SINR Regular Beamforming

June 1, 2018

```
In [1]: import numpy as np
        from matplotlib import pyplot as plt
        from matplotlib import gridspec
        from matplotlib import animation
        from matplotlib import gridspec
        from scipy.stats import norm
        from cmath import sqrt
        from time import time
         = np.pi
        num_points = 500
        tol = 1e-14

In [2]: %matplotlib inline
        plt.rcParams["figure.dpi"] = 300

In [3]: def dist(k,,r,N,) :
            '''
            Calculates the distance from the array element (middle of the antenna array is ori
            which is r away from the origin.

            Inputs:
                k (int)        - index of antenna
                 (rad)        - angle off from orthogonal to array
                r (unit-less) - distance to transmitter from origin
                N (int)        - number of antenna + 1
                 (?)          - wavelength (c = f where c is the speed of light and f is the fr

            Output:
                Distance from antenna to transmitter
            '''
            dx = k*/2 - (N-1)*/4
            x = np.cos()*r # Might need to be sin
            y = np.sin()*r # Might need to be cos
            return sqrt((x-dx)**2+y**2)

        def dst(,r,N,) :
            ds = np.zeros(N).astype(complex)
```

```
    for k in range(N) :
        ds[k] = np.exp(dist(k,,r,N,)*2**1j)
    ds = ds/np.linalg.norm(ds)
    return ds

def weights(,N,r,) :
    '''
    Calculates the coefficients of the beam equation

    Inputs:
          (rad) - angle off from orthogonal to array
        N (int) - number of antenna +1

    Output:
        a_k for the beam form equation _1^N <a_k(), x_k> where x_k is the volatge resp
        NOTE: This vector is normalized (why? I don't know)
    '''
     = *np.sin()
    bs = np.zeros(N).astype(complex)
    for k in range(N) :
        bs[k] = np.exp(*k*1j)
    return bs/np.linalg.norm(bs)

def sinr_ber_plp(signal_beam,noise_beams,var_awgn=1,var_ray=1,h_sig=None,pack_len=10,d
    '''
    Calculates the estimated SINR, BER, and PLP (packet loss percentage)
        for certain locations based on transmission beams.
    Assumes a Rayleigh channel with BPSK modulation and CRC.

    Input :
        Beams are of the form [power_levels (n,) array, weights (L,) array]
        signal_beam  - beam  - The signal beam
        noise_beams  - list  - List of noise beams (each beam like signal beam)
        var_awgn     - float - White noise variance
        var_ray      - float - Fading variance of the Rayleigh channel
        h_sig        - array - Fading from the Rayleigh channel [CN(0,var_ray) distrib
        pack_len     - int   - Number of bits per packet (including the checking bit)
        dist_fad_exp - float - Exponent for the (optional) distance attenuation fading
        verbose      - bool  - Whether or not you want an update every 100 iterations

    Output :
        SINR -  (n,n) array  - Signal to Interference and Noise Ratio
        BER  -  (n,n) array  - Bit Error Rate (for BPSK under https://www.unilim.fr/pa
        PLP  -  (n,n) array  - Packet Loss Percentage
    '''
    sig_beam = signal_beam[0]
    sig_weights = signal_beam[1]
    n_beams = [beam[0] for beam in noise_beams]
```

```
        n_weights = [beam[1] for beam in noise_beams]
        K = len(n_weights)
        n = len(sig_beam)
        L = sig_weights.shape[0]
        r = np.linspace(tol,max(sig_beam),n)
        SINR = np.zeros((n,n))
        if h_sig is None :
            h_sig = np.random.normal(loc=np.array([0,0]),scale=np.array([var_ray,var_ray])
            h_sig = 1/sqrt(2)*(h_sig[:,0] + 1j*h_sig[:,1])
        sig_const = abs(h_sig @ sig_weights)**2
        noise_const = [abs(h_sig[i] @ weight[i])**2 for i in range(K)]
        for j in range(n) : # Iterating over
            sig_pow = sig_beam[j]
            noise_pows = [beam[j] for beam in n_beams]
            if dist_fad_exp :
                SINR[j,:] = [((sig_pow/(r[i]**dist_fad_exp))*sig_const)/(var_awgn + sum([(r
            else :
                SINR[j,:] = [(sig_pow*sig_const)/(var_awgn + sum([noise_pows[k]*noise_const
            if verbose and (j+1) % 100 == 0 :
                print(f'{j+1}th iteration complete.')
        mask = SINR >= max(sig_beam)
        SINR[mask] = max(sig_beam)
        BER = 1 - norm.cdf(np.sqrt(2*SINR*abs(h_sig@h_sig)))
        PLP = 1 - (1 - BER)**pack_len
        SINR = 10*np.log(SINR)/np.log(10)
        return SINR, BER, PLP
```

