
MULTI-ANTENNA AND SIGNAL PROCESSING & MIMO COMMUNICATION

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(ICE – MASTERS)

Uniform Linear Array Beam Pattern Using Matlab

Beam pattern of a uniformly weighted linear array is given by the following equation:

$$B(f, \theta, \phi) = \frac{1}{M} \frac{\sin\left(\frac{\pi M \Delta \sin \theta}{\lambda}\right)}{\sin\left(\frac{\pi \Delta \sin \theta}{\lambda}\right)} \dots\dots\dots \text{Eq.1}$$

Where Δ = distance between adjacent sensors of the array
M = Number of sensors in the array
 λ = wavelength of the signal
 θ = angle made by the unit vector of plane wave with the vertical axis.

The analysis of the beam pattern can be done using Matlab. Eq.1 is used to analyze the beam pattern of a uniformly weighted linear array.

In Matlab, *plot* command and *polar* command can be used to draw the beam pattern. The *Plot* command will draw the pattern in 2D in Cartesian coordinates. The *Polar* command will draw the pattern in 2D in Polar coordinates by taking the magnitude and angle in consideration.

In Eq.1, we can replace the term $\frac{\Delta \sin \theta}{\lambda}$ by f_s , where f_s is the spatial frequency.

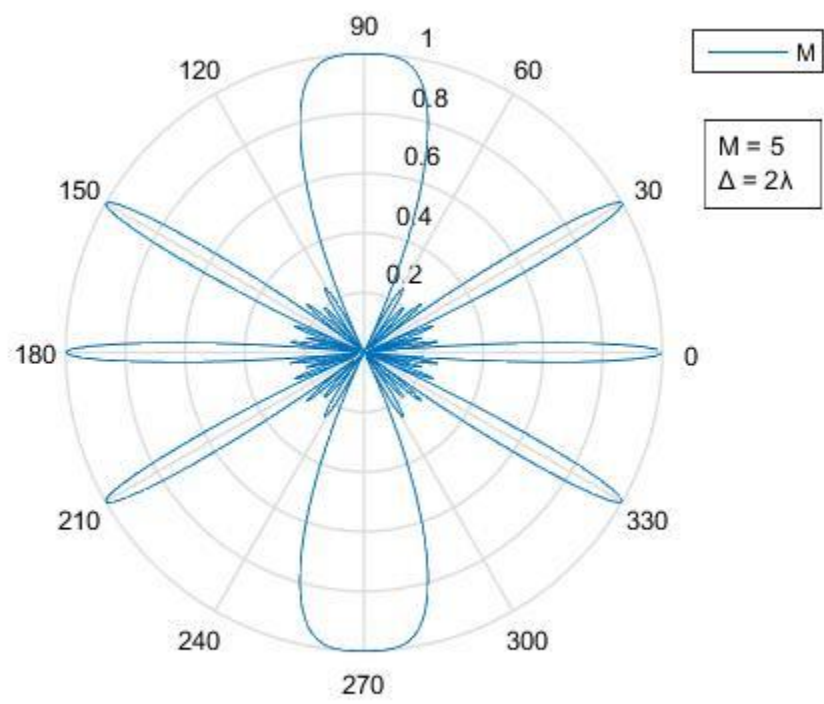
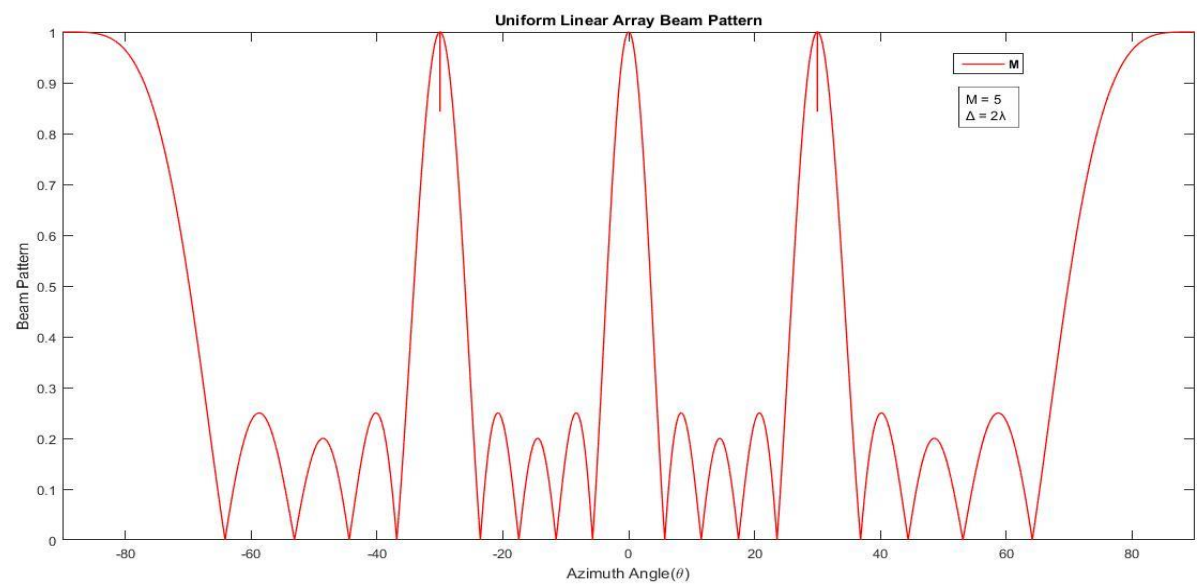
After replacing $\frac{\Delta \sin \theta}{\lambda}$ by f_s Eq.1 becomes

