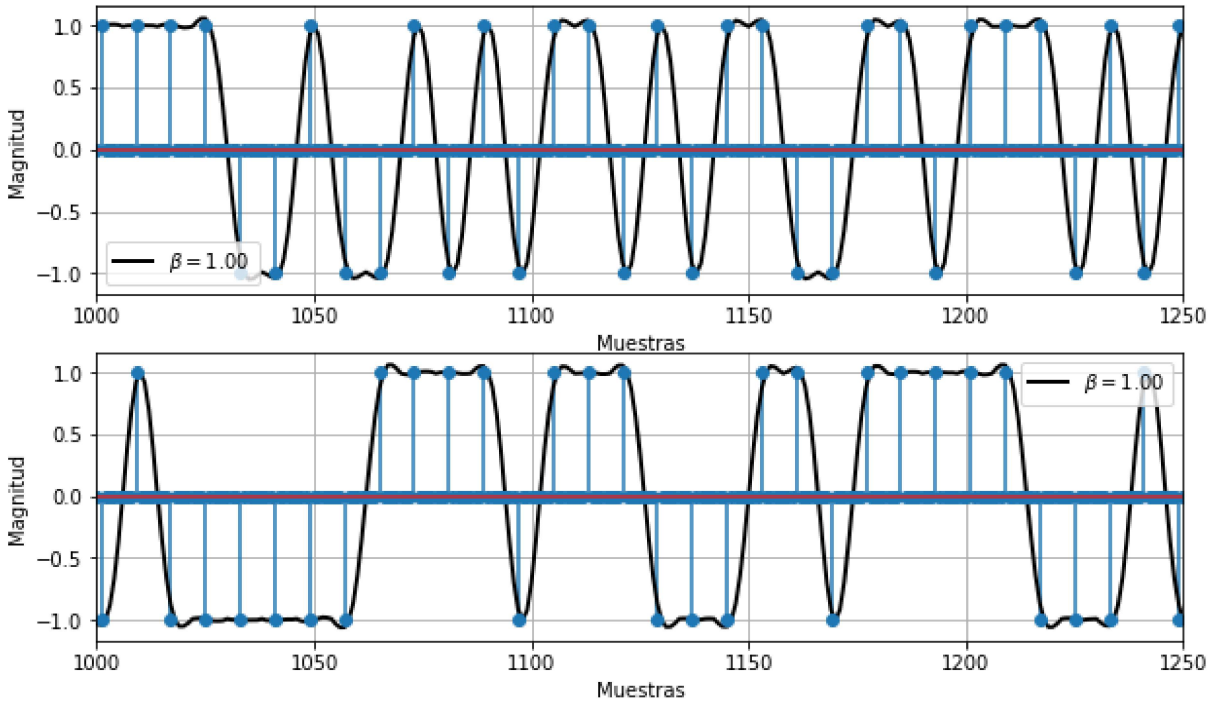


Grafico para rolloff 1.0

In [68]:

```
symb_out2I = np.convolve(rc2,zsymbI,'same')
symb_out2Q = np.convolve(rc2,zsymbQ,'same')

plt.figure(figsize=[10,6])
plt.subplot(2,1,1)
plt.plot(symb_out2I,'k-',linewidth=2.0,label=r'$\beta=%2.2f$'%beta[2])
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')

plt.subplot(2,1,2)
plt.plot(symb_out2Q,'k-',linewidth=2.0,label=r'$\beta=%2.2f$'%beta[2])
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')

plt.show()
```

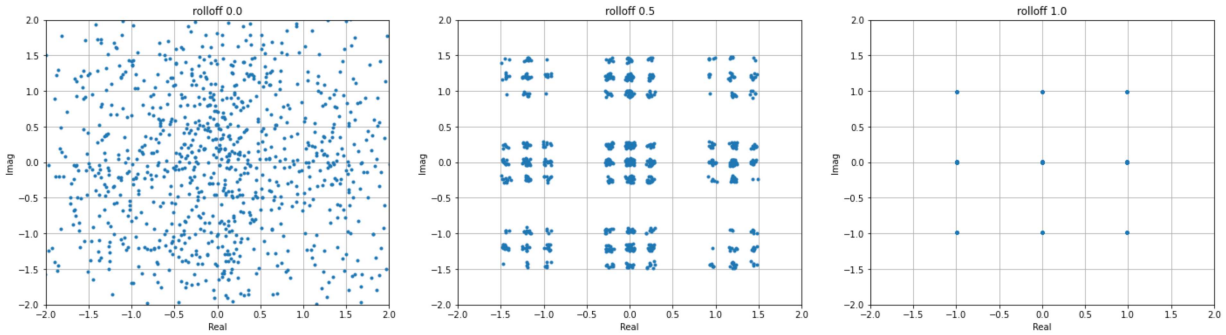


Busqueda de fase optima

Constellación con offset 2.

In [69]:

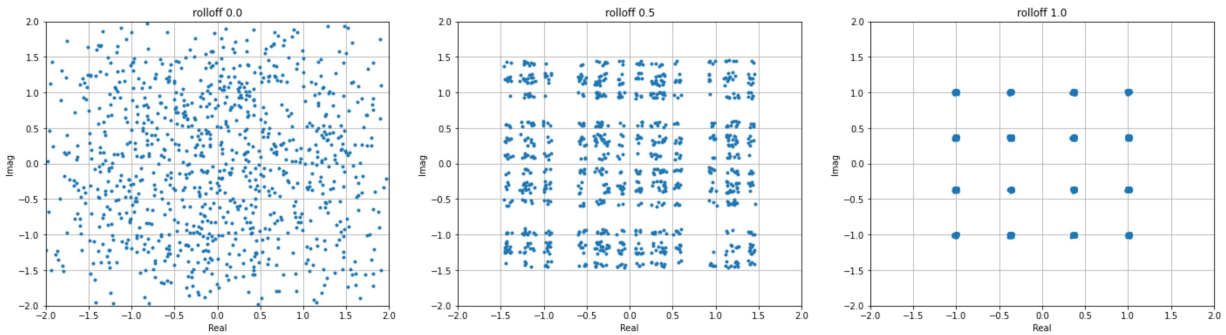
```
offset = 2

plt.figure(figsize=[6*4,6])
plt.subplot(1,3,1)
plt.plot(symb_out0I[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out0Q[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0")

plt.subplot(1,3,2)
plt.plot(symb_out1I[100+offset:len(symb_out1I)-(100-offset):int(os)],
         symb_out1Q[100+offset:len(symb_out1Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.5")

plt.subplot(1,3,3)
plt.plot(symb_out2I[100+offset:len(symb_out2I)-(100-offset):int(os)],
         symb_out2Q[100+offset:len(symb_out2Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0")

plt.show()
```



Constellación con offset 3.

In [70]:

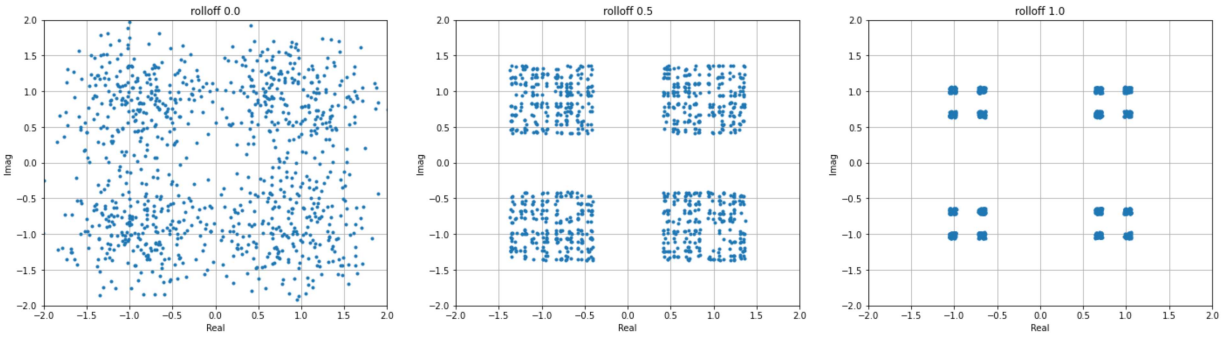
```
offset = 3

plt.figure(figsize=[6*4,6])
plt.subplot(1,3,1)
plt.plot(symb_out0I[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out0Q[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0")

plt.subplot(1,3,2)
plt.plot(symb_out1I[100+offset:len(symb_out1I)-(100-offset):int(os)],
         symb_out1Q[100+offset:len(symb_out1Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.5")

plt.subplot(1,3,3)
plt.plot(symb_out2I[100+offset:len(symb_out2I)-(100-offset):int(os)],
         symb_out2Q[100+offset:len(symb_out2Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0")

plt.show()
```



Constellación con offset 4.

In [71]:

```
offset = 4

plt.figure(figsize=[6*4,6])
plt.subplot(1,3,1)
plt.plot(symb_out0I[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out0Q[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0")

plt.subplot(1,3,2)
plt.plot(symb_out1I[100+offset:len(symb_out1I)-(100-offset):int(os)],
         symb_out1Q[100+offset:len(symb_out1Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.5")

plt.subplot(1,3,3)
plt.plot(symb_out2I[100+offset:len(symb_out2I)-(100-offset):int(os)],
         symb_out2Q[100+offset:len(symb_out2Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0")

plt.show()
```

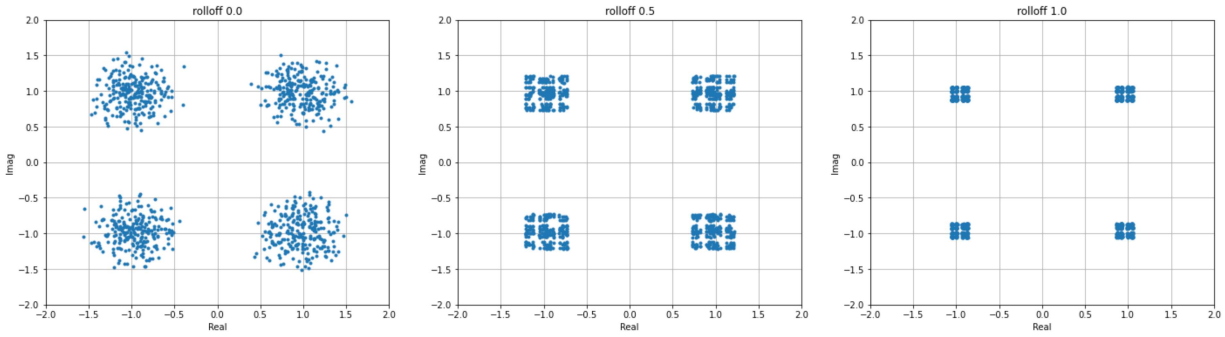


Constellación con offset 5.

In [72]:

```
offset = 5

plt.figure(figsize=[6*4,6])
plt.subplot(1,3,1)
plt.plot(symb_out0I[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out0Q[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
```

```
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0")

plt.subplot(1,3,2)
plt.plot(symb_out1I[100+offset:len(symb_out1I)-(100-offset):int(os)],
         symb_out1Q[100+offset:len(symb_out1Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.5")

plt.subplot(1,3,3)
plt.plot(symb_out2I[100+offset:len(symb_out2I)-(100-offset):int(os)],
         symb_out2Q[100+offset:len(symb_out2Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0")

plt.show()
```

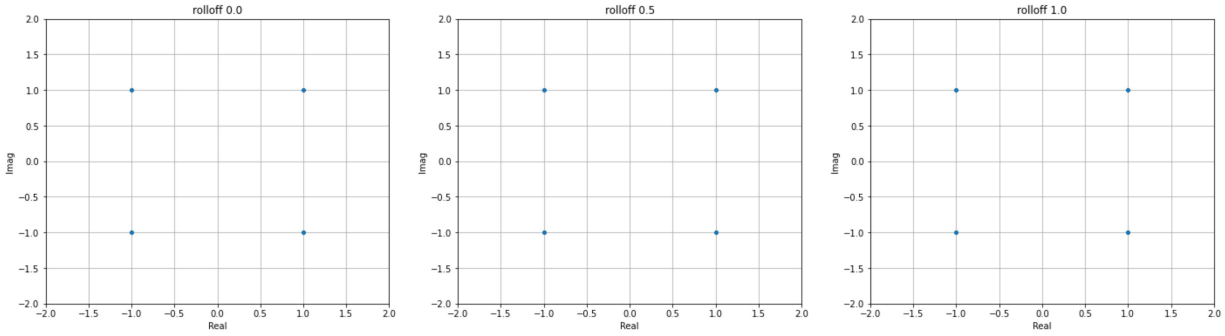


Constellación con offset 6.

In [73]:

```
offset = 6

plt.figure(figsize=[6*4,6])
plt.subplot(1,3,1)
plt.plot(symb_out0I[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out0Q[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0")

plt.subplot(1,3,2)
plt.plot(symb_out1I[100+offset:len(symb_out1I)-(100-offset):int(os)],
         symb_out1Q[100+offset:len(symb_out1Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
```

```
plt.title("rolloff 0.5")

plt.subplot(1,3,3)
plt.plot(symb_out2I[100+offset:len(symb_out2I)-(100-offset):int(os)],
         symb_out2Q[100+offset:len(symb_out2Q)-(100-offset):int(os)],
             '.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0")

plt.show()
```



Como se puede ver en los graficos, la fase optima se consigue con un valor de 6.

Actividad 4, 5 y 6

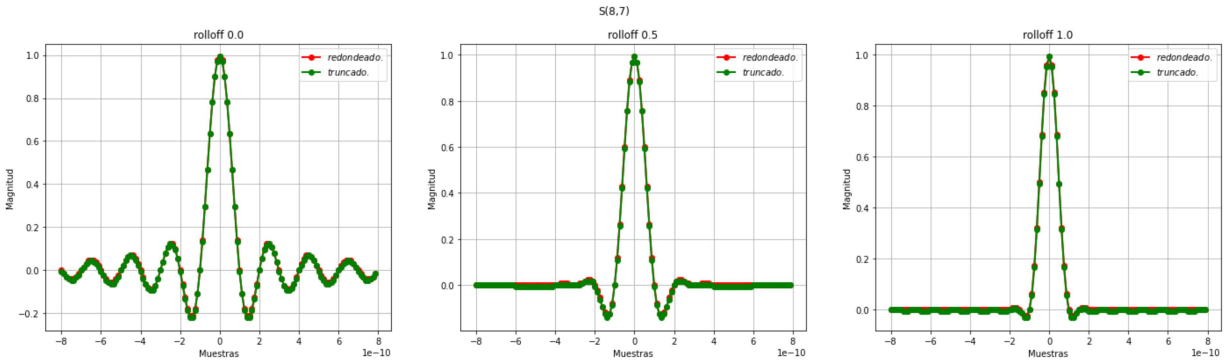
Sobre cada filtro aplicar las siguiente cuantizaciones: S(8, 7) truncado, S(8, 7) redondeo, S(3, 2) truncado, S(3, 2) redondeo, S(6, 4) truncado y S(6, 4) redondeo. En todos los casos considerar saturación.