0.0.1 For a single beam

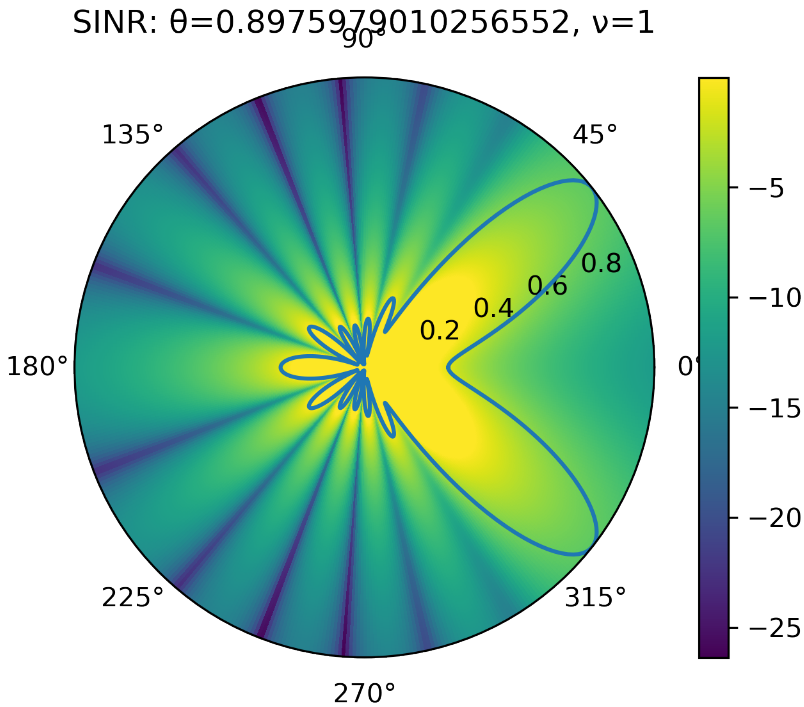
```
In [4]: N = 7                                                       # Number of antenna
         = 1                                                       # Wavelength
         = 1                                                       # Functional Beamforming Exponent
        2_awgn = 1                                                 # Noise/AWGN variance
        2_ray = 1                                                  # Noise/Fading variance
        beams = 2*/7                                               # Desired azmith angle
        s_k = 10                                                    # Alice's signal strength
        packet_len = 10
        s = np.linspace(0,2*,num_points)
        ak = weights(beams,N,s_k,)
        sig_beam = [abs(dst(,s_k,N,)@ak) for  in s]
        signal_beam = [sig_beam,ak]
```

```
In [5]: start = time()
        SINR, BER, PLP = sinr_ber_plp(signal_beam,[],var_awgn=2_awgn,var_ray=2_ray,pack_len=pac
        end = time()
        print(f'Took {(end-start)//3600} hour(s), {((end-start)%3600)//60} minute(s) and {(((en
```

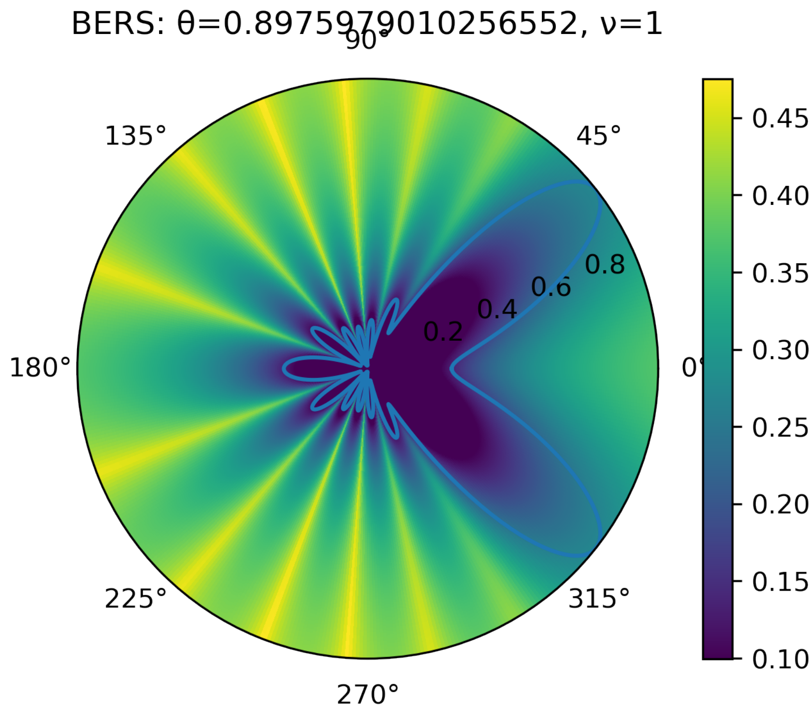
```
100th iteration complete.
200th iteration complete.
```

```
300th iteration complete.
400th iteration complete.
500th iteration complete.
Took 0.0 hour(s), 0.0 minute(s) and 0.360414981842041 seconds.
```