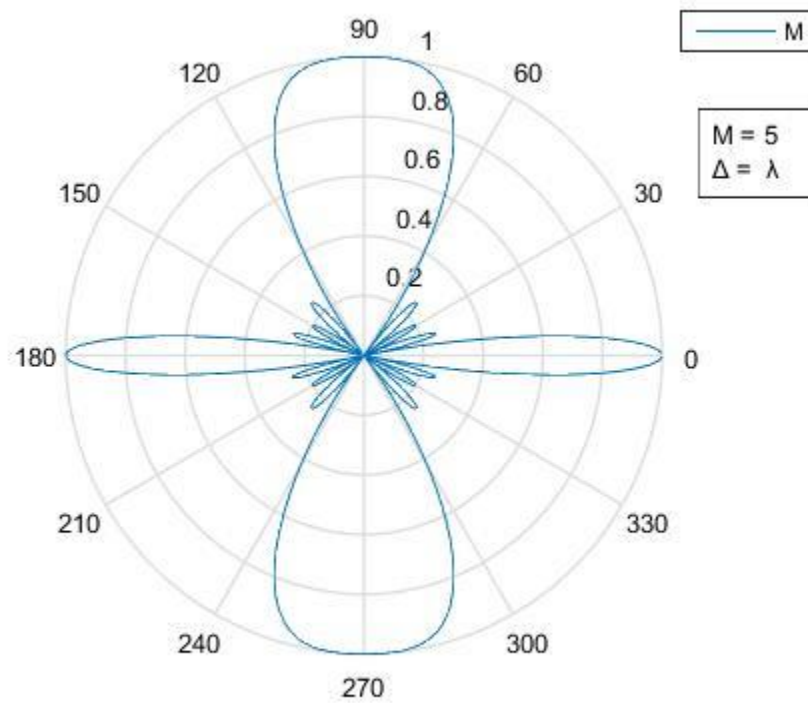
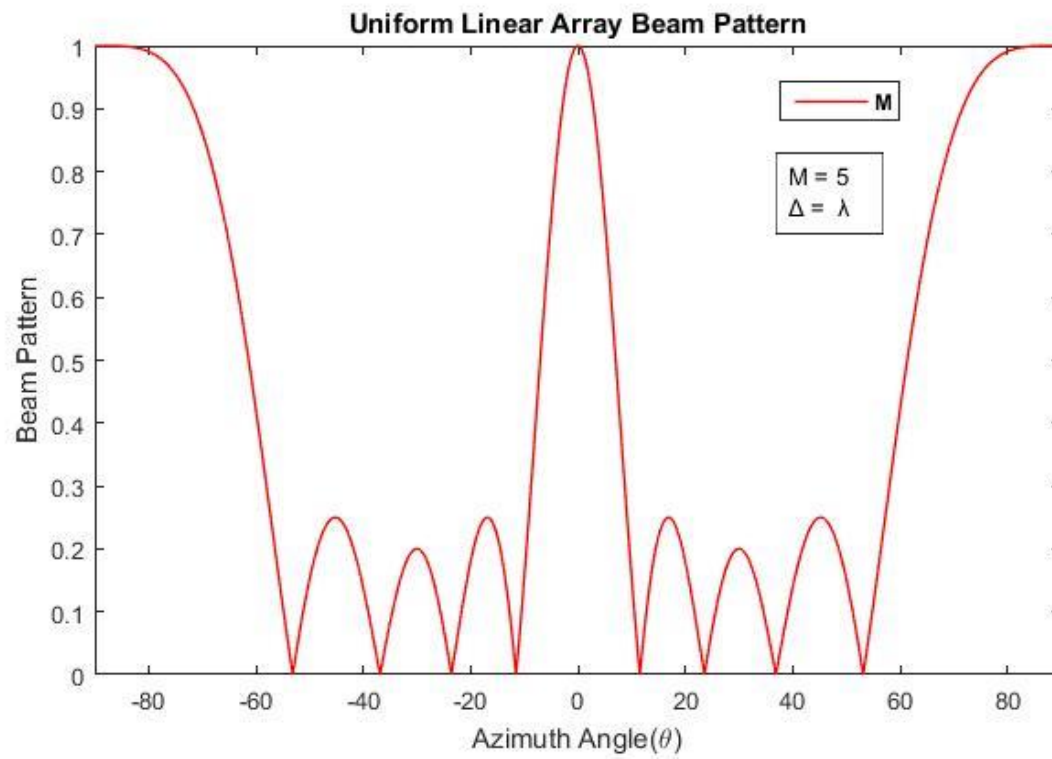
$$B(f, \theta, \phi) = \frac{1}{M} \frac{\sin(\pi M f_s)}{\sin(\pi f_s)} \dots\dots\dots \text{Eq.2}$$