Cuantización S(8,7).

In [74]:

```
#_____________________ rolloff  0.0 _____________________
rc0_aux=arrayFixedInt(8, 7,rc0 , signedMode='S', roundMode='round', saturateMode='sa
rc0_sxx_r=np.array([rc0_aux[i].fValue for i in range(len(rc0_aux))])
rc0_aux=arrayFixedInt(8, 7,rc0 , signedMode='S', roundMode='trunc', saturateMode='sa
rc0_sxx_t=np.array([rc0_aux[i].fValue for i in range(len(rc0_aux))])
#_____________________ rolloff  0.5 _____________________
rc1_aux=arrayFixedInt(8, 7,rc1 , signedMode='S', roundMode='round', saturateMode='sa
rc1_sxx_r=np.array([rc1_aux[i].fValue for i in range(len(rc0_aux))])
rc1_aux=arrayFixedInt(8, 7,rc1 , signedMode='S', roundMode='trunc', saturateMode='sa
rc1_sxx_t=np.array([rc1_aux[i].fValue for i in range(len(rc0_aux))])
#_____________________ rolloff  1.0 _____________________
rc2_aux=arrayFixedInt(8, 7,rc2 , signedMode='S', roundMode='round', saturateMode='sa
rc2_sxx_r=np.array([rc2_aux[i].fValue for i in range(len(rc0_aux))])
rc2_aux=arrayFixedInt(8, 7,rc2 , signedMode='S', roundMode='trunc', saturateMode='sa
rc2_sxx_t=np.array([rc2_aux[i].fValue for i in range(len(rc0_aux))])

plt.figure(figsize=[6*4,6])
plt.subplot(1,3,1)
plt.plot(t,rc0_sxx_r,'ro-',linewidth=2.0,label=r'$redondeado.$')
plt.plot(t,rc0_sxx_t,'go-',linewidth=2.0,label=r'$truncado.$')
plt.legend()
plt.grid(True)
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title("rolloff 0.0")
```

```
plt.subplot(1,3,2)
plt.plot(t,rc1_sxx_r,'ro-',linewidth=2.0,label=r'$redondeado.$')
plt.plot(t,rc1_sxx_t,'go-',linewidth=2.0,label=r'$truncado.$')
plt.legend()
plt.grid(True)
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title("rolloff 0.5")


plt.subplot(1,3,3)
plt.plot(t,rc2_sxx_r,'ro-',linewidth=2.0,label=r'$redondeado.$')
plt.plot(t,rc2_sxx_t,'go-',linewidth=2.0,label=r'$truncado.$')
plt.legend()
plt.grid(True)
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title("rolloff 1.0")
plt.suptitle('S(8,7)')
plt.show()
```

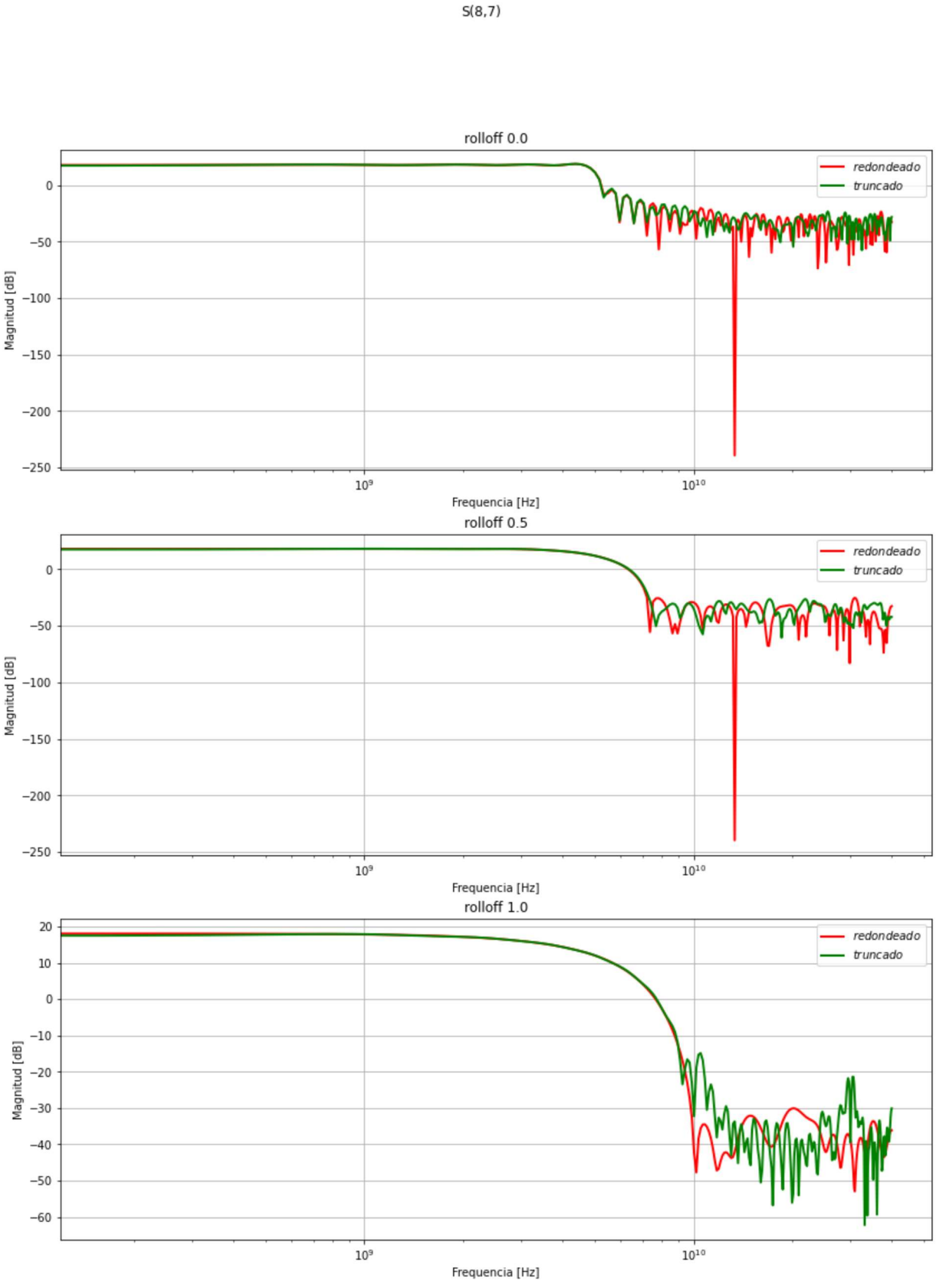


Respuesta en frecuencia.

In [75]:

```
#_____________________ rolloff  0.0 _____________________
[H0_r,A0_r,F0_r] = resp_freq(rc0_sxx_r, Ts, Nfreqs)
[H0_t,A0_t,F0_t] = resp_freq(rc0_sxx_t, Ts, Nfreqs)
#_____________________ rolloff  0.5 _____________________
[H1_r,A1_r,F1_r] = resp_freq(rc1_sxx_r, Ts, Nfreqs)
[H1_t,A1_t,F1_t] = resp_freq(rc1_sxx_t, Ts, Nfreqs)
#_____________________ rolloff  1.0 _____________________
[H2_r,A2_r,F2_r] = resp_freq(rc2_sxx_r, Ts, Nfreqs)
[H2_t,A2_t,F2_t] = resp_freq(rc2_sxx_t, Ts, Nfreqs)
#_____________________ rolloff  0.0 _____________________
plt.figure(figsize=[14,6*3])
plt.subplot(3,1,1)
plt.semilogx(F0_r, 20*np.log10(H0_r),'r', linewidth=2.0, label=r'$redondeado$')
plt.semilogx(F0_t, 20*np.log10(H0_t),'g', linewidth=2.0, label=r'$truncado$')
plt.legend()
plt.grid(True)
plt.xlabel('Frequencia [Hz]')
plt.ylabel('Magnitud [dB]')
plt.title('rolloff 0.0')
#_____________________ rolloff  0.5 _____________________
plt.subplot(3,1,2)
plt.semilogx(F1_r, 20*np.log10(H1_r),'r', linewidth=2.0, label=r'$redondeado$')
plt.semilogx(F1_t, 20*np.log10(H1_t),'g', linewidth=2.0, label=r'$truncado$')
plt.legend()
plt.grid(True)
plt.xlabel('Frequencia [Hz]')
plt.ylabel('Magnitud [dB]')
plt.title('rolloff 0.5')
```

```
#_____________________ rolloff  1.0 ____________________
plt.subplot(3,1,3)
plt.semilogx(F2_r, 20*np.log10(H2_r),'r', linewidth=2.0, label=r'$redondeado$')
plt.semilogx(F2_t, 20*np.log10(H2_t),'g', linewidth=2.0, label=r'$truncado$')
plt.legend()
plt.grid(True)
plt.xlabel('Frequencia [Hz]')
plt.ylabel('Magnitud [dB]')
plt.title('rolloff 1.0')
plt.suptitle('S(8,7)')
plt.show()
```

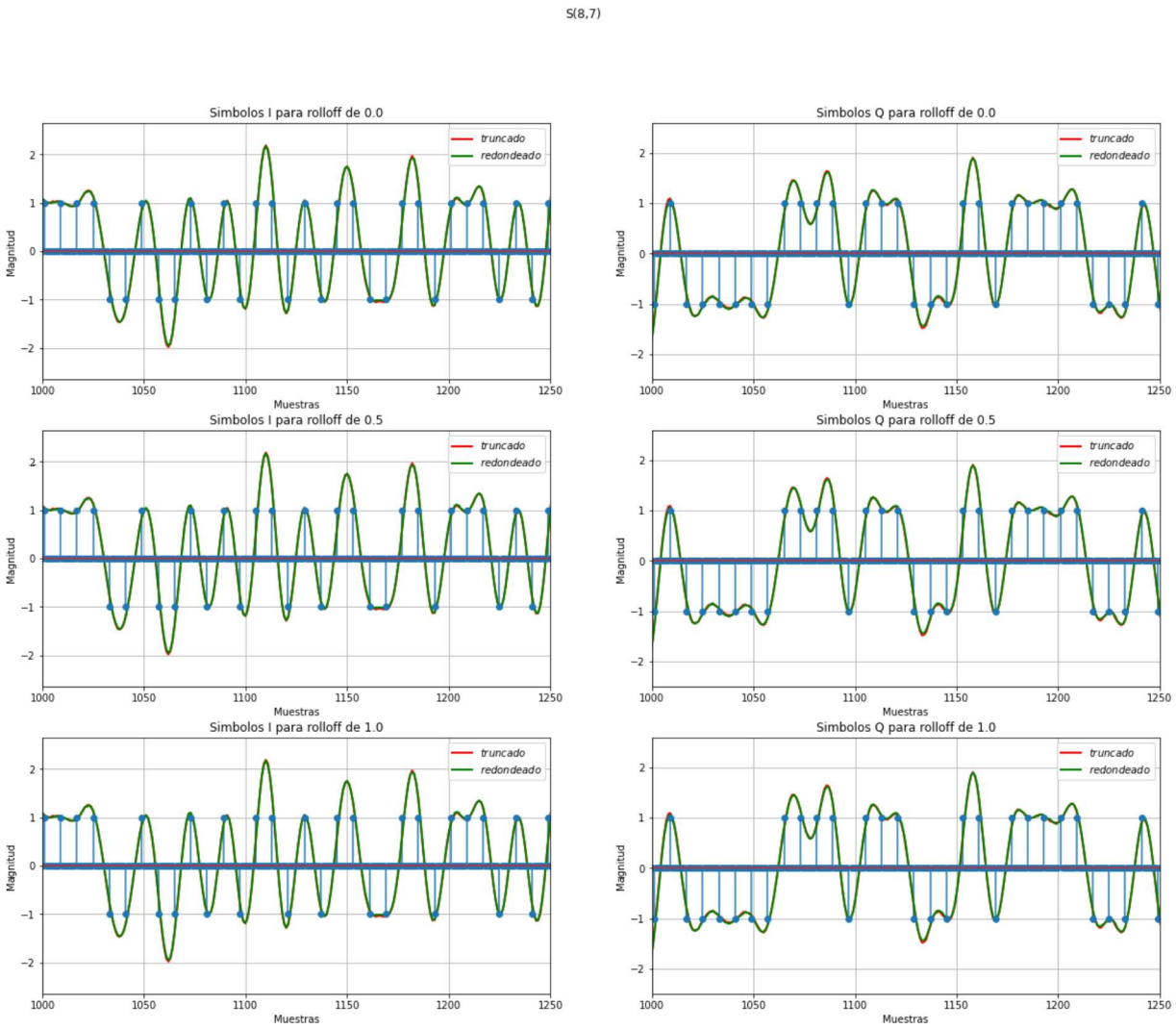


Convolución.