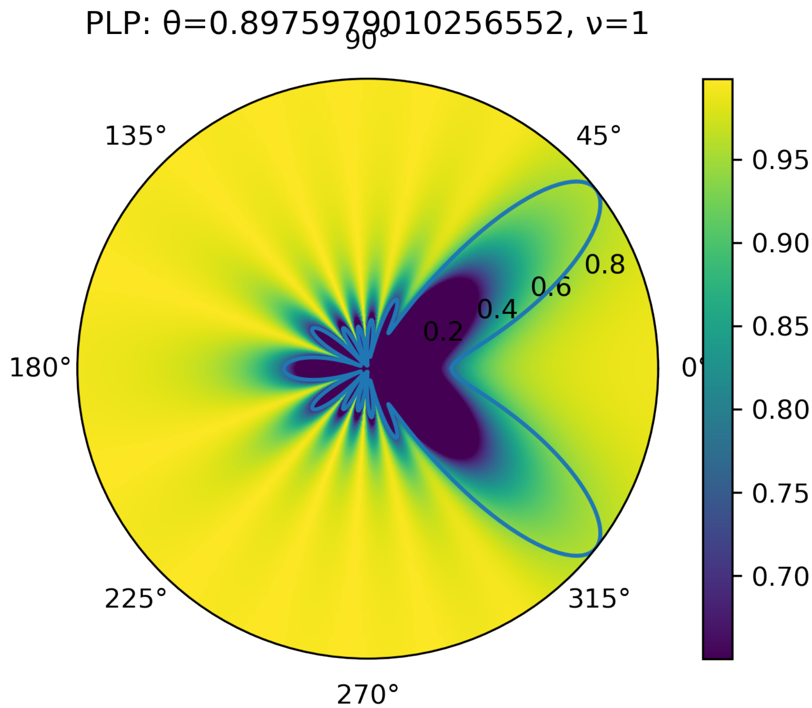
```
In [6]:  = np.linspace(0,2*,num_points)
        r = np.linspace(0,max(sig_beam),num_points)
        R, = np.meshgrid(r,)
        plt.polar(,sig_beam)
        plt.pcolor(,R,SINR)
        plt.colorbar()
        plt.title(f'SINR: ={beams}, ={}')
        plt.show()
```




```
In [7]: plt.polar(,sig_beam)
        plt.pcolor(,R,BER)
        plt.colorbar()
        plt.title(f'BERS: ={beams}, ={}')
        plt.show()
```




```
In [8]: plt.polar(,sig_beam)
        plt.pcolor(,R,PLP)
        plt.colorbar()
        plt.title(f'PLP: ={beams}, ={}')
        plt.show()
```



0.0.2 Moving the beam

```
In [9]: N = 7                                                          # Number of antenna
         = 1                                                          # Wavelength
         = 1                                                          # Functional Beamforming Exponent
        2_awgn = 1                                                    # Noise/AWGN variance
        2_ray = 1                                                     # Noise/Fading variance
        beam_cent = /4                                                # Azmith angle to Bob
        num_packets = 51
        beams = np.linspace(beam_cent-/12,beam_cent+/12,num_packets)
        s_k = 10                                                       # Alice's signal strength
        packet_len = 10
        func = lambda x : x**(1/)
        s = np.linspace(0,2*,num_points)
        all_beams = []
        SINRs = np.zeros((num_points,num_points,num_packets))
        BERs = np.zeros((num_points,num_points,num_packets))
        PLPs = np.zeros((num_points,num_points,num_packets))
        hsig = np.random.normal(loc=np.array([0,0]),scale=np.array([2_ray,2_ray]),size=(N,2))
        hsig = 1/sqrt(2)*(hsig[:,0] + 1j*hsig[:,1])
        start = time()
        for i in range(num_packets) :
            ak = weights(beams[i],N,s_k,)
            sig_beam = [abs(dst(,s_k,N,)@ak) for  in s]
```

```
            all_beams.append(sig_beam)
            signal_beam = [sig_beam,ak]
            SINRs[:,:,i], BERs[:,:,i], PLPs[:,:,i] = sinr_ber_plp(signal_beam,[],var_awgn=2_awg
        end = time()
        all_beams = np.array(all_beams)
        print(f'Took {(end-start)//3600} hour(s), {((end-start)%3600)//60} minute(s) and {(((e
```

```
Took 0.0 hour(s), 0.0 minute(s) and 18.28603506088257 seconds.
```