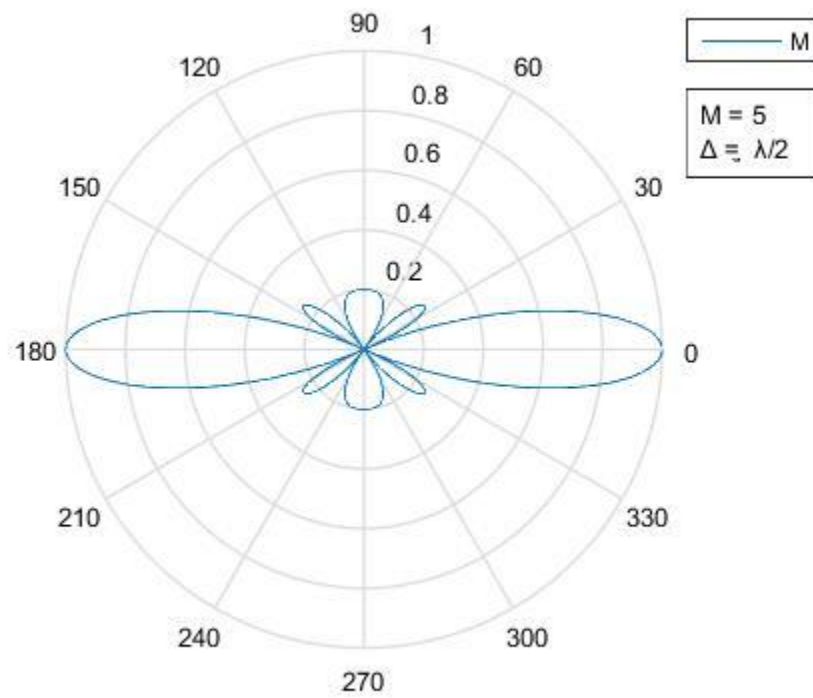
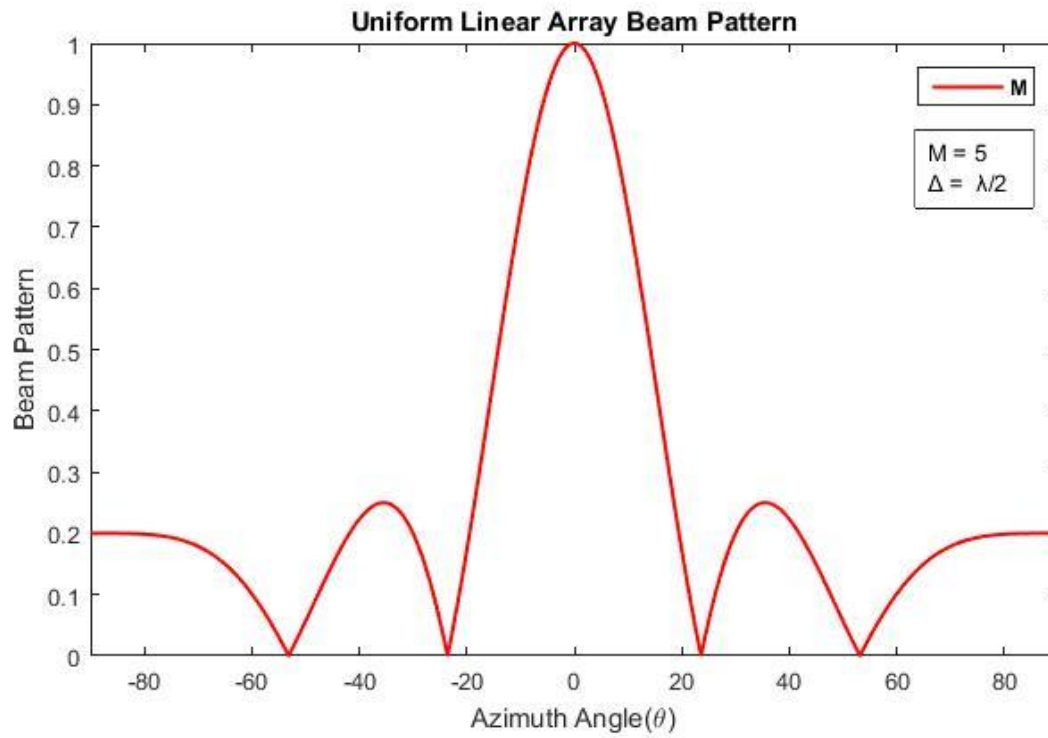
Beam pattern can also be analyzed using Eq.2.

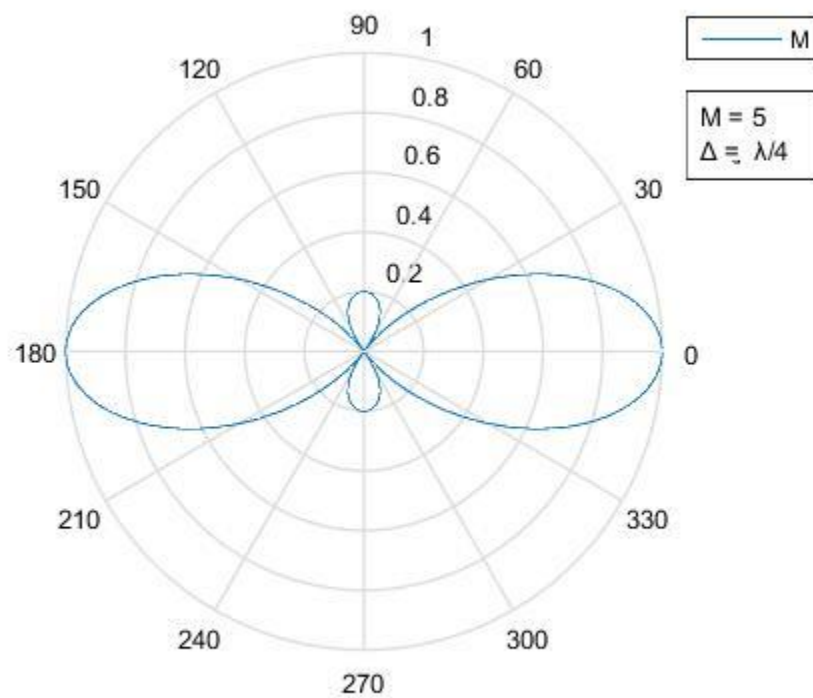
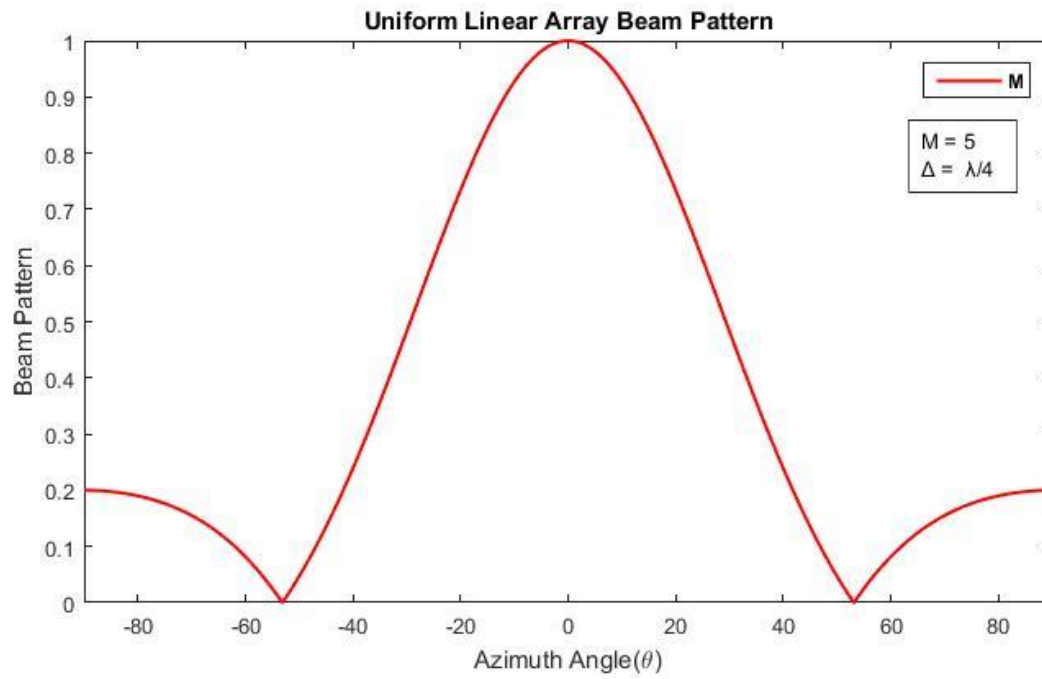
To analyze Eq.1 and Eq.2, **ula_pattern_analysis_1** and **ula_pattern_analysis_2** Matlab code files are used.