In [76]:

```
#_____________________ rolloff  0.0 ____________________
symb_out0I_r = np.convolve(rc0_sxx_r,zsymbI,'same')
symb_out0Q_r = np.convolve(rc0_sxx_r,zsymbQ,'same')
symb_out0I_t = np.convolve(rc0_sxx_t,zsymbI,'same')
symb_out0Q_t = np.convolve(rc0_sxx_t,zsymbQ,'same')
#_____________________ rolloff  0.5 ____________________
symb_out1I_r = np.convolve(rc1_sxx_r,zsymbI,'same')
symb_out1Q_r = np.convolve(rc1_sxx_r,zsymbQ,'same')
symb_out1I_t = np.convolve(rc1_sxx_t,zsymbI,'same')
symb_out1Q_t = np.convolve(rc1_sxx_t,zsymbQ,'same')
#_____________________ rolloff  1.0 ____________________
symb_out2I_r = np.convolve(rc2_sxx_r,zsymbI,'same')
symb_out2Q_r = np.convolve(rc2_sxx_r,zsymbQ,'same')
symb_out2I_t = np.convolve(rc2_sxx_t,zsymbI,'same')
symb_out2Q_t = np.convolve(rc2_sxx_t,zsymbQ,'same')

plt.figure(figsize=[10*2,4*4])
plt.subplot(3,2,1)
plt.plot(symb_out0I_t,'r-',linewidth=2.0,label=r'$truncado$')
plt.plot(symb_out0I_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos I para rolloff de 0.0')
plt.subplot(3,2,2)
plt.plot(symb_out0Q_t,'r-',linewidth=2.0,label=r'$truncado$' )
plt.plot(symb_out0Q_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos Q para rolloff de 0.0')


plt.subplot(3,2,3)
plt.plot(symb_out0I_t,'r-',linewidth=2.0,label=r'$truncado$')
plt.plot(symb_out0I_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos I para rolloff de 0.5')
plt.subplot(3,2,4)
plt.plot(symb_out0Q_t,'r-',linewidth=2.0,label=r'$truncado$' )
plt.plot(symb_out0Q_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos Q para rolloff de 0.5')


plt.subplot(3,2,5)
```

```
plt.plot(symb_out0I_t,'r-',linewidth=2.0,label=r'$truncado$')
plt.plot(symb_out0I_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos I para rolloff de 1.0')
plt.subplot(3,2,6)
plt.plot(symb_out0Q_t,'r-',linewidth=2.0,label=r'$truncado$' )
plt.plot(symb_out0Q_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos Q para rolloff de 1.0')
plt.suptitle('S(8,7)')

plt.show()
```

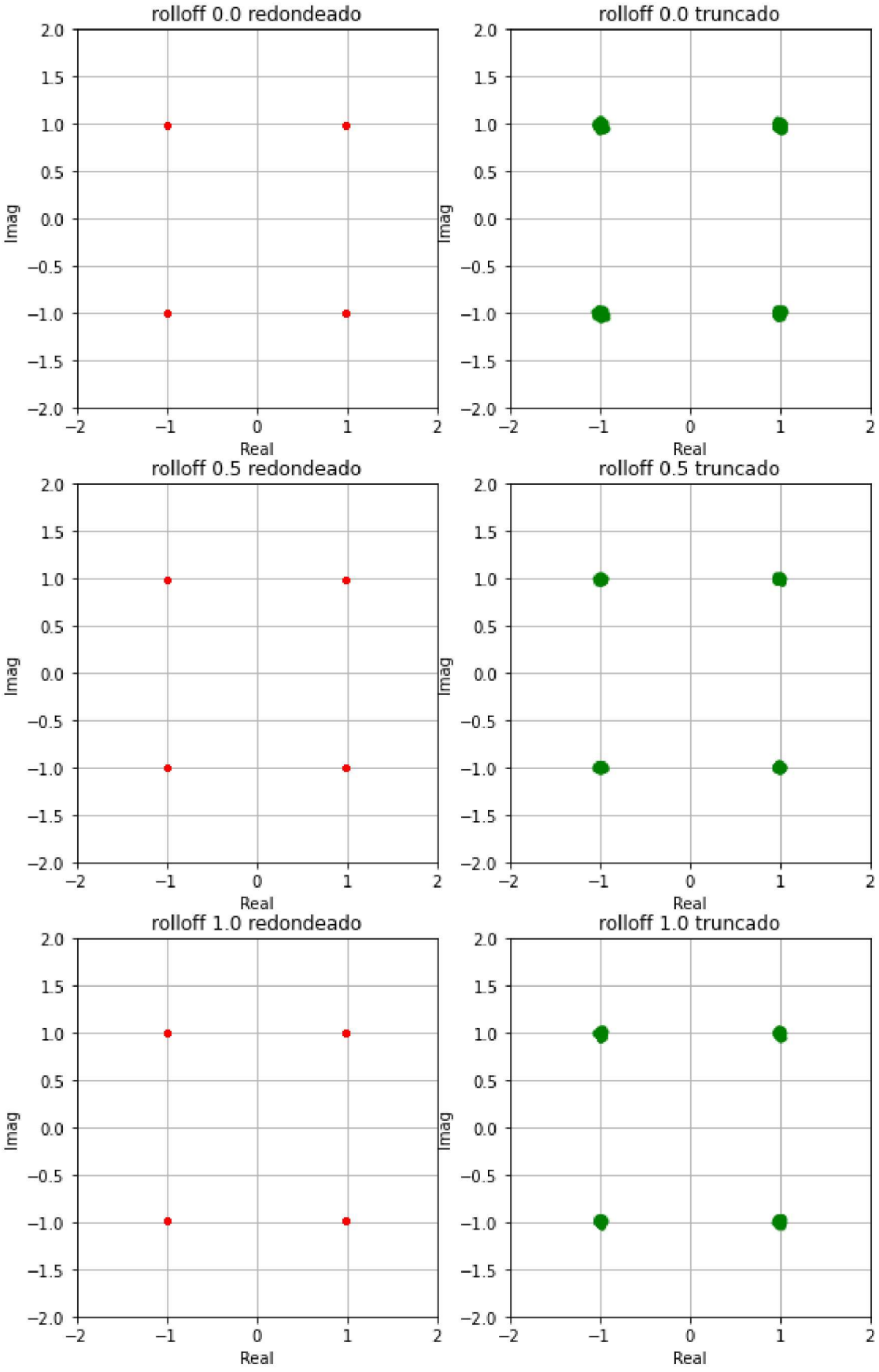


Constelación.

In [77]:

```
offset = 6

plt.figure(figsize=[3*3,3*5])
plt.subplot(3,2,1)
plt.plot(symb_out0I_r[100+offset:len(symb_out0I)-(100-offset):int(os)],
```

```
         symb_out0Q_r[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'r.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0 redondeado")
plt.subplot(3,2,2)
plt.plot(symb_out0I_t[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out0Q_t[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'g.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0 truncado")

#_____________________ rolloff  0.5 _____________________
plt.subplot(3,2,3)
plt.plot(symb_out1I_r[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out1Q_r[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'r.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.5 redondeado")
plt.subplot(3,2,4)
plt.plot(symb_out1I_t[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out1Q_t[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'g.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.5 truncado")

#_____________________ rolloff  1.0 _____________________
plt.subplot(3,2,5)
plt.plot(symb_out2I_r[100+offset:len(symb_out2I)-(100-offset):int(os)],
         symb_out2Q_r[100+offset:len(symb_out2Q)-(100-offset):int(os)],
             'r.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0 redondeado")
plt.subplot(3,2,6)
plt.plot(symb_out2I_t[100+offset:len(symb_out2I)-(100-offset):int(os)],
         symb_out2Q_t[100+offset:len(symb_out2Q)-(100-offset):int(os)],
             'g.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0 truncado")
plt.suptitle('S(8,7)')
plt.show()
```



SNR:

In [78]:
```
#_____________________ rolloff  0.0 _____________________
```

```
pow_rc0_I=np.sum(symb_out0I**2)/len(symb_out0I)
pow_rc0_Q=np.sum(symb_out0Q**2)/len(symb_out0Q)

pow_rc0_I_r=np.sum(symb_out0I_r**2)/len(symb_out0I_r)
pow_rc0_Q_r=np.sum(symb_out0Q_r**2)/len(symb_out0Q_r)

pow_rc0_I_t=np.sum(symb_out0I_t**2)/len(symb_out0I_t)
pow_rc0_Q_t=np.sum(symb_out0Q_t**2)/len(symb_out0Q_t)

snr_rc0_I_r=abs(pow_rc0_I/(pow_rc0_I-pow_rc0_I_r))
snr_rc0_Q_r=abs(pow_rc0_Q/(pow_rc0_Q-pow_rc0_Q_r))

snr_rc0_I_t=abs(pow_rc0_I/(pow_rc0_I-pow_rc0_I_t))
snr_rc0_Q_t=abs(pow_rc0_Q/(pow_rc0_Q-pow_rc0_Q_t))
#_____________________ rolloff  0.5 ____________________
pow_rc1_I=np.sum(symb_out1I**2)/len(symb_out1I)
pow_rc1_Q=np.sum(symb_out1Q**2)/len(symb_out1Q)
pow_rc1_I_r=np.sum(symb_out1I_r**2)/len(symb_out1I_r)
pow_rc1_Q_r=np.sum(symb_out1Q_r**2)/len(symb_out1Q_r)
pow_rc1_I_t=np.sum(symb_out1I_t**2)/len(symb_out1I_t)
pow_rc1_Q_t=np.sum(symb_out1Q_t**2)/len(symb_out1Q_t)

snr_rc1_I_r=abs(pow_rc1_I/(pow_rc1_I-pow_rc1_I_r))
snr_rc1_Q_r=abs(pow_rc1_Q/(pow_rc1_Q-pow_rc1_Q_r))

snr_rc1_I_t=abs(pow_rc1_I/(pow_rc1_I-pow_rc1_I_t))
snr_rc1_Q_t=abs(pow_rc1_Q/(pow_rc1_Q-pow_rc1_Q_t))
#_____________________ rolloff  1.0 ____________________
pow_rc2_I=np.sum(symb_out2I**2)/len(symb_out2I)
pow_rc2_Q=np.sum(symb_out2Q**2)/len(symb_out2Q)
pow_rc2_I_r=np.sum(symb_out2I_r**2)/len(symb_out2I_r)
pow_rc2_Q_r=np.sum(symb_out2Q_r**2)/len(symb_out2Q_r)
pow_rc2_I_t=np.sum(symb_out2I_t**2)/len(symb_out2I_t)
pow_rc2_Q_t=np.sum(symb_out2Q_t**2)/len(symb_out2Q_t)

snr_rc2_I_r=abs(pow_rc2_I/(pow_rc2_I-pow_rc2_I_r))
snr_rc2_Q_r=abs(pow_rc2_Q/(pow_rc2_Q-pow_rc2_Q_r))

snr_rc2_I_t=abs(pow_rc2_I/(pow_rc2_I-pow_rc2_I_t))
snr_rc2_Q_t=abs(pow_rc2_Q/(pow_rc2_Q-pow_rc2_Q_t))

print("rolloff 0.0 ")
print('  redondeo SNR_I: '+str(10*np.log(snr_rc0_I_r))+' dB  SNR_Q: '+str(10*np.log(
print('  truncado SNR_I: '+str(10*np.log(snr_rc0_I_t))+' dB  SNR_Q: '+str(10*np.log(
print("rolloff 0.5 ")
print('  redondeo SNR_I: '+str(10*np.log(snr_rc1_I_r))+' dB  SNR_Q: '+str(10*np.log(
print('  truncado SNR_I: '+str(10*np.log(snr_rc1_I_t))+' dB  SNR_Q: '+str(10*np.log(
print("rolloff 1.0 ")
print('  redondeo SNR_I: '+str(10*np.log(snr_rc2_I_r))+' dB  SNR_Q: '+str(10*np.log(
print('  truncado SNR_I: '+str(10*np.log(snr_rc2_I_t))+' dB  SNR_Q: '+str(10*np.log(
```

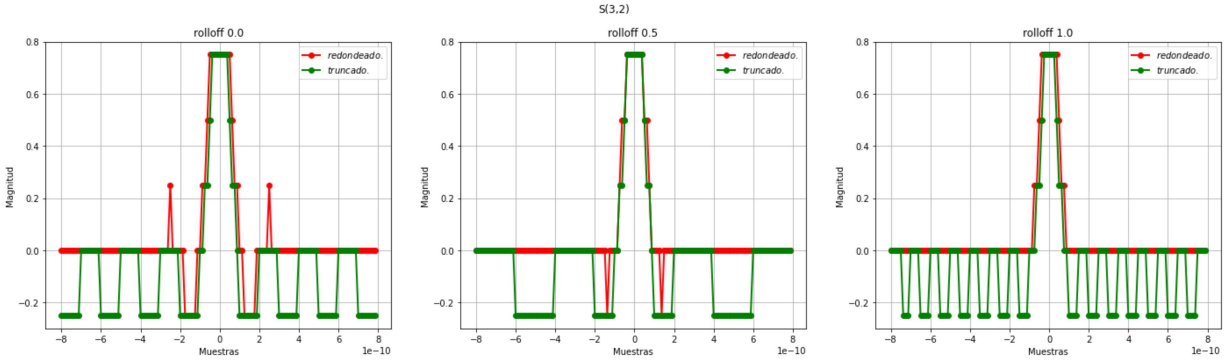
```
rolloff 0.0
  redondeo SNR_I: 50.59403926616386 dB  SNR_Q: 50.35197540193866 dB
  truncado SNR_I: 54.812826101409115 dB  SNR_Q: 50.119432797428104 dB
rolloff 0.5
  redondeo SNR_I: 63.30346370396611 dB  SNR_Q: 67.21192440203706 dB
  truncado SNR_I: 51.04639180392898 dB  SNR_Q: 46.52134621120369 dB
rolloff 1.0
  redondeo SNR_I: 72.7071848411111 dB  SNR_Q: 70.08606905674203 dB
  truncado SNR_I: 43.90640233665928 dB  SNR_Q: 41.08254660321269 dB
```

Cuantización S(3,2).

In [79]:

```
#_____________________ rolloff  0.0 ____________________
```

```
rc0_aux=arrayFixedInt(3, 2,rc0 , signedMode='S', roundMode='round', saturateMode='sa
rc0_sxx_r=np.array([rc0_aux[i].fValue for i in range(len(rc0_aux))])
rc0_aux=arrayFixedInt(3, 2,rc0 , signedMode='S', roundMode='trunc', saturateMode='sa
rc0_sxx_t=np.array([rc0_aux[i].fValue for i in range(len(rc0_aux))])
#_____________________ rolloff  0.5 ____________________
rc1_aux=arrayFixedInt(3, 2,rc1 , signedMode='S', roundMode='round', saturateMode='sa
rc1_sxx_r=np.array([rc1_aux[i].fValue for i in range(len(rc0_aux))])
rc1_aux=arrayFixedInt(3, 2,rc1 , signedMode='S', roundMode='trunc', saturateMode='sa
rc1_sxx_t=np.array([rc1_aux[i].fValue for i in range(len(rc0_aux))])
#_____________________ rolloff  1.0 ____________________
rc2_aux=arrayFixedInt(3, 2,rc2 , signedMode='S', roundMode='round', saturateMode='sa
rc2_sxx_r=np.array([rc2_aux[i].fValue for i in range(len(rc0_aux))])
rc2_aux=arrayFixedInt(3, 2,rc2 , signedMode='S', roundMode='trunc', saturateMode='sa
rc2_sxx_t=np.array([rc2_aux[i].fValue for i in range(len(rc0_aux))])

plt.figure(figsize=[6*4,6])
plt.subplot(1,3,1)
plt.plot(t,rc0_sxx_r,'ro-',linewidth=2.0,label=r'$redondeado.$')
plt.plot(t,rc0_sxx_t,'go-',linewidth=2.0,label=r'$truncado.$')
plt.legend()
plt.grid(True)
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title("rolloff 0.0")


plt.subplot(1,3,2)
plt.plot(t,rc1_sxx_r,'ro-',linewidth=2.0,label=r'$redondeado.$')
plt.plot(t,rc1_sxx_t,'go-',linewidth=2.0,label=r'$truncado.$')
plt.legend()
plt.grid(True)
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title("rolloff 0.5")


plt.subplot(1,3,3)
plt.plot(t,rc2_sxx_r,'ro-',linewidth=2.0,label=r'$redondeado.$')
plt.plot(t,rc2_sxx_t,'go-',linewidth=2.0,label=r'$truncado.$')
plt.legend()
plt.grid(True)
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title("rolloff 1.0")
plt.suptitle('S(3,2)')
plt.show()
```

