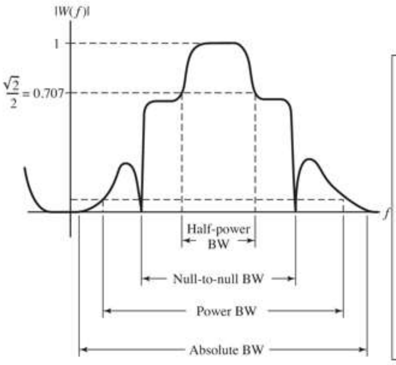
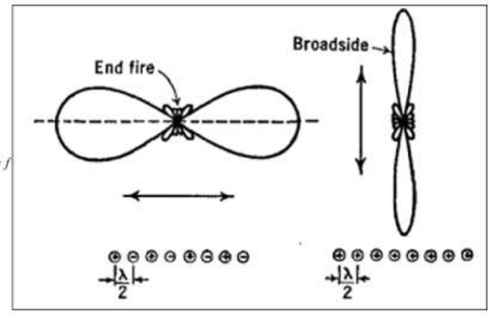
Linear array- (a few of) parameters computation using python script

Authgor: Jay Gautam, Darmstadt Germany. (Please download code from my GitHub)\ Objective of python script:

```
1. Compute null to null beam width in case of broadside array
2. Compute null to null beam width in case of end-fire array
3. Compute directivity of array antenna
4. Compute received power by a receiving antenna.
```

Note: I used functional approach paradigm. Object oriented approach can also be used to make it more compact and robust.





Mathematics to implement to compute several parameters related to array antennas. Many other parameter can be implemented as well.

```
array length = l, number of elements in array = N, spacing between antenna = d, wavelength = lambda
Pt = transmit power, Pr = received power, Gt = Gain of transmit antenna, Gr = Gain of receive antenna

spacing between antenna(d) = l/N
Beamwith(broadside) = 2*lambda/(l*N)
Beamwith(end-fire) = 2*sqrt(2*lambda/(l*N)
Received power(Pr) = (Pt*Gt*Gr*(lambda)^2))/(4*Pi*d)^2
Directivity(D) = 2*l/lambda
Directivity(D)_dB = 10*log10(D)
```

Compute the null to null beam width of a broadside array (antenna elements are placed with 0 phase degree), with different case of number of antenna elements and array length.

In [1]:
```python
def bw_broadside(l_array_length, N_number_elements):
    """
    l_array_length:  array length
    N_number_elements: number of elements in the array
    d_spacing_between_antennas: spacing between the antennas
    BW_bandwidth: null to null beamwidth
    """

    d_spacing_between_antennas = l_array_length/N_number_elements # spacing between the antennas
    BW_bandwidth = (2*(1/d_spacing_between_antennas)*(1/N_number_elements)) # null to null beamwidth
    print(f"Broadside array: the null to null beamwidth for l = {l_array_length}\u03BB and N = {N_number_elements} is: ", round(BW_bandwidth, 3))

bw_broadside(10, 20)
bw_broadside(50, 100)
bw_broadside(20, 50)
```

```
Broadside array: the null to null beamwidth for l = 10λ and N = 20 is:  0.2
Broadside array: the null to null beamwidth for l = 50λ and N = 100 is:  0.04
Broadside array: the null to null beamwidth for l = 20λ and N = 50 is:  0.1
```

Compute the null to null beam width of a end-fire array (same as broadside except individual elements are fed with out of phase i.e. 180 degree), with different case of number of antenna elements and array length.

```python
In [2]: import math
def bw_end_fire(l_array_length, N_number_elements):
    """"""
    l_array_length: array length
    N_number_elements: number of elements in the array
    d_spacing_between_antennas: spacing between the antennas
    """"""

    d_spacing_between_antennas = l_array_length/N_number_elements # spacing between the antennas
    BW_bandwidth = 2*math.sqrt(2*(1/d_spacing_between_antennas)*(1/N_number_elements)) # null to null beamwidth
    print(f"End fire array: the null to null beamwidth for l = {l_array_length}\u03BB and N = {N_number_elements} is: ", round(BW_bandwid
th, 3))

bw_end_fire(10, 20)
bw_end_fire(50, 100)
bw_end_fire(20, 50)
```

```
End fire array: the null to null beamwidth for l = 10λ and N = 20 is:  0.894
End fire array: the null to null beamwidth for l = 50λ and N = 100 is:  0.4
End fire array: the null to null beamwidth for l = 20λ and N = 50 is:  0.632
```