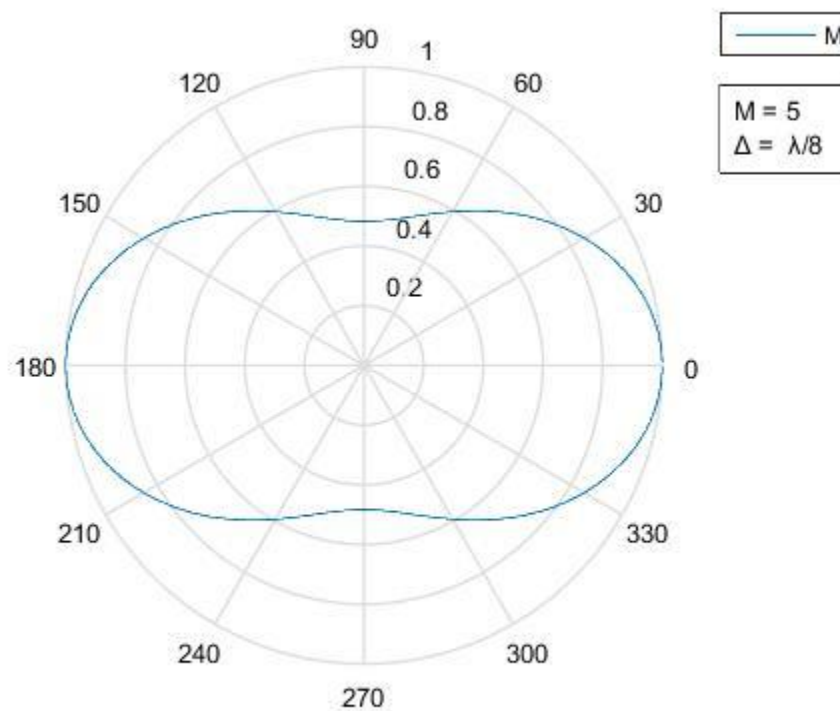
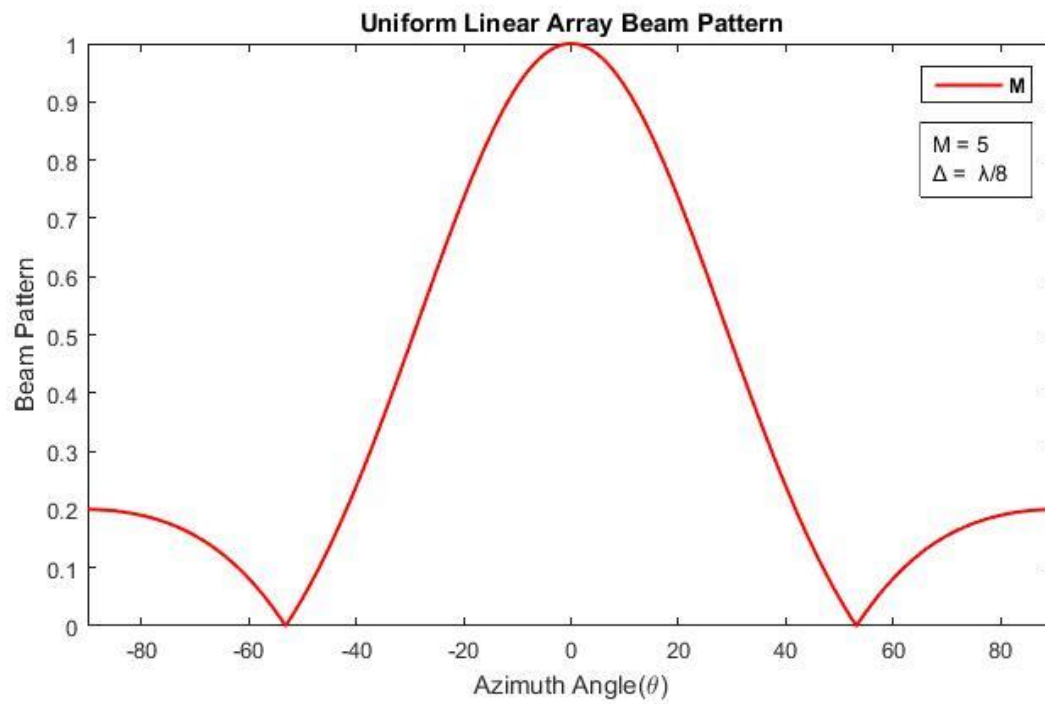
Beam Pattern for M = 10:



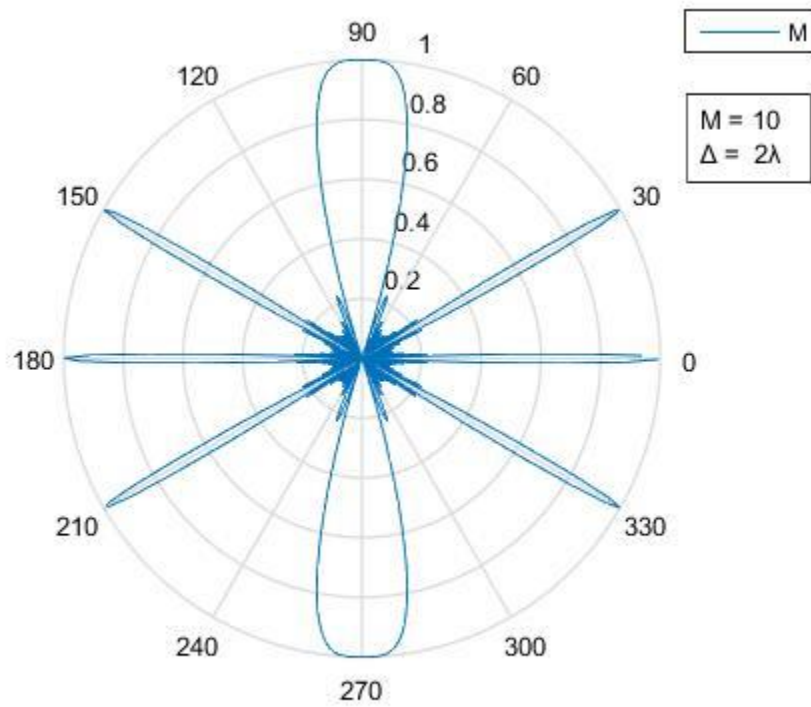
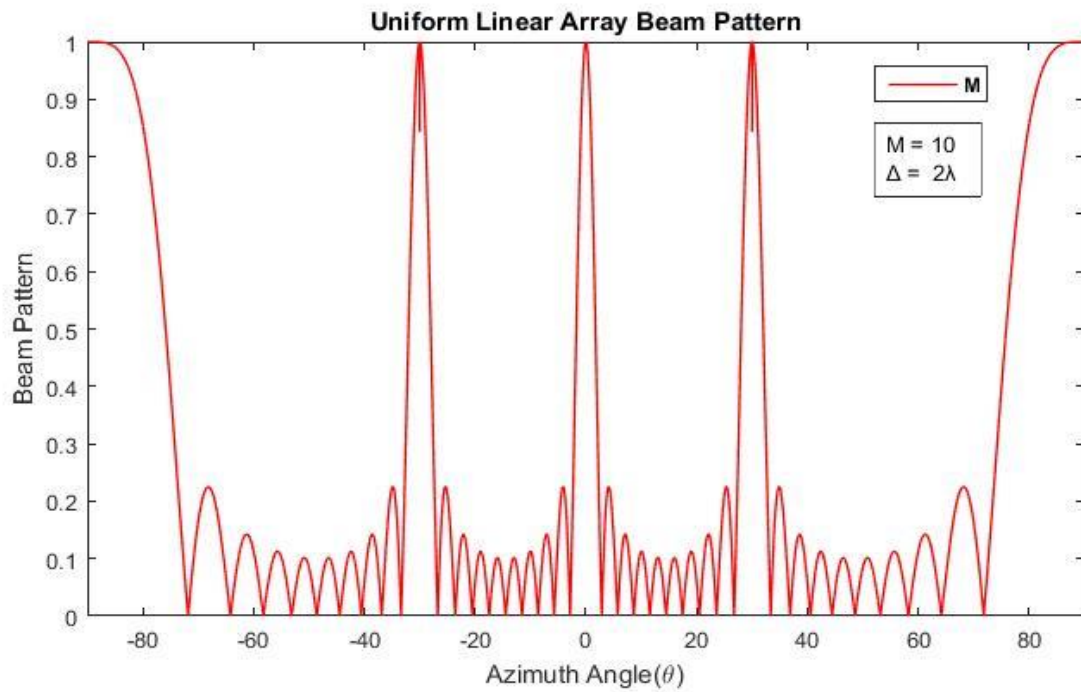


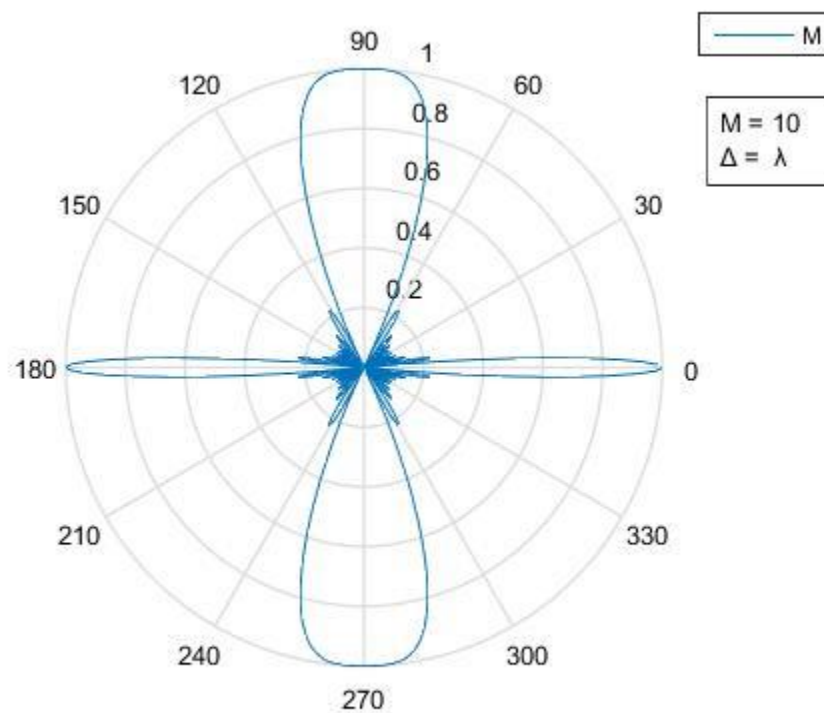
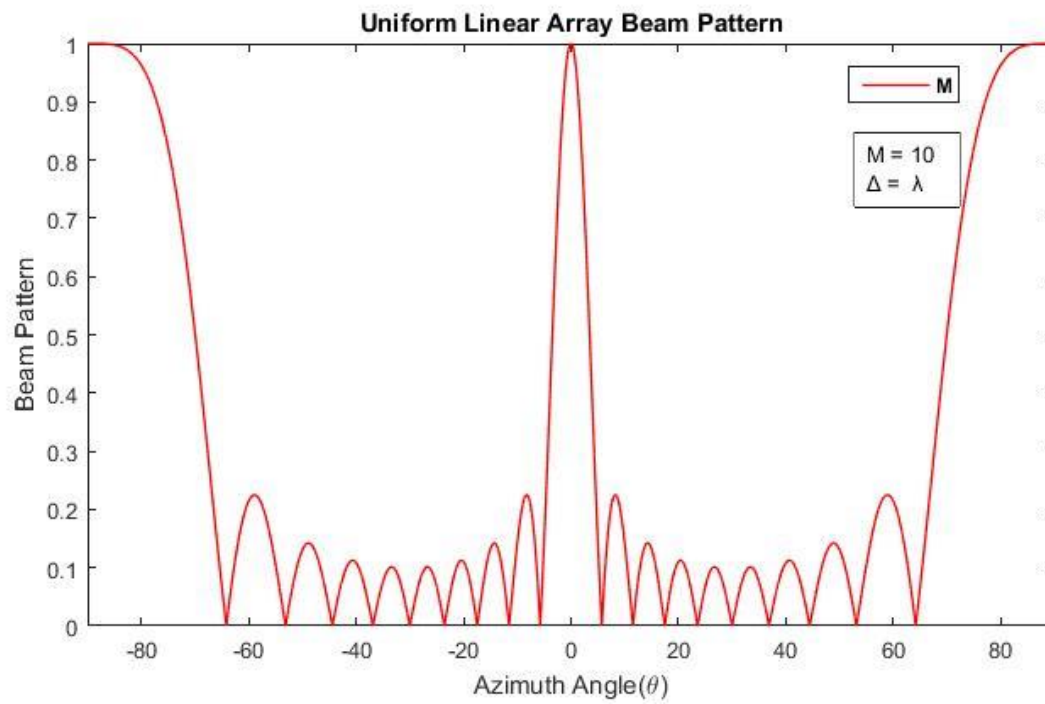