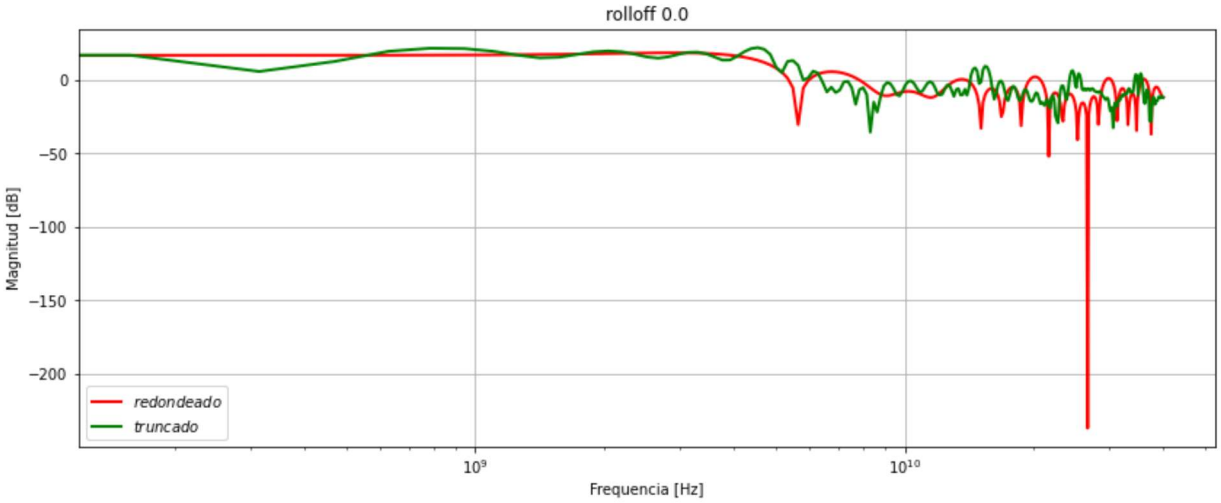


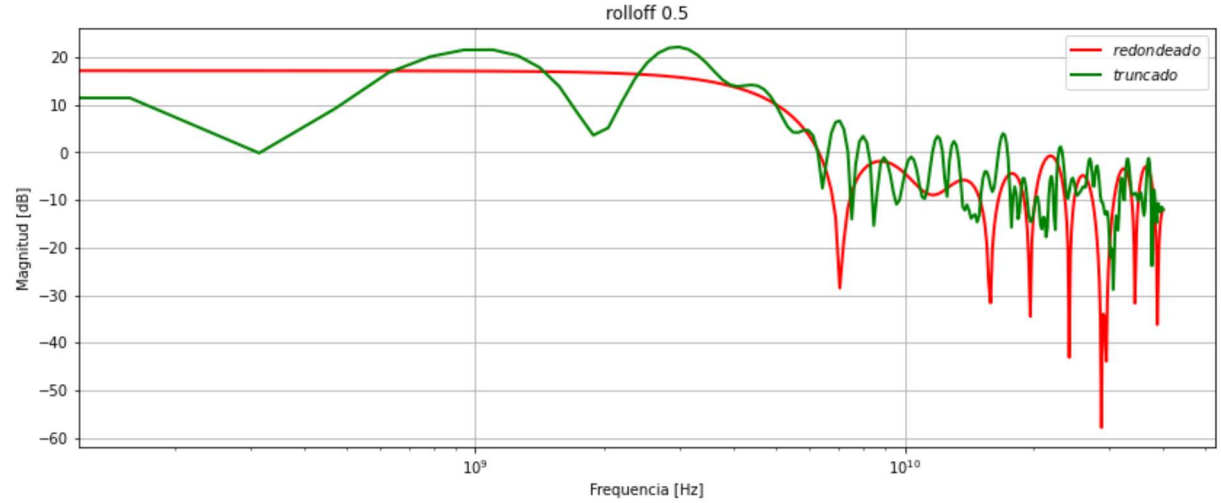
Respuesta en frecuencia.

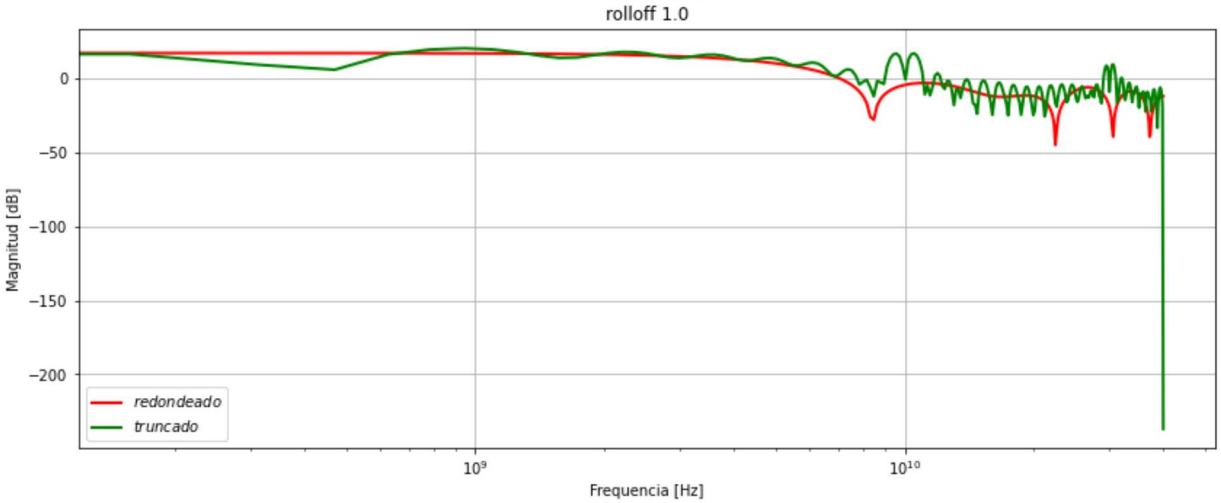
In [80]:

```
#_____________________ rolloff  0.0 ____________________
[H0_r,A0_r,F0_r] = resp_freq(rc0_sxx_r, Ts, Nfreqs)
[H0_t,A0_t,F0_t] = resp_freq(rc0_sxx_t, Ts, Nfreqs)
```

```
#_____________________ rolloff  0.5 ____________________
[H1_r,A1_r,F1_r] = resp_freq(rc1_sxx_r, Ts, Nfreqs)
[H1_t,A1_t,F1_t] = resp_freq(rc1_sxx_t, Ts, Nfreqs)
#_____________________ rolloff  1.0 ____________________
[H2_r,A2_r,F2_r] = resp_freq(rc2_sxx_r, Ts, Nfreqs)
[H2_t,A2_t,F2_t] = resp_freq(rc2_sxx_t, Ts, Nfreqs)
#_____________________ rolloff  0.0 ____________________
plt.figure(figsize=[14,6*3])
plt.subplot(3,1,1)
plt.semilogx(F0_r, 20*np.log10(H0_r),'r', linewidth=2.0, label=r'$redondeado$')
plt.semilogx(F0_t, 20*np.log10(H0_t),'g', linewidth=2.0, label=r'$truncado$')
plt.legend()
plt.grid(True)
plt.xlabel('Frequencia [Hz]')
plt.ylabel('Magnitud [dB]')
plt.title('rolloff 0.0')
#_____________________ rolloff  0.5 ____________________
plt.subplot(3,1,2)
plt.semilogx(F1_r, 20*np.log10(H1_r),'r', linewidth=2.0, label=r'$redondeado$')
plt.semilogx(F1_t, 20*np.log10(H1_t),'g', linewidth=2.0, label=r'$truncado$')
plt.legend()
plt.grid(True)
plt.xlabel('Frequencia [Hz]')
plt.ylabel('Magnitud [dB]')
plt.title('rolloff 0.5')
#_____________________ rolloff  1.0 ____________________
plt.subplot(3,1,3)
plt.semilogx(F2_r, 20*np.log10(H2_r),'r', linewidth=2.0, label=r'$redondeado$')
plt.semilogx(F2_t, 20*np.log10(H2_t),'g', linewidth=2.0, label=r'$truncado$')
plt.legend()
plt.grid(True)
plt.xlabel('Frequencia [Hz]')
plt.ylabel('Magnitud [dB]')
plt.title('rolloff 1.0')
plt.suptitle('S(3,2)')
plt.show()
```







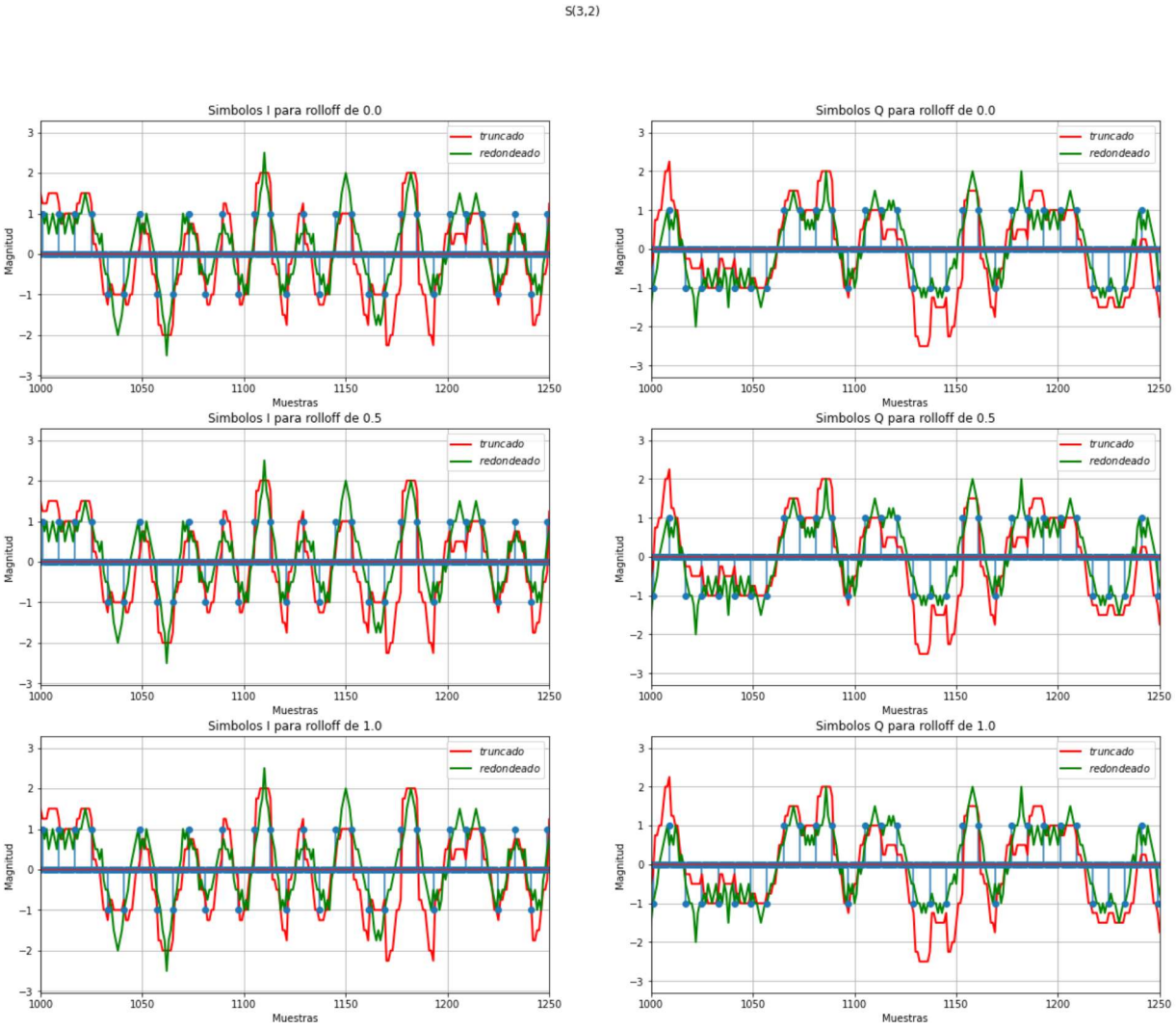
Convolución.

In [81]:

```
#_____________________ rolloff  0.0 _____________________
symb_out0I_r = np.convolve(rc0_sxx_r,zsymbI,'same')
symb_out0Q_r = np.convolve(rc0_sxx_r,zsymbQ,'same')
symb_out0I_t = np.convolve(rc0_sxx_t,zsymbI,'same')
symb_out0Q_t = np.convolve(rc0_sxx_t,zsymbQ,'same')
#_____________________ rolloff  0.5 _____________________
symb_out1I_r = np.convolve(rc1_sxx_r,zsymbI,'same')
symb_out1Q_r = np.convolve(rc1_sxx_r,zsymbQ,'same')
symb_out1I_t = np.convolve(rc1_sxx_t,zsymbI,'same')
```

```
symb_out1Q_t = np.convolve(rc1_sxx_t,zsymbQ,'same')
#_____________________ rolloff  1.0 ____________________
symb_out2I_r = np.convolve(rc2_sxx_r,zsymbI,'same')
symb_out2Q_r = np.convolve(rc2_sxx_r,zsymbQ,'same')
symb_out2I_t = np.convolve(rc2_sxx_t,zsymbI,'same')
symb_out2Q_t = np.convolve(rc2_sxx_t,zsymbQ,'same')

plt.figure(figsize=[10*2,4*4])
plt.subplot(3,2,1)
plt.plot(symb_out0I_t,'r-',linewidth=2.0,label=r'$truncado$')
plt.plot(symb_out0I_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos I para rolloff de 0.0')
plt.subplot(3,2,2)
plt.plot(symb_out0Q_t,'r-',linewidth=2.0,label=r'$truncado$' )
plt.plot(symb_out0Q_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos Q para rolloff de 0.0')


plt.subplot(3,2,3)
plt.plot(symb_out0I_t,'r-',linewidth=2.0,label=r'$truncado$')
plt.plot(symb_out0I_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos I para rolloff de 0.5')
plt.subplot(3,2,4)
plt.plot(symb_out0Q_t,'r-',linewidth=2.0,label=r'$truncado$' )
plt.plot(symb_out0Q_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos Q para rolloff de 0.5')


plt.subplot(3,2,5)
plt.plot(symb_out0I_t,'r-',linewidth=2.0,label=r'$truncado$')
plt.plot(symb_out0I_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos I para rolloff de 1.0')
plt.subplot(3,2,6)
plt.plot(symb_out0Q_t,'r-',linewidth=2.0,label=r'$truncado$' )
plt.plot(symb_out0Q_r,'g-',linewidth=2.0,label=r'$redondeado$')
```

```
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos Q para rolloff de 1.0')
plt.suptitle('S(3,2)')

plt.show()
```