In [10]:
```
np.save('../../../IRES_Files/Beams_Reg',all_beams)
np.save('../../../IRES_Files/SINRs_Reg',SINRs)
np.save('../../../IRES_Files/BERs_Reg',BERs)
np.save('../../../IRES_Files/PLPs_Reg',PLPs)
```

In [11]:
```
%matplotlib notebook
%matplotlib notebook
```

In [12]:
```
"""
https://jakevdp.github.io/blog/2012/08/18/matplotlib-animation-tutorial/

Matplotlib Animation Example

author: Jake Vanderplas
email: vanderplas@astro.washington.edu
website: http://jakevdp.github.com
license: BSD
"""

# Initialize values
fig = plt.figure()
ax = plt.axes(xlim=(0,2*),ylim=(0,1))
ax.set_title(f'Beam from {/4-/12} to {/4+/12}')
beam, = ax.plot([],[],lw=2)

# Define constructor fucntion
def constructor() :
    beam.set_data([],[])
    return beam,

# Define animation function
def animating(i) :
     = np.linspace(0,2*,num_points)
    r = all_beams[i,:]
    beam.set_data(,r)
    return beam,

# call the animator.  blit=True means only re-draw the parts that have changed.
anim = animation.FuncAnimation(fig, animating, init_func=constructor,frames=num_packe
```

```
    # Something's wrong with the save
    #anim.save('../../../IRES_Files/Animations/reg_beam.html', fps=30, extra_args=['-vcod
    #plt.show()
```

```
<IPython.core.display.Javascript object>
```

```
<IPython.core.display.HTML object>
```

```
In [13]: %matplotlib notebook
         # Initialize values
         fig = plt.figure(figsize=(14,14), facecolor='white')
         gs = gridspec.GridSpec(11,1)

         ax1 = plt.subplot(gs[:2,:])
         ax1.set_xlim(0,2*)
         ax1.set_ylim(0,1)
         ax1.set_xlabel('')
         ax1.set_title(f'Beam from {beam_cent-/12} to {beam_cent+/12}')
         beam, = ax1.plot([],[],lw=2)

         R,  = np.meshgrid(np.linspace(0,1,num_points),np.linspace(0,2*,num_points))
         SNR = SINRs[:,:,0]
         ax2 = plt.subplot(gs[3:5,:])
         ax2.set_xlim(0,2*)
         ax2.set_ylim(0,1)
         ax2.set_xlabel('')
         ax2.set_title(f'SINRs')
         snr = ax2.pcolormesh(,R,SNR,shading='gouraud')
         #cb = fig.colorbar(snr)

         BER = BERs[:,:,0]
         ax3 = plt.subplot(gs[6:8,:])
         ax3.set_xlim(0,2*)
         ax3.set_ylim(0,1)
         ax3.set_xlabel('')
         ax3.set_title(f'BERs')
         ber = ax3.pcolormesh(,R,BER,shading='gouraud')

         PLP = PLPs[:,:,0]
         ax4 = plt.subplot(gs[9:,:])
         ax4.set_xlim(0,2*)
         ax4.set_ylim(0,1)
         ax4.set_xlabel('')
         ax4.set_title(f'PLP')
         plp = ax4.pcolormesh(,R,PLP,shading='gouraud')
```

```python
    # Define constructor fucntion
    def constructor() :
        beam.set_data([],[])
        snr.set_array(np.array([]))
        ber.set_array(np.array([]))
        plp.set_array(np.array([]))
        return beam,snr,ber,plp

    # Define animation function
    def animating(i) :
         = np.linspace(0,2*,num_points)
        r = all_beams[i,:]
        beam.set_data(,r)
        snr.set_array(SINRs[:,:,i].ravel())
        ber.set_array(BERs[:,:,i].ravel())
        plp.set_array(PLPs[:,:,i].ravel())
        return beam,snr,ber,plp

    # call the animator.  blit=True means only re-draw the parts that have changed.
    anim = animation.FuncAnimation(fig, animating, init_func=constructor,frames=num_packe
    # Something's wrong with the save
    #anim.save('Reg_Full.html', writer='ffmpeg', fps=30, extra_args=['-vcodec', 'libx264'
    #plt.show()
```

```
<IPython.core.display.Javascript object>
```

```
<IPython.core.display.HTML object>
```