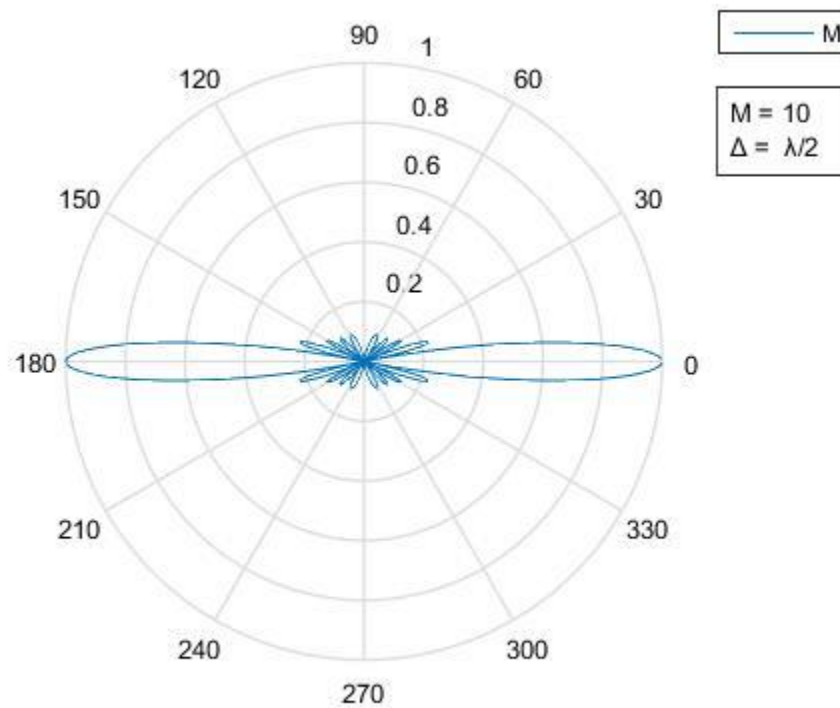
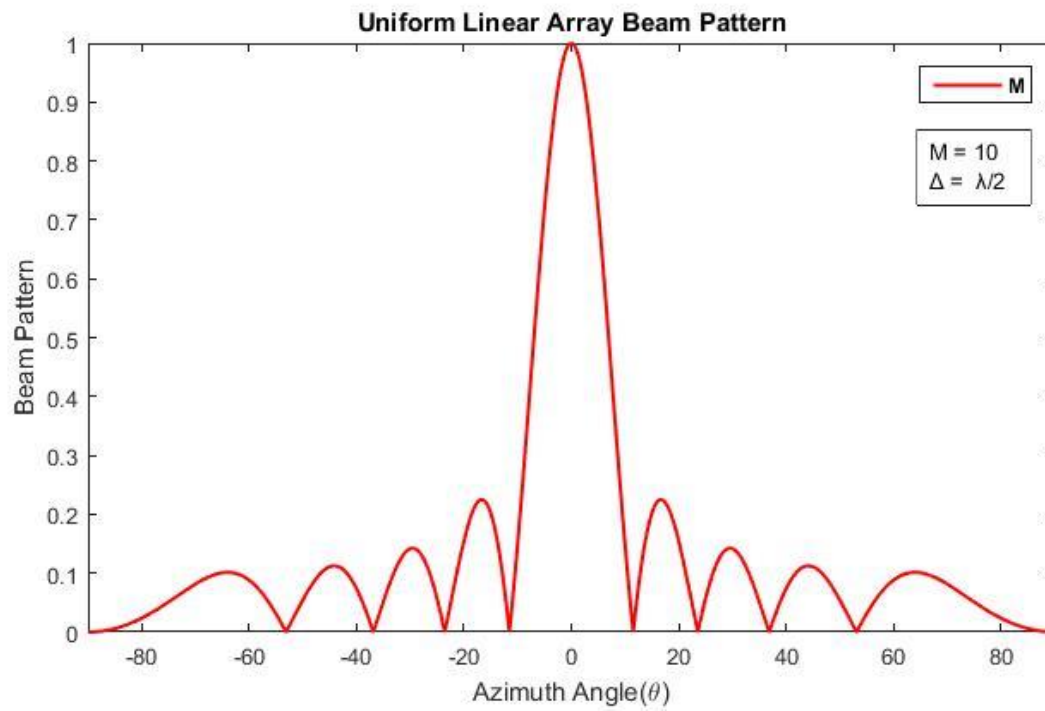