Computation of null to null beam width and directivity in broadside case at particular frequency and array length.

```python
In [9]: def directivity_BW_null_to_null(f_ghz, l_array_length):
    """"""
    f_ghz: frequency in GHz
    f_hz: frequency in Hz
    l_array_length: array length in meter
    """"""
    f_hz = f_ghz*10**9    # frequency in Hz
    c = 3*10**8 # speed of light
    l_array_length = 10 # array length in meter
    wavelength = c/f_hz # lambda = speed_light/frequency
    BW_null_to_null = 2*(wavelength/l_array_length) # bandwidth in radian; BW = 2*lambda/l
    directivity = 2*(l_array_length/wavelength) # Directivity: D = 2*l/lambda
    directivity_db = 10*math.log10(directivity)
    print(f"Data: given frequency = {f_ghz} GHz and Array length = {l_array_length} meter.")
    print(f"Broadside array: Null to null beamwidth = {BW_null_to_null} radian")
    print(f"Directivity(D) = {directivity}")
    print(f"Directivity(D) in dB scale = {directivity_db} dB")
    print()

directivity_BW_null_to_null(6, 10)
directivity_BW_null_to_null(0.006, 10)
```

```
Data: given frequency = 6 GHz and Array length = 10 meter.
Broadside array: Null to null beamwidth = 0.01 radian
Directivity(D) = 400.0
Directivity(D) in dB scale = 26.020599913279625 dB

Data: given frequency = 0.006 GHz and Array length = 10 meter.
Broadside array: Null to null beamwidth = 10.0 radian
Directivity(D) = 0.4
Directivity(D) in dB scale = -3.979400086720376 dB
```

Computation of received power by a receiver dipole when power is transmitted by a transmitting dipole at some frequency and some distance between the Tx and Rx antennas.

```python
In [4]: import math
def received_power(p_transmit_watt, f_Mhz, d_meter):
    """
    p_transmit_watt: transmitted(radiated) power from the transmitter in watt
    f_Mhz : frequency of operation in MHz.
    d_meter: distance between the dipoles in meters

    """
    f_hz = f_Mhz*10**6 # frequency in Hz
    c = 3*10**8 # speed of light in m/s

    wavelength = c/f_hz # lambda = speed_light/frequency
    G_transmit = 1.64 # gain of transmitting dipole in dB
    G_receive = 1.64 # gain of receiving dipole in dB

    p_received = (p_transmit_watt*G_transmit*G_receive*(wavelength)**2/(4*(math.pi)*d_meter)**2) # received power by the second dipole in
watt

    print(f"Provided data: Distance between dipole = {d_meter} m, frequency = {f_Mhz} MHz, Transmitted power = {p_transmit_watt} Watt.")
    #print()
    print(f"The received power by the receiving dipole = {round(p_received, 3)} Watt")
    print()

received_power(15, 60, 10)
received_power(15, 60000, 10)
received_power(15000000, 60000, 10)
```

```
Provided data: Distance between dipole = 10 m, frequency = 60 MHz, Transmitted power = 15 Watt.
The received power by the receiving dipole = 0.064 Watt

Provided data: Distance between dipole = 10 m, frequency = 60000 MHz, Transmitted power = 15 Watt.
The received power by the receiving dipole = 0.0 Watt

Provided data: Distance between dipole = 10 m, frequency = 60000 MHz, Transmitted power = 15000000 Watt.
The received power by the receiving dipole = 0.064 Watt
```