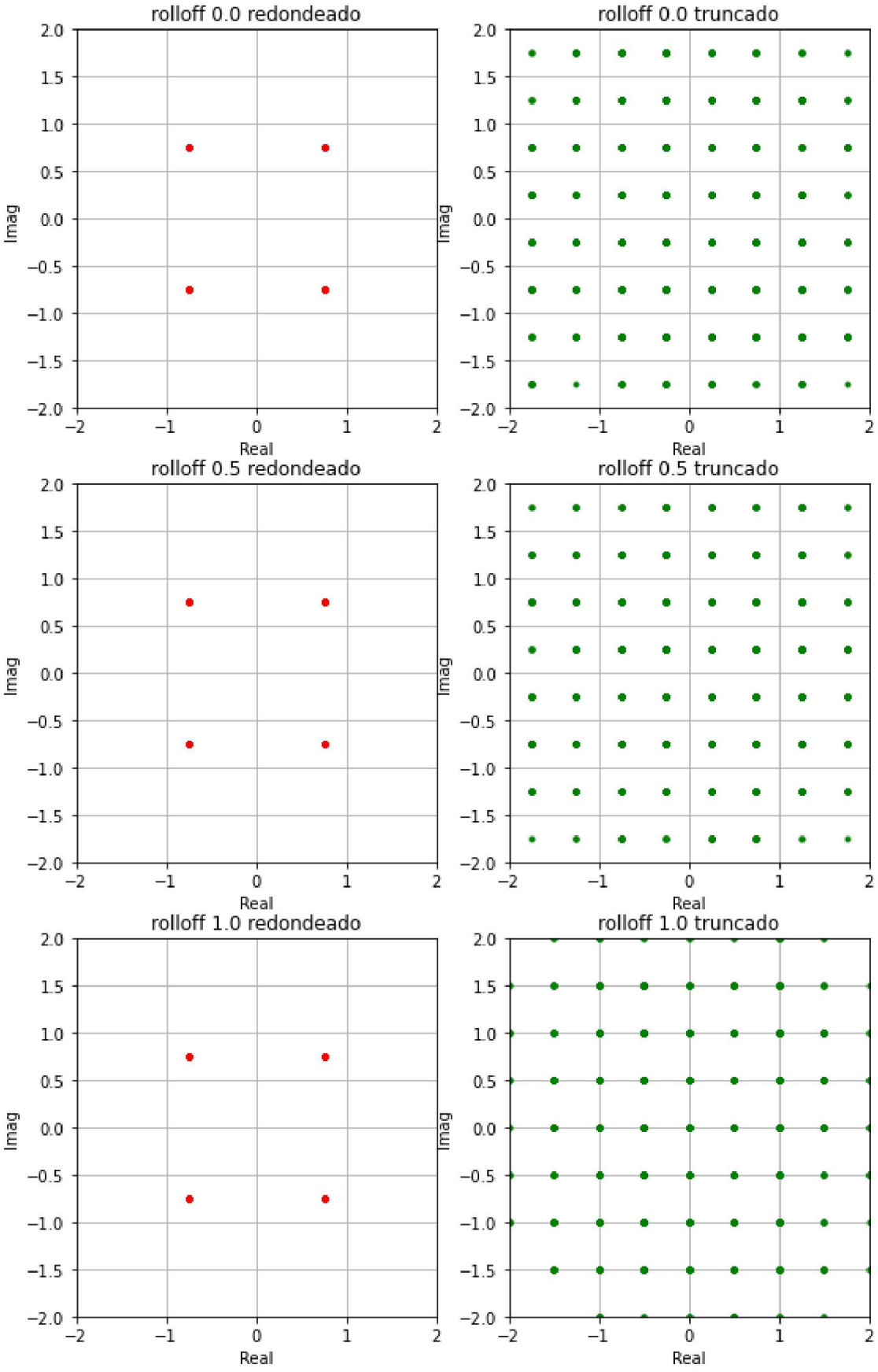
Constelación.

In [82]:

```
offset = 6



plt.figure(figsize=[3*3,3*5])
plt.subplot(3,2,1)
plt.plot(symb_out0I_r[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out0Q_r[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'r.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0 redondeado")
plt.subplot(3,2,2)
plt.plot(symb_out0I_t[100+offset:len(symb_out0I)-(100-offset):int(os)],
```

```
         symb_out0Q_t[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'g.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0 truncado")

#_____________________ rolloff  0.5 _____________________
plt.subplot(3,2,3)
plt.plot(symb_out1I_r[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out1Q_r[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'r.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.5 redondeado")
plt.subplot(3,2,4)
plt.plot(symb_out1I_t[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out1Q_t[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'g.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.5 truncado")

#_____________________ rolloff  1.0 _____________________
plt.subplot(3,2,5)
plt.plot(symb_out2I_r[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out2Q_r[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'r.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0 redondeado")
plt.subplot(3,2,6)
plt.plot(symb_out2I_t[100+offset:len(symb_out2I)-(100-offset):int(os)],
         symb_out2Q_t[100+offset:len(symb_out2Q)-(100-offset):int(os)],
             'g.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0 truncado")
plt.suptitle('S(3,2)')
plt.show()
```

S(3,2)



SNR:

In [83]:
```
#_____________________ rolloff  0.0 _____________________
```

```
pow_rc0_I=np.sum(symb_out0I**2)/len(symb_out0I)
pow_rc0_Q=np.sum(symb_out0Q**2)/len(symb_out0Q)

pow_rc0_I_r=np.sum(symb_out0I_r**2)/len(symb_out0I_r)
pow_rc0_Q_r=np.sum(symb_out0Q_r**2)/len(symb_out0Q_r)

pow_rc0_I_t=np.sum(symb_out0I_t**2)/len(symb_out0I_t)
pow_rc0_Q_t=np.sum(symb_out0Q_t**2)/len(symb_out0Q_t)

snr_rc0_I_r=abs(pow_rc0_I/(pow_rc0_I-pow_rc0_I_r))
snr_rc0_Q_r=abs(pow_rc0_Q/(pow_rc0_Q-pow_rc0_Q_r))

snr_rc0_I_t=abs(pow_rc0_I/(pow_rc0_I-pow_rc0_I_t))
snr_rc0_Q_t=abs(pow_rc0_Q/(pow_rc0_Q-pow_rc0_Q_t))
#_____________________ rolloff  0.5 ____________________
pow_rc1_I=np.sum(symb_out1I**2)/len(symb_out1I)
pow_rc1_Q=np.sum(symb_out1Q**2)/len(symb_out1Q)
pow_rc1_I_r=np.sum(symb_out1I_r**2)/len(symb_out1I_r)
pow_rc1_Q_r=np.sum(symb_out1Q_r**2)/len(symb_out1Q_r)
pow_rc1_I_t=np.sum(symb_out1I_t**2)/len(symb_out1I_t)
pow_rc1_Q_t=np.sum(symb_out1Q_t**2)/len(symb_out1Q_t)

snr_rc1_I_r=abs(pow_rc1_I/(pow_rc1_I-pow_rc1_I_r))
snr_rc1_Q_r=abs(pow_rc1_Q/(pow_rc1_Q-pow_rc1_Q_r))

snr_rc1_I_t=abs(pow_rc1_I/(pow_rc1_I-pow_rc1_I_t))
snr_rc1_Q_t=abs(pow_rc1_Q/(pow_rc1_Q-pow_rc1_Q_t))
#_____________________ rolloff  1.0 ____________________
pow_rc2_I=np.sum(symb_out2I**2)/len(symb_out2I)
pow_rc2_Q=np.sum(symb_out2Q**2)/len(symb_out2Q)
pow_rc2_I_r=np.sum(symb_out2I_r**2)/len(symb_out2I_r)
pow_rc2_Q_r=np.sum(symb_out2Q_r**2)/len(symb_out2Q_r)
pow_rc2_I_t=np.sum(symb_out2I_t**2)/len(symb_out2I_t)
pow_rc2_Q_t=np.sum(symb_out2Q_t**2)/len(symb_out2Q_t)

snr_rc2_I_r=abs(pow_rc2_I/(pow_rc2_I-pow_rc2_I_r))
snr_rc2_Q_r=abs(pow_rc2_Q/(pow_rc2_Q-pow_rc2_Q_r))

snr_rc2_I_t=abs(pow_rc2_I/(pow_rc2_I-pow_rc2_I_t))
snr_rc2_Q_t=abs(pow_rc2_Q/(pow_rc2_Q-pow_rc2_Q_t))

print("rolloff 0.0 ")
print('  redondeo SNR_I: '+str(10*np.log(snr_rc0_I_r))+' dB  SNR_Q: '+str(10*np.log(
print('  truncado SNR_I: '+str(10*np.log(snr_rc0_I_t))+' dB  SNR_Q: '+str(10*np.log(
print("rolloff 0.5 ")
print('  redondeo SNR_I: '+str(10*np.log(snr_rc1_I_r))+' dB  SNR_Q: '+str(10*np.log(
print('  truncado SNR_I: '+str(10*np.log(snr_rc1_I_t))+' dB  SNR_Q: '+str(10*np.log(
print("rolloff 1.0 ")
print('  redondeo SNR_I: '+str(10*np.log(snr_rc2_I_r))+' dB  SNR_Q: '+str(10*np.log(
print('  truncado SNR_I: '+str(10*np.log(snr_rc2_I_t))+' dB  SNR_Q: '+str(10*np.log(
```

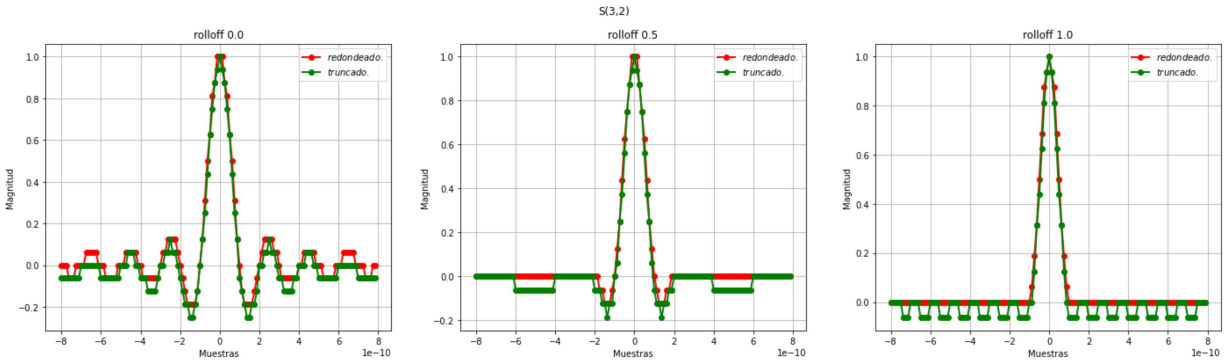
```
rolloff 0.0
  redondeo SNR_I: 17.32172800348154 dB  SNR_Q: 17.40822125252732 dB
  truncado SNR_I: 19.583857941377968 dB  SNR_Q: 22.73933972105359 dB
rolloff 0.5
  redondeo SNR_I: 13.290683899006197 dB  SNR_Q: 13.59066738435825 dB
  truncado SNR_I: 17.760365868694745 dB  SNR_Q: 23.125037083207882 dB
rolloff 1.0
  redondeo SNR_I: 15.045259532626279 dB  SNR_Q: 15.332641415211958 dB
  truncado SNR_I: 17.533916503720704 dB  SNR_Q: 16.248225326158895 dB
```

Cuantización S(6,4).

In [84]:

```
#_____________________ rolloff  0.0 ____________________
```

```
rc0_aux=arrayFixedInt(6, 4,rc0 , signedMode='S', roundMode='round', saturateMode='sa
rc0_sxx_r=np.array([rc0_aux[i].fValue for i in range(len(rc0_aux))])
rc0_aux=arrayFixedInt(6, 4,rc0 , signedMode='S', roundMode='trunc', saturateMode='sa
rc0_sxx_t=np.array([rc0_aux[i].fValue for i in range(len(rc0_aux))])
#_____________________ rolloff  0.5 ____________________
rc1_aux=arrayFixedInt(6, 4,rc1 , signedMode='S', roundMode='round', saturateMode='sa
rc1_sxx_r=np.array([rc1_aux[i].fValue for i in range(len(rc0_aux))])
rc1_aux=arrayFixedInt(6, 4,rc1 , signedMode='S', roundMode='trunc', saturateMode='sa
rc1_sxx_t=np.array([rc1_aux[i].fValue for i in range(len(rc0_aux))])
#_____________________ rolloff  1.0 ____________________
rc2_aux=arrayFixedInt(6, 4,rc2 , signedMode='S', roundMode='round', saturateMode='sa
rc2_sxx_r=np.array([rc2_aux[i].fValue for i in range(len(rc0_aux))])
rc2_aux=arrayFixedInt(6, 4,rc2 , signedMode='S', roundMode='trunc', saturateMode='sa
rc2_sxx_t=np.array([rc2_aux[i].fValue for i in range(len(rc0_aux))])

plt.figure(figsize=[6*4,6])
plt.subplot(1,3,1)
plt.plot(t,rc0_sxx_r,'ro-',linewidth=2.0,label=r'$redondeado.$')
plt.plot(t,rc0_sxx_t,'go-',linewidth=2.0,label=r'$truncado.$')
plt.legend()
plt.grid(True)
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title("rolloff 0.0")


plt.subplot(1,3,2)
plt.plot(t,rc1_sxx_r,'ro-',linewidth=2.0,label=r'$redondeado.$')
plt.plot(t,rc1_sxx_t,'go-',linewidth=2.0,label=r'$truncado.$')
plt.legend()
plt.grid(True)
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title("rolloff 0.5")


plt.subplot(1,3,3)
plt.plot(t,rc2_sxx_r,'ro-',linewidth=2.0,label=r'$redondeado.$')
plt.plot(t,rc2_sxx_t,'go-',linewidth=2.0,label=r'$truncado.$')
plt.legend()
plt.grid(True)
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title("rolloff 1.0")
plt.suptitle('S(3,2)')
plt.show()
```

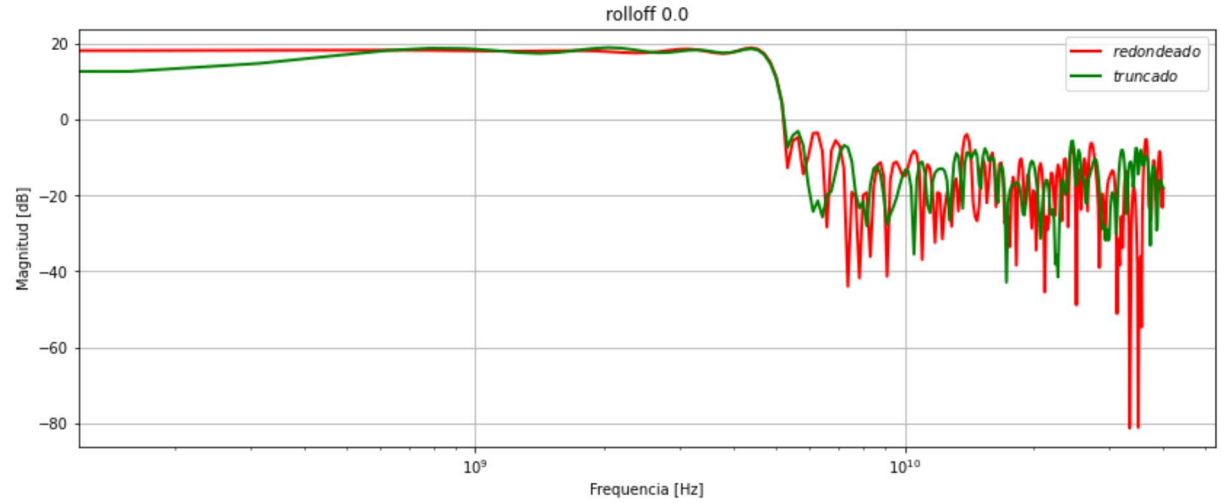


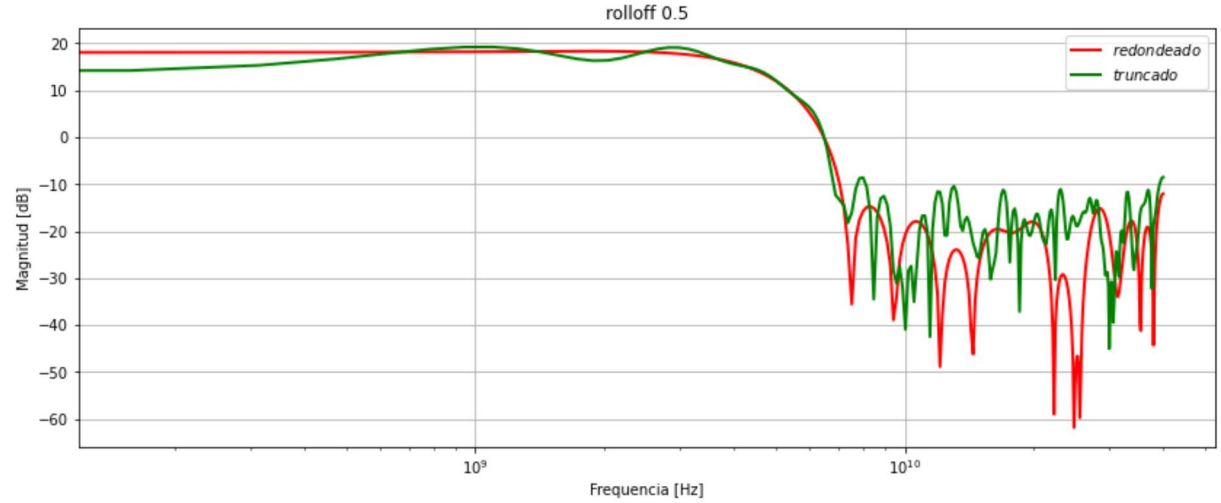
Respuesta en frecuencia.