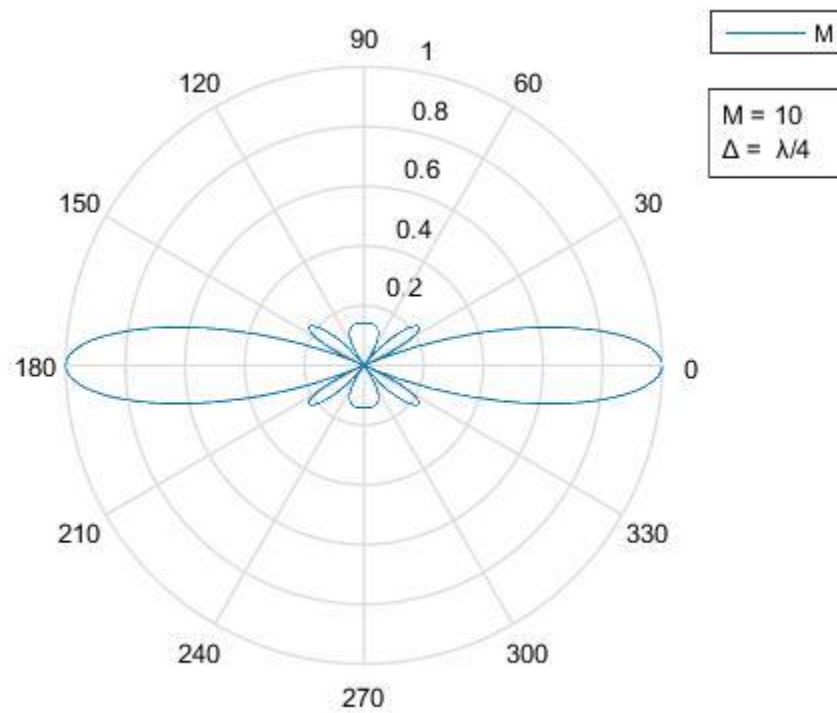
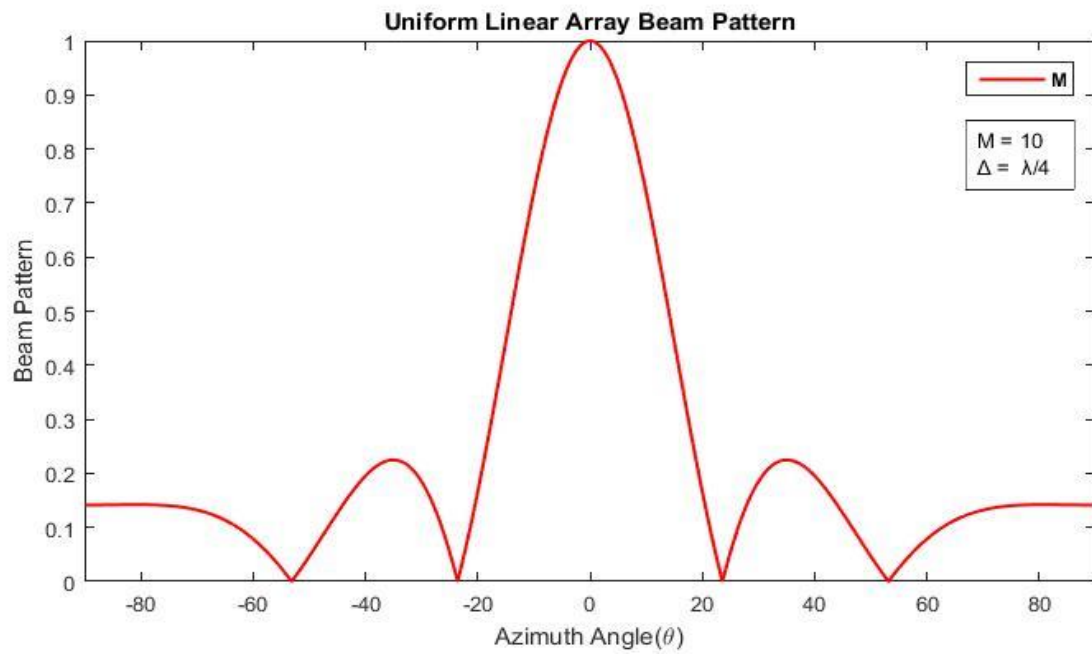


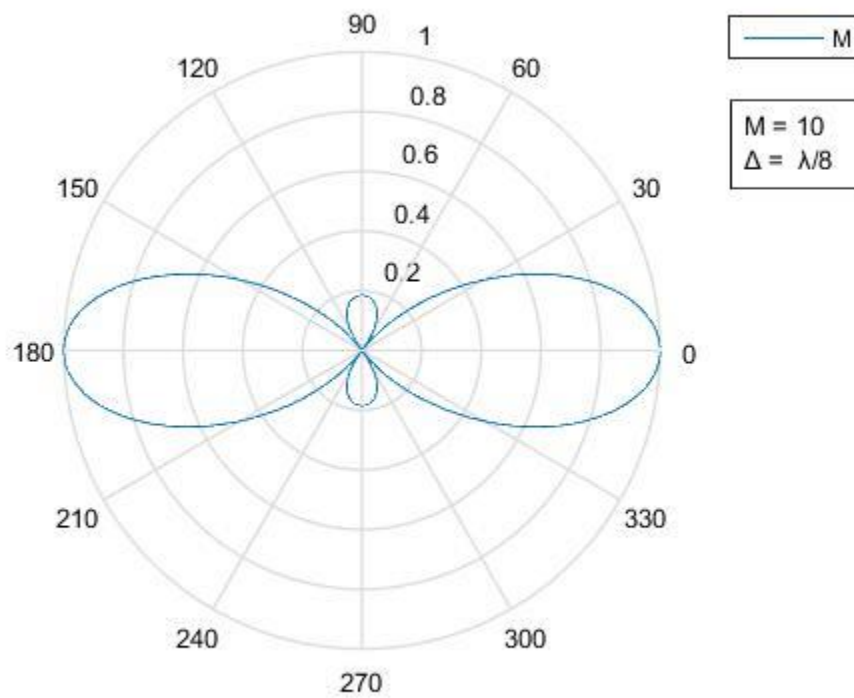
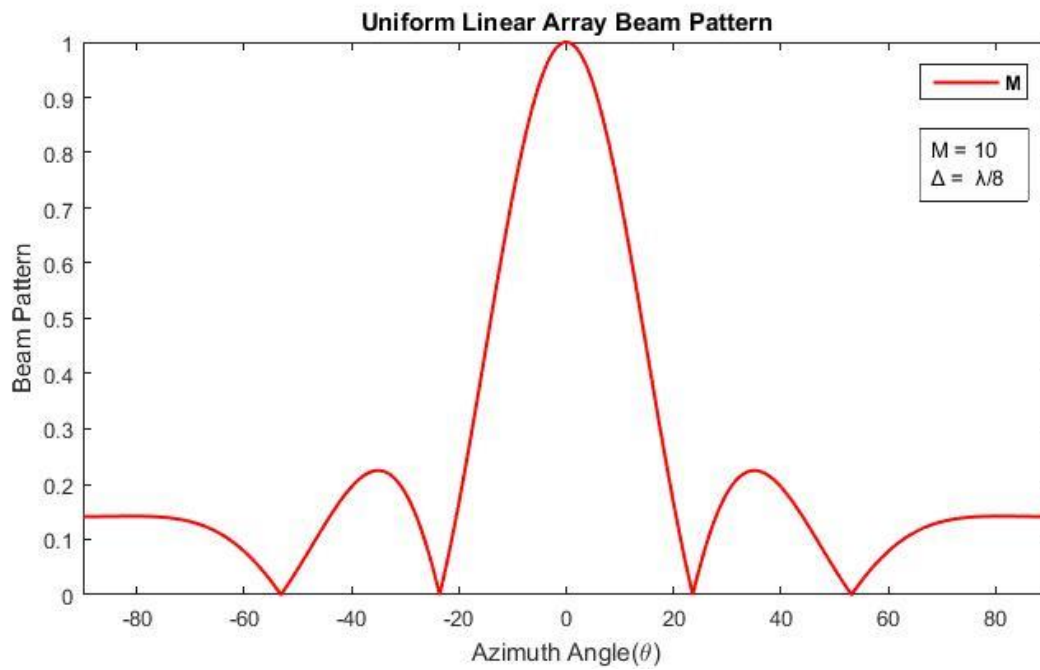
Beam Pattern for M = 10:



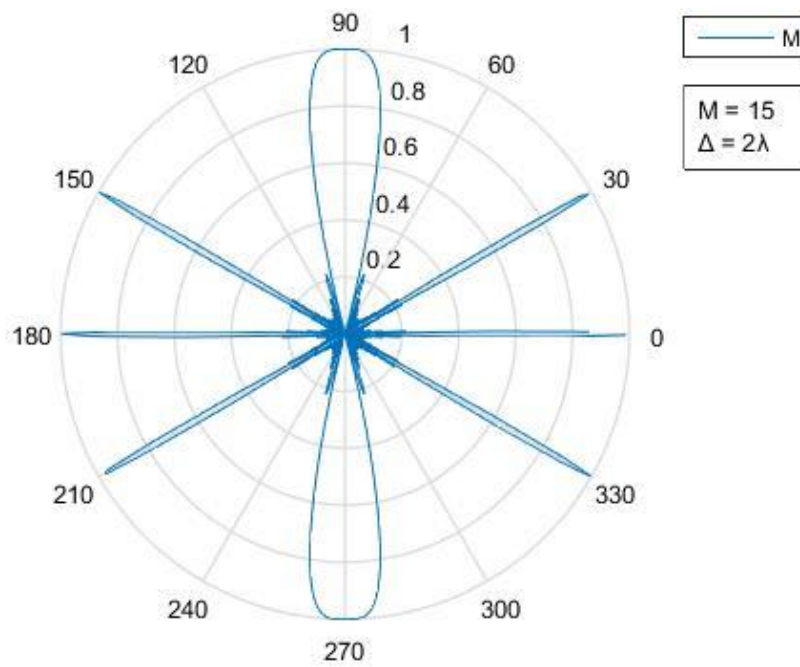
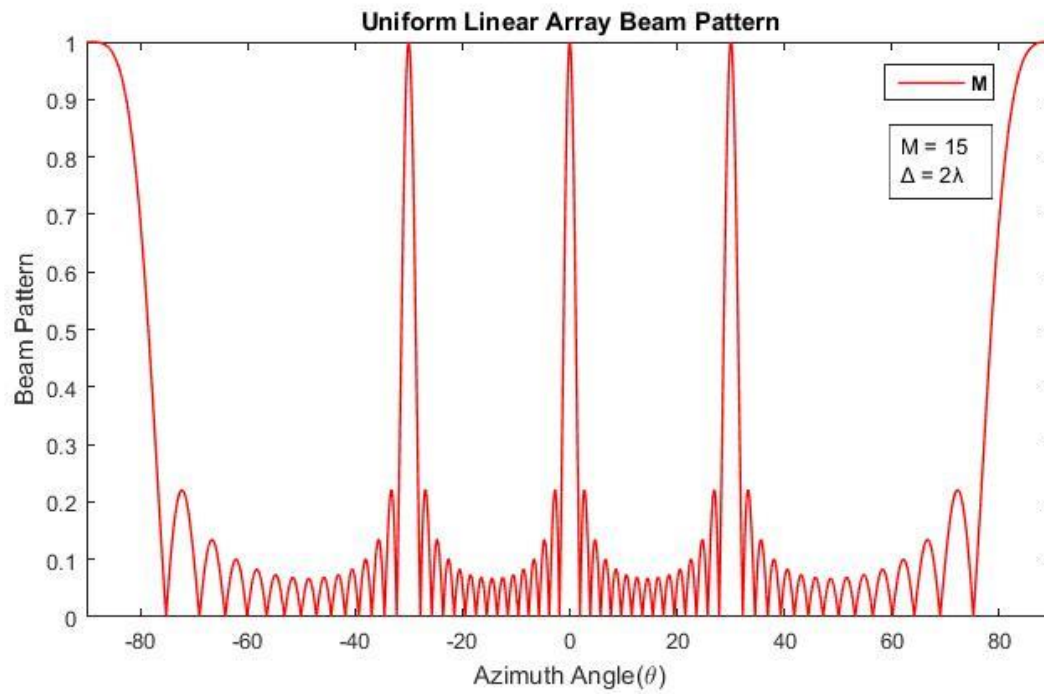