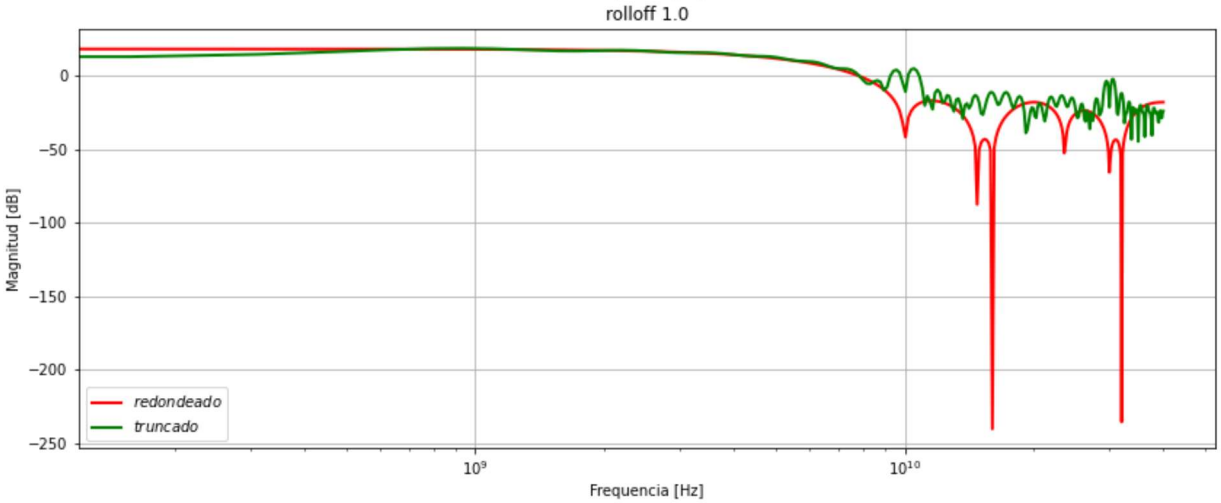
In [85]:

```
#_____________________ rolloff  0.0 ____________________
[H0_r,A0_r,F0_r] = resp_freq(rc0_sxx_r, Ts, Nfreqs)
[H0_t,A0_t,F0_t] = resp_freq(rc0_sxx_t, Ts, Nfreqs)
```

```
#_____________________ rolloff  0.5 ____________________
[H1_r,A1_r,F1_r] = resp_freq(rc1_sxx_r, Ts, Nfreqs)
[H1_t,A1_t,F1_t] = resp_freq(rc1_sxx_t, Ts, Nfreqs)
#_____________________ rolloff  1.0 ____________________
[H2_r,A2_r,F2_r] = resp_freq(rc2_sxx_r, Ts, Nfreqs)
[H2_t,A2_t,F2_t] = resp_freq(rc2_sxx_t, Ts, Nfreqs)
#_____________________ rolloff  0.0 ____________________
plt.figure(figsize=[14,6*3])
plt.subplot(3,1,1)
plt.semilogx(F0_r, 20*np.log10(H0_r),'r', linewidth=2.0, label=r'$redondeado$')
plt.semilogx(F0_t, 20*np.log10(H0_t),'g', linewidth=2.0, label=r'$truncado$')
plt.legend()
plt.grid(True)
plt.xlabel('Frequencia [Hz]')
plt.ylabel('Magnitud [dB]')
plt.title('rolloff 0.0')
#_____________________ rolloff  0.5 ____________________
plt.subplot(3,1,2)
plt.semilogx(F1_r, 20*np.log10(H1_r),'r', linewidth=2.0, label=r'$redondeado$')
plt.semilogx(F1_t, 20*np.log10(H1_t),'g', linewidth=2.0, label=r'$truncado$')
plt.legend()
plt.grid(True)
plt.xlabel('Frequencia [Hz]')
plt.ylabel('Magnitud [dB]')
plt.title('rolloff 0.5')
#_____________________ rolloff  1.0 ____________________
plt.subplot(3,1,3)
plt.semilogx(F2_r, 20*np.log10(H2_r),'r', linewidth=2.0, label=r'$redondeado$')
plt.semilogx(F2_t, 20*np.log10(H2_t),'g', linewidth=2.0, label=r'$truncado$')
plt.legend()
plt.grid(True)
plt.xlabel('Frequencia [Hz]')
plt.ylabel('Magnitud [dB]')
plt.title('rolloff 1.0')
plt.suptitle('S(6,4)')
plt.show()
```







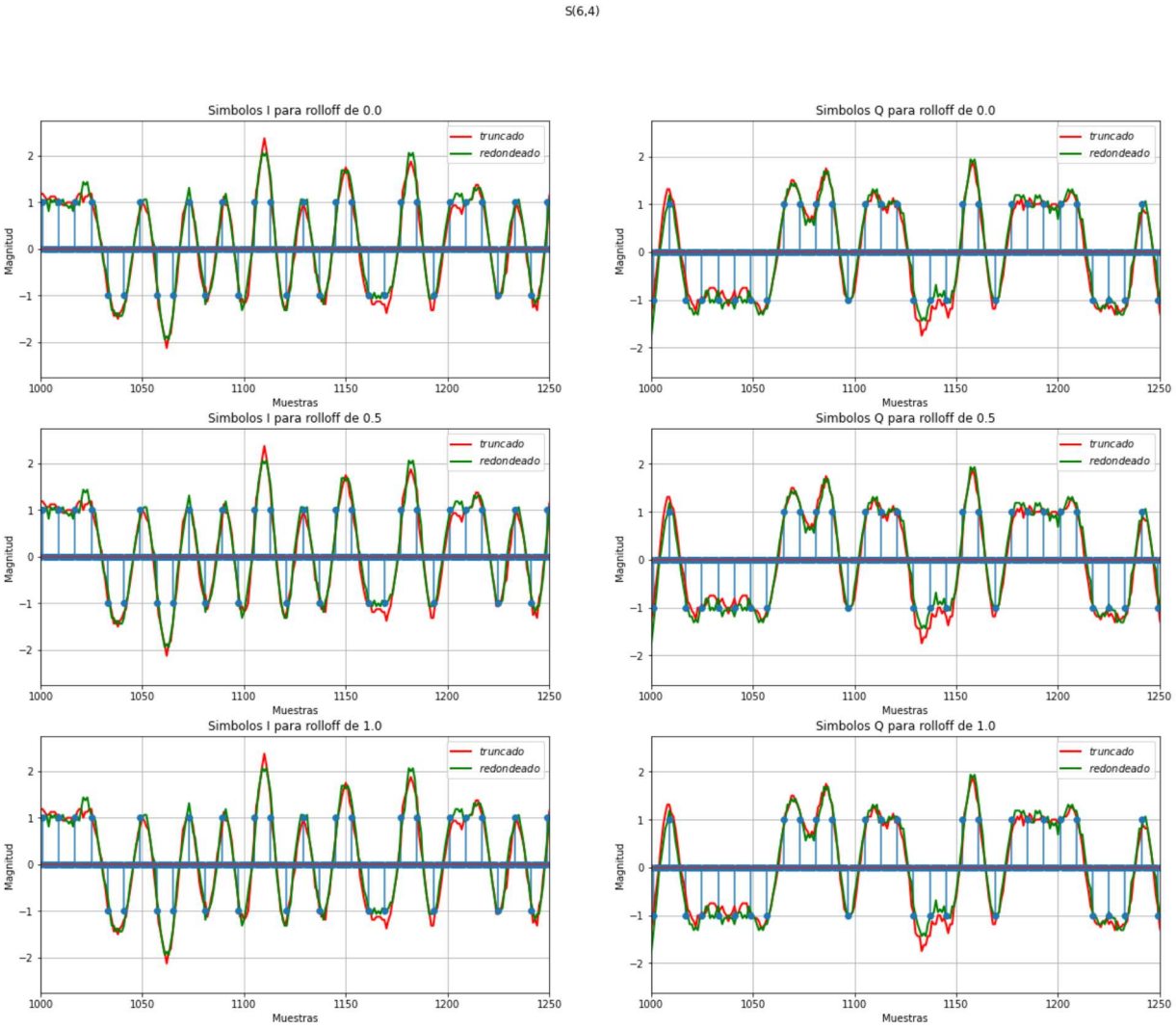
Convolución.

In [86]:

```
#_____________________ rolloff  0.0 _____________________
symb_out0I_r = np.convolve(rc0_sxx_r,zsymbI,'same')
symb_out0Q_r = np.convolve(rc0_sxx_r,zsymbQ,'same')
symb_out0I_t = np.convolve(rc0_sxx_t,zsymbI,'same')
symb_out0Q_t = np.convolve(rc0_sxx_t,zsymbQ,'same')
#_____________________ rolloff  0.5 _____________________
symb_out1I_r = np.convolve(rc1_sxx_r,zsymbI,'same')
symb_out1Q_r = np.convolve(rc1_sxx_r,zsymbQ,'same')
symb_out1I_t = np.convolve(rc1_sxx_t,zsymbI,'same')
```

```
symb_out1Q_t = np.convolve(rc1_sxx_t,zsymbQ,'same')
#_____________________ rolloff  1.0 ____________________
symb_out2I_r = np.convolve(rc2_sxx_r,zsymbI,'same')
symb_out2Q_r = np.convolve(rc2_sxx_r,zsymbQ,'same')
symb_out2I_t = np.convolve(rc2_sxx_t,zsymbI,'same')
symb_out2Q_t = np.convolve(rc2_sxx_t,zsymbQ,'same')

plt.figure(figsize=[10*2,4*4])
plt.subplot(3,2,1)
plt.plot(symb_out0I_t,'r-',linewidth=2.0,label=r'$truncado$')
plt.plot(symb_out0I_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos I para rolloff de 0.0')
plt.subplot(3,2,2)
plt.plot(symb_out0Q_t,'r-',linewidth=2.0,label=r'$truncado$' )
plt.plot(symb_out0Q_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos Q para rolloff de 0.0')


plt.subplot(3,2,3)
plt.plot(symb_out0I_t,'r-',linewidth=2.0,label=r'$truncado$')
plt.plot(symb_out0I_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos I para rolloff de 0.5')
plt.subplot(3,2,4)
plt.plot(symb_out0Q_t,'r-',linewidth=2.0,label=r'$truncado$' )
plt.plot(symb_out0Q_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos Q para rolloff de 0.5')


plt.subplot(3,2,5)
plt.plot(symb_out0I_t,'r-',linewidth=2.0,label=r'$truncado$')
plt.plot(symb_out0I_r,'g-',linewidth=2.0,label=r'$redondeado$')
plt.stem(zsymbI,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos I para rolloff de 1.0')
plt.subplot(3,2,6)
plt.plot(symb_out0Q_t,'r-',linewidth=2.0,label=r'$truncado$' )
plt.plot(symb_out0Q_r,'g-',linewidth=2.0,label=r'$redondeado$')
```

```
plt.stem(zsymbQ,use_line_collection=True)
plt.xlim(1000,1250)
plt.grid(True)
plt.legend()
plt.xlabel('Muestras')
plt.ylabel('Magnitud')
plt.title('Simbolos Q para rolloff de 1.0')
plt.suptitle('S(6,4)')

plt.show()
```



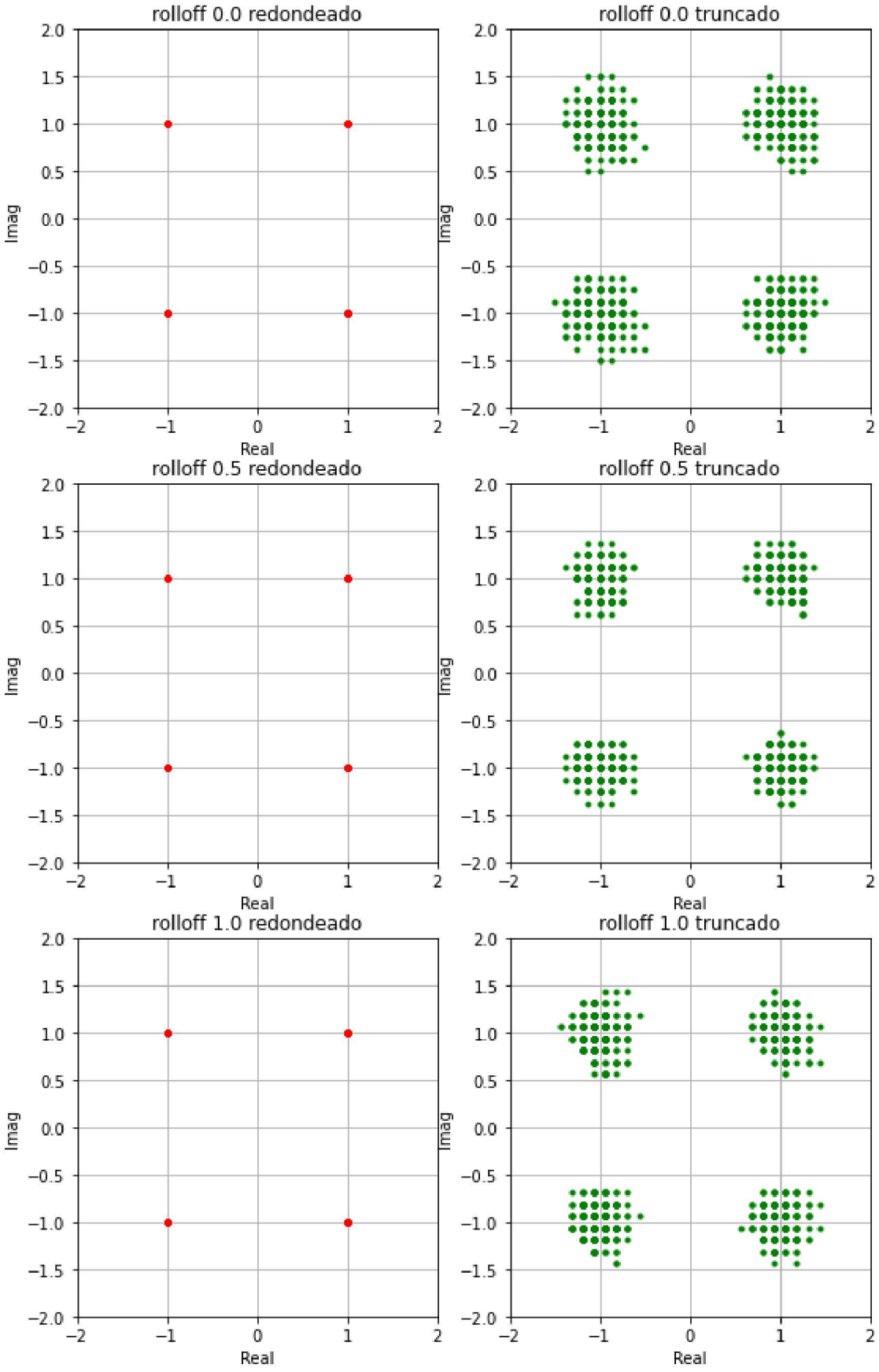
Constelación.

In [87]:

```
offset = 6
plt.figure(figsize=[3*3,3*5])
plt.subplot(3,2,1)
plt.plot(symb_out0I_r[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out0Q_r[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'r.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0 redondeado")
plt.subplot(3,2,2)
plt.plot(symb_out0I_t[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out0Q_t[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'g.',linewidth=2.0)
plt.xlim((-2, 2))
```

```
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.0 truncado")

#_____________________ rolloff  0.5 _____________________
plt.subplot(3,2,3)
plt.plot(symb_out1I_r[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out1Q_r[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'r.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.5 redondeado")
plt.subplot(3,2,4)
plt.plot(symb_out1I_t[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out1Q_t[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'g.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 0.5 truncado")

#_____________________ rolloff  1.0 _____________________
plt.subplot(3,2,5)
plt.plot(symb_out2I_r[100+offset:len(symb_out0I)-(100-offset):int(os)],
         symb_out2Q_r[100+offset:len(symb_out0Q)-(100-offset):int(os)],
             'r.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0 redondeado")
plt.subplot(3,2,6)
plt.plot(symb_out2I_t[100+offset:len(symb_out2I)-(100-offset):int(os)],
         symb_out2Q_t[100+offset:len(symb_out2Q)-(100-offset):int(os)],
             'g.',linewidth=2.0)
plt.xlim((-2, 2))
plt.ylim((-2, 2))
plt.grid(True)
plt.xlabel('Real')
plt.ylabel('Imag')
plt.title("rolloff 1.0 truncado")
plt.suptitle('S(6,4)')
plt.show()
```

S(6,4)



SNR:

In [88]:
```
#_____________________ rolloff  0.0 ____________________
```

```
pow_rc0_I=np.sum(symb_out0I**2)/len(symb_out0I)
pow_rc0_Q=np.sum(symb_out0Q**2)/len(symb_out0Q)

pow_rc0_I_r=np.sum(symb_out0I_r**2)/len(symb_out0I_r)
pow_rc0_Q_r=np.sum(symb_out0Q_r**2)/len(symb_out0Q_r)

pow_rc0_I_t=np.sum(symb_out0I_t**2)/len(symb_out0I_t)
pow_rc0_Q_t=np.sum(symb_out0Q_t**2)/len(symb_out0Q_t)

snr_rc0_I_r=abs(pow_rc0_I/(pow_rc0_I-pow_rc0_I_r))
snr_rc0_Q_r=abs(pow_rc0_Q/(pow_rc0_Q-pow_rc0_Q_r))

snr_rc0_I_t=abs(pow_rc0_I/(pow_rc0_I-pow_rc0_I_t))
snr_rc0_Q_t=abs(pow_rc0_Q/(pow_rc0_Q-pow_rc0_Q_t))
#_____________________ rolloff  0.5 ____________________
pow_rc1_I=np.sum(symb_out1I**2)/len(symb_out1I)
pow_rc1_Q=np.sum(symb_out1Q**2)/len(symb_out1Q)
pow_rc1_I_r=np.sum(symb_out1I_r**2)/len(symb_out1I_r)
pow_rc1_Q_r=np.sum(symb_out1Q_r**2)/len(symb_out1Q_r)
pow_rc1_I_t=np.sum(symb_out1I_t**2)/len(symb_out1I_t)
pow_rc1_Q_t=np.sum(symb_out1Q_t**2)/len(symb_out1Q_t)

snr_rc1_I_r=abs(pow_rc1_I/(pow_rc1_I-pow_rc1_I_r))
snr_rc1_Q_r=abs(pow_rc1_Q/(pow_rc1_Q-pow_rc1_Q_r))

snr_rc1_I_t=abs(pow_rc1_I/(pow_rc1_I-pow_rc1_I_t))
snr_rc1_Q_t=abs(pow_rc1_Q/(pow_rc1_Q-pow_rc1_Q_t))
#_____________________ rolloff  1.0 ____________________
pow_rc2_I=np.sum(symb_out2I**2)/len(symb_out2I)
pow_rc2_Q=np.sum(symb_out2Q**2)/len(symb_out2Q)
pow_rc2_I_r=np.sum(symb_out2I_r**2)/len(symb_out2I_r)
pow_rc2_Q_r=np.sum(symb_out2Q_r**2)/len(symb_out2Q_r)
pow_rc2_I_t=np.sum(symb_out2I_t**2)/len(symb_out2I_t)
pow_rc2_Q_t=np.sum(symb_out2Q_t**2)/len(symb_out2Q_t)

snr_rc2_I_r=abs(pow_rc2_I/(pow_rc2_I-pow_rc2_I_r))
snr_rc2_Q_r=abs(pow_rc2_Q/(pow_rc2_Q-pow_rc2_Q_r))

snr_rc2_I_t=abs(pow_rc2_I/(pow_rc2_I-pow_rc2_I_t))
snr_rc2_Q_t=abs(pow_rc2_Q/(pow_rc2_Q-pow_rc2_Q_t))

print("rolloff 0.0 ")
print('  redondeo SNR_I: '+str(10*np.log(snr_rc0_I_r))+' dB  SNR_Q: '+str(10*np.log(
print('  truncado SNR_I: '+str(10*np.log(snr_rc0_I_t))+' dB  SNR_Q: '+str(10*np.log(
print("rolloff 0.5 ")
print('  redondeo SNR_I: '+str(10*np.log(snr_rc1_I_r))+' dB  SNR_Q: '+str(10*np.log(
print('  truncado SNR_I: '+str(10*np.log(snr_rc1_I_t))+' dB  SNR_Q: '+str(10*np.log(
print("rolloff 1.0 ")
print('  redondeo SNR_I: '+str(10*np.log(snr_rc2_I_r))+' dB  SNR_Q: '+str(10*np.log(
print('  truncado SNR_I: '+str(10*np.log(snr_rc2_I_t))+' dB  SNR_Q: '+str(10*np.log(
```

```
rolloff 0.0
  redondeo SNR_I: 39.00840150871232 dB  SNR_Q: 38.45241803030688 dB
  truncado SNR_I: 38.34931822648525 dB  SNR_Q: 32.640380282508914 dB
rolloff 0.5
  redondeo SNR_I: 44.78900194626328 dB  SNR_Q: 44.0171092394737 dB
  truncado SNR_I: 55.12351593676204 dB  SNR_Q: 36.72337793378836 dB
rolloff 1.0
  redondeo SNR_I: 81.04543843352126 dB  SNR_Q: 55.43222802941166 dB
  truncado SNR_I: 34.78708283940136 dB  SNR_Q: 29.198181074812712 dB
```

Ejercicio 2

Para este ejercicio se tuvo en cuenta que las variables o las asignaciones de puertos tengan el mismo noombre tanto en los script como en los archivos. Esto permitie que la lectura y el seguimiento del programa sea mas facil.
Por otro lado se puede realizar la generación de vectores y el matching de los mismo desde el archivo tp4_Ejercico2.ipynb. Tambien se debería cambiar PATH definido en los verilog por la direccion en la cual esté la carpeta que contiene todos los archivos para poder ejecutar los mismos sin ningín problema.

Actividad 1

Escribir un módulo en Verilog que permita realizar una suma de dos entradas en punto fijo con los siguientes formatos: S16.14 y S12.11, entregando diferentes salidas en los siguientes formatos.

- Full-resolution
- S11.10 con overflow y truncado.
- S11.10 con saturación y truncado.
- S9.8 con saturación y redondeo.

Descripción en verilog

```
module sumador_fixed
#(
    parameter NBA  =16, parameter  NBFA  =14, // Entrada A S(xx,xx)
    parameter NBB  =12, parameter  NBFB  =11, // Entrada B S(xx,xx)
    parameter NBS1 =11,  parameter NBFS1 =10, // Salida  1 S(xx,xx)
    parameter NBS2 =9 ,  parameter NBFS2 =8   // Salida  2 S(xx,xx)
)
(
    input signed   [NBA-1:0]  i_saa_aa,              //S(16,14) S,E,14D
    input signed   [NBB-1:0]  i_sbb_bb,              //S(12,11) S,11D
    output signed  [NBA:0]    o_sxx_xx_full,         //S(17,14)C,S,E,14D
    output signed  [NBS1-1:0] o_s11_11_over_trunc,   //S(11,10)
    output signed  [NBS1-1:0] o_s11_11_satu_trunc,   //S(11,10)
    output signed  [NBS2-1:0] o_s22_22_satu_round    //S(9,8)
);
localparam NEA   =  NBA  - NBFA;
localparam NEB   =  NBB  - NBFB;
localparam NES1  =  NBS1 - NBFS1;
localparam NES2  =  NBS2 - NBFS2;

localparam DOT   =  NEA-NBFA-1;

localparam DEAB  =  NEA  - NEB;
localparam DFAB  =  NBFA - NBFB;


wire signed [NBA  :0] s_full;
wire signed [NBA-1:0] s_aj_sbb_bb;
wire signed [NBS1 :0] s_trunc_sat;
```

```
wire signed [NBS2  :0] s_s22_22;
wire signed [NBS2+1:0] s_s22_22_round;
wire signed [NBS2-1:0]  s_s22_22_round_satu;

assign s_aj_sbb_bb = {{DEAB{i_sbb_bb[NBB-1]}},i_sbb_bb,{DFAB{1'b0}}};

assign s_full = i_saa_aa + s_aj_sbb_bb; // Alternativa reemplazar
s_aj_sbb_bb por $signed({i_sbb_bb[11],i_sbb_bb,3'b000})

assign s_trunc_sat = &s_full[NBA : NEA-DOT-NES1] || ~|s_full[NBA : NEA-DOT-
NES1] ? s_full[NEA-DOT-NES1 -: NBS1]:
                     &s_full[NBA]
? {1'b1,{10{1'b0}}} :

{1'b0,{10{1'b1}}} ;

assign s_s22_22 = s_full[NEA-DOT-NES2 -:NBS2+1];
assign s_s22_22_round = s_s22_22 + 1'b1;

assign s_s22_22_round_satu = &s_s22_22_round[NBS2+1:NBS2] ||
~|s_s22_22_round[NBS2+1:NBS2] ? s_s22_22_round[NBS2:1] :
                                &s_s22_22_round[NBS2+1]
? {1'b1,{NBFS2{1'b0}}} :

{1'b0,{NBFS2{1'b1}}} ;

assign o_sxx_xx_full = s_full;
assign o_s11_11_over_trunc = s_full[NEA-DOT-NES1 -: NBS1];
assign o_s11_11_satu_trunc = s_trunc_sat;
assign o_s22_22_satu_round = s_s22_22_round_satu;

endmodule
```

Testbench

Generador de vectores.

In [2]:

```
import math
import numpy as np
from tool._fixedInt import *
```

In [11]:

```
i_a_rand = np.random.uniform(low=-0.9, high=0.9, size=(5))
i_b_rand = np.random.uniform(low=-0.9, high=0.9, size=(5))
i_saa_aa = arrayFixedInt(16,14, i_a_rand, signedMode='S', roundMode='round', saturat
i_sbb_bb = arrayFixedInt(12,11, i_b_rand, signedMode='S', roundMode='round', saturat
o_sxx_xx_full_sum=DeFixedInt(roundMode='trunc',signedMode = 'S',totalWidth=17,fractW
o_s11_11_over_trunc_c=DeFixedInt(roundMode='trunc',signedMode = 'S',totalWidth=11,fr
o_s11_11_satu_trunc_c=DeFixedInt(roundMode='trunc',signedMode = 'S',totalWidth=11,fr
o_s22_22_satu_round_c=DeFixedInt(roundMode='round',signedMode = 'S',totalWidth=9,fra
o_saa_aa=""
o_sbb_bb=""
o_sxx_xx_full=""
o_s11_11_over_trunc=""
o_s11_11_satu_trunc=""
o_s22_22_satu_round=""
for i in range(len(i_saa_aa)):
    o_saa_aa+=str((bin(i_saa_aa[i].intvalue))[2:].zfill(i_saa_aa[i].width))+'\n'
```

```
    o_sbb_bb+=str((bin(i_sbb_bb[i].intvalue))[2:].zfill(i_sbb_bb[i].width))+'\n'
    o_sxx_xx_full_sum.assign(i_saa_aa[i]+i_sbb_bb[i])
    o_s11_11_over_trunc_c.value=o_sxx_xx_full_sum.fValue
    o_s11_11_satu_trunc_c.value=o_sxx_xx_full_sum.fValue
    o_s22_22_satu_round_c.value=o_sxx_xx_full_sum.fValue
    o_sxx_xx_full+=str((bin(o_sxx_xx_full_sum.intvalue))[2:].zfill(o_sxx_xx_full_sum
    o_s11_11_over_trunc+=str((bin(o_s11_11_over_trunc_c.intvalue))[2:].zfill(o_s11_1
    o_s11_11_satu_trunc+=str((bin(o_s11_11_satu_trunc_c.intvalue))[2:].zfill(o_s11_1
    o_s22_22_satu_round+=str((bin(o_s22_22_satu_round_c.intvalue))[2:].zfill(o_s22_2

f = open ('test_files/py_i_saa_aa.txt','w')
f.write(o_saa_aa)
f.close()
f = open ('test_files/py_i_sbb_bb.txt','w')
f.write(o_sbb_bb)
f.close()
f = open ('test_files/py_o_sxx_xx_full.txt','w')
f.write(o_sxx_xx_full)
f.close()
f = open ('test_files/py_o_s11_11_over_trunc.txt','w')
f.write(o_s11_11_over_trunc)
f.close()
f = open ('test_files/py_o_s11_11_satu_trunc.txt','w')
f.write(o_s11_11_satu_trunc)
f.close()
f = open ('test_files/py_o_s22_22_satu_round.txt','w')
f.write(o_s22_22_satu_round)
f.close()
print("Vectores generados.")
```

```
Vectores generados.
```

comparador de vectores

In [12]:

```
path='test_files/'
py_vectors=['py_o_sxx_xx_full.txt','py_o_s11_11_over_trunc.txt','py_o_s11_11_satu_tr
v_vectors  = ["v_o_sxx_xx_full.txt",'v_o_s11_11_over_trunc.txt','v_o_s11_11_satu_tru
for i in range(len(py_vectors)):
    archivo = open(path+py_vectors[i], 'r')
    py_vector_temp = archivo.read().split('\n')
    archivo.close()
    archivo = open(path+v_vectors[i], 'r')
    V_vector_temp = archivo.read().split('\n')
    archivo.close()
    print('---- matching '+py_vectors[i]+' with '+v_vectors[i]+'----')
    flag=0
    for j in range(len(py_vector_temp)):
        if(py_vector_temp[j]== V_vector_temp[j]):
            pass
        else:
            print('index '+str(j)+' python: '+ py_vector_temp[j]+ ' verilog: ' + V_v
            flag=1
    if not flag:
        print("all Passed.")
```

```
---- matching py_o_sxx_xx_full.txt with v_o_sxx_xx_full.txt----
all Passed.
---- matching py_o_s11_11_over_trunc.txt with v_o_s11_11_over_trunc.txt----
all Passed.
---- matching py_o_s11_11_satu_trunc.txt with v_o_s11_11_satu_trunc.txt----
all Passed.
---- matching py_o_s22_22_satu_round.txt with v_o_s22_22_satu_round.txt----
all Passed.
```

Actividad 2

Escribir un módulo en Verilog que permita realizar una multiplicación de dos entradas en punto fijo con los siguientes formatos: S8.6 y S12.11, entregando diferentes salidas en los siguientes formatos.

- Full-resolution.
- S12.11 con overflow y truncado.
- S12.11 con saturación y truncado.
- S10.9 con saturación y redondeo.

Descripción en verilog.

```
module multiplicador_fixed
#(
    parameter NBA  =12, parameter  NBFA  =11, // Entrada A S(xx,xx)
    parameter NBB  =08, parameter  NBFB  =06,  // Entrada B S(xx,xx)
    parameter NBS1 =12, parameter  NBFS1 =11, // Salida  1 S(xx,xx)
    parameter NBS2 =10 , parameter NBFS2 =09   // Salida  2 S(xx,xx)
)
(
    input signed   [NBA-1:0]        i_saa_aa,
    input signed   [NBB-1:0]        i_sbb_bb,
    output signed  [NBA+NBB-1 :0]   o_sxx_xx_full,
    output signed  [NBS1-1:0]       o_s11_11_over_trunc,
    output signed  [NBS1-1:0]       o_s11_11_satu_trunc,
    output signed  [NBS2-1:0]       o_s22_22_satu_round
);
localparam NEA   =  NBA  - NBFA;
localparam NEB   =  NBB  - NBFB;
localparam NES1  =  NBS1 - NBFS1;
localparam NES2  =  NBS2 - NBFS2;
localparam NEM   =  NBA+NBB -1;
localparam DOT   =  NEM-NBFA-NBFB-1;

wire signed [NEM:0]    s_full;
wire signed [NBS1 :0]  s_trunc_sat;

wire signed [NBS2  :0] s_s22_22;
wire signed [NBS2+1:0] s_s22_22_round;
wire signed [NBS2-1:0] s_s22_22_round_satu;



assign s_full = i_saa_aa * i_sbb_bb;

assign s_trunc_sat = &s_full[NEM : NEM-DOT-NES1] || ~|s_full[NEM : NEM-DOT-
NES1] ? s_full[NEM-DOT-NES1 -: NBS1]:
                    &s_full[NEM]
? {1'b1,{10{1'b0}}} :

{1'b0,{10{1'b1}}} ;

assign s_s22_22 = s_full[NEM-DOT-NES2 -:NBS2+1];
assign s_s22_22_round = s_s22_22 + 1'b1;
```

```
assign s_s22_22_round_satu = &s_s22_22_round[NBS2+1:NBS2] ||
~|s_s22_22_round[NBS2+1:NBS2] ? s_s22_22_round[NBS2:1] :
                                &s_s22_22_round[NBS2+1]
? {1'b1,{NBFS2{1'b0}}} :

{1'b0,{NBFS2{1'b1}}} ;

assign o_sxx_xx_full = s_full;
assign o_s11_11_over_trunc = s_full[NEM-DOT-NES1 -: NBS1];
assign o_s11_11_satu_trunc = s_trunc_sat;
assign o_s22_22_satu_round = s_s22_22_round_satu;

endmodule
```

Testbench

```
`timescale 1 ns/10 ps  // time-unit = 1 ns, precision = 10 ps
`define PATH
"C:/Users/matia/Documents/UTN/0_Extracurricular/0_Fundacion_Fulgor/Diseno_Digit

module tb_multiplicador_fixed;
    parameter NBA  =12;  parameter  NBFA  =11;   // Entrada A S(xx,xx)
    parameter NBB  =08;  parameter  NBFB  =06;   // Entrada B S(xx,xx)
    parameter NBS1 =12;  parameter  NBFS1 =11;   // Salida  1 S(xx,xx)
    parameter NBS2 =10;  parameter  NBFS2 =09;   // Salida  2 S(xx,xx)
    parameter path_dir = `PATH;
    reg signed   [NBA-1:0]  i_saa_aa;
    reg signed   [NBB-1:0]  i_sbb_bb;
    reg          [NBA+NBB-1 :0]    o_sxx_xx_full_w;
    reg          [NBS1-1:0]        o_s11_11_over_trunc_w;
    reg          [NBS1-1:0]        o_s11_11_satu_trunc_w;
    reg          [NBS2-1:0]        o_s22_22_satu_round_w;
    wire         [NBA+NBB-1 :0]    o_sxx_xx_full;
    wire         [NBS1-1:0]        o_s11_11_over_trunc;
    wire         [NBS1-1:0]        o_s11_11_satu_trunc;
    wire         [NBS2-1:0]        o_s22_22_satu_round;
    reg signed   [NBA-1:0]         read_data_i_saa_aa [0:5];
    reg signed   [NBB-1:0]         read_data_i_sbb_bb [0:5];
    integer tb_o_sxx_xx_full_dir;
    integer tb_o_s11_11_over_trunc_dir;
    integer tb_o_s11_11_satu_trunc_dir;
    integer tb_s22_22_satu_round_dir;
    integer i;
    initial
    begin
        $readmemb({path_dir,"py_i_saa_aa.txt"}, read_data_i_saa_aa);
        $readmemb({path_dir,"py_i_sbb_bb.txt"}, read_data_i_sbb_bb);
        tb_o_sxx_xx_full_dir       =
$fopen({path_dir,"v_o_sxx_xx_full.txt"});
        tb_o_s11_11_over_trunc_dir =
$fopen({path_dir,"v_o_s11_11_over_trunc.txt"});
        tb_o_s11_11_satu_trunc_dir =
$fopen({path_dir,"v_o_s11_11_satu_trunc.txt"});
        tb_s22_22_satu_round_dir   =
$fopen({path_dir,"v_o_s22_22_satu_round.txt"});
```

```
        for (i=0; i<5; i=i+1)
        begin
            i_saa_aa = read_data_i_saa_aa[i];
            i_sbb_bb = read_data_i_sbb_bb[i];
            o_sxx_xx_full_w <= o_sxx_xx_full;
            o_s11_11_over_trunc_w<=  o_s11_11_over_trunc;
            o_s11_11_satu_trunc_w<=  o_s11_11_satu_trunc;
            o_s22_22_satu_round_w<=  o_s22_22_satu_round;
            #2;
            o_sxx_xx_full_w <= o_sxx_xx_full;
            o_s11_11_over_trunc_w<=  o_s11_11_over_trunc;
            o_s11_11_satu_trunc_w<=  o_s11_11_satu_trunc;
            o_s22_22_satu_round_w<=  o_s22_22_satu_round;
            #2;
            $fdisplay(tb_o_sxx_xx_full_dir, "%b",o_sxx_xx_full_w);
            $fdisplay(tb_o_s11_11_over_trunc_dir,
"%b",o_s11_11_over_trunc_w);
            $fdisplay(tb_o_s11_11_satu_trunc_dir,
"%b",o_s11_11_satu_trunc_w);
            $fdisplay(tb_s22_22_satu_round_dir,
"%b",o_s22_22_satu_round_w);
            #100;
        end
        $fclose(tb_o_sxx_xx_full_dir);
        $fclose(tb_o_s11_11_over_trunc_dir);
        $fclose(tb_o_s11_11_satu_trunc_dir);
        $fclose(tb_s22_22_satu_round_dir);
    end

multiplicador_fixed
    u_multiplicador_fixed(
        .i_saa_aa(i_saa_aa),
        .i_sbb_bb(i_sbb_bb),
        .o_sxx_xx_full(o_sxx_xx_full),
        .o_s11_11_over_trunc(o_s11_11_over_trunc),
        .o_s11_11_satu_trunc(o_s11_11_satu_trunc),
        .o_s22_22_satu_round(o_s22_22_satu_round)
    );
endmodule
```

Generador de vectores.

In [18]:

```
i_a_rand = np.random.uniform(low=-0.9, high=0.9, size=(5))
i_b_rand = np.random.uniform(low=-0.9, high=0.9, size=(5))
i_saa_aa = arrayFixedInt(12,11, i_a_rand, signedMode='S', roundMode='round', saturat
i_sbb_bb = arrayFixedInt(8,6, i_b_rand, signedMode='S', roundMode='round', saturateM
o_sxx_xx_full_op = DeFixedInt(roundMode='trunc',signedMode = 'S',totalWidth=20,fract
o_s11_11_over_trunc_c=DeFixedInt(roundMode='trunc',signedMode = 'S',totalWidth=12,fr
o_s11_11_satu_trunc_c=DeFixedInt(roundMode='trunc',signedMode = 'S',totalWidth=12,fr
o_s22_22_satu_round_c=DeFixedInt(roundMode='round',signedMode = 'S',totalWidth=10,fr
o_saa_aa=""
o_sbb_bb=""
o_sxx_xx_full=""
o_s11_11_over_trunc=""
o_s11_11_satu_trunc=""
o_s22_22_satu_round=""
```

```
for i in range(len(i_saa_aa)):
    o_saa_aa+=str((bin(i_saa_aa[i].intvalue))[2:].zfill(i_saa_aa[i].width))+'\n'
    o_sbb_bb+=str((bin(i_sbb_bb[i].intvalue))[2:].zfill(i_sbb_bb[i].width))+'\n'
    o_sxx_xx_full_op.assign(i_saa_aa[i]*i_sbb_bb[i])
    o_s11_11_over_trunc_c.value=o_sxx_xx_full_op.fValue
    o_s11_11_satu_trunc_c.value=o_sxx_xx_full_op.fValue
    o_s22_22_satu_round_c.value=o_sxx_xx_full_op.fValue
    o_sxx_xx_full+=str((bin(o_sxx_xx_full_op.intvalue))[2:].zfill(o_sxx_xx_full_op.w
    o_s11_11_over_trunc+=str((bin(o_s11_11_over_trunc_c.intvalue))[2:].zfill(o_s11_1
    o_s11_11_satu_trunc+=str((bin(o_s11_11_satu_trunc_c.intvalue))[2:].zfill(o_s11_1
    o_s22_22_satu_round+=str((bin(o_s22_22_satu_round_c.intvalue))[2:].zfill(o_s22_2

f = open ('test_files/py_i_saa_aa.txt','w')
f.write(o_saa_aa)
f.close()
f = open ('test_files/py_i_sbb_bb.txt','w')
f.write(o_sbb_bb)
f.close()
f = open ('test_files/py_o_sxx_xx_full.txt','w')
f.write(o_sxx_xx_full)
f.close()
f = open ('test_files/py_o_s11_11_over_trunc.txt','w')
f.write(o_s11_11_over_trunc)
f.close()
f = open ('test_files/py_o_s11_11_satu_trunc.txt','w')
f.write(o_s11_11_satu_trunc)
f.close()
f = open ('test_files/py_o_s22_22_satu_round.txt','w')
f.write(o_s22_22_satu_round)
f.close()
print("Vectores generados.")
```

```
Vectores generados.
```

Comparador de vectores

In [19]:

```
path='test_files/'
py_vectors=['py_o_sxx_xx_full.txt','py_o_s11_11_over_trunc.txt','py_o_s11_11_satu_tr
v_vectors  = ["v_o_sxx_xx_full.txt",'v_o_s11_11_over_trunc.txt','v_o_s11_11_satu_tru
for i in range(len(py_vectors)):
    archivo = open(path+py_vectors[i], 'r')
    py_vector_temp = archivo.read().split('\n')
    archivo.close()
    archivo = open(path+v_vectors[i], 'r')
    V_vector_temp = archivo.read().split('\n')
    archivo.close()
    print('---- matching '+py_vectors[i]+' with '+v_vectors[i]+'----')
    flag=0
    for j in range(len(py_vector_temp)):
        if(py_vector_temp[j]== V_vector_temp[j]):
            pass
        else:
            print('index '+str(j)+' python: '+ py_vector_temp[j]+ ' verilog: ' + V_v
            flag=1
    if not flag:
        print("all Passed.")
```

```
---- matching py_o_sxx_xx_full.txt with v_o_sxx_xx_full.txt----
all Passed.
---- matching py_o_s11_11_over_trunc.txt with v_o_s11_11_over_trunc.txt----
all Passed.
---- matching py_o_s11_11_satu_trunc.txt with v_o_s11_11_satu_trunc.txt----
all Passed.
---- matching py_o_s22_22_satu_round.txt with v_o_s22_22_satu_round.txt----
```

```
index 1 python: 1111100110 verilog: 0111111111
index 3 python: 1111101000 verilog: 0111111111
```

Nota

Los errores de matching en las operaciones de redondeo y saturacion aparentemente son problemas de la biblioteca utilizada en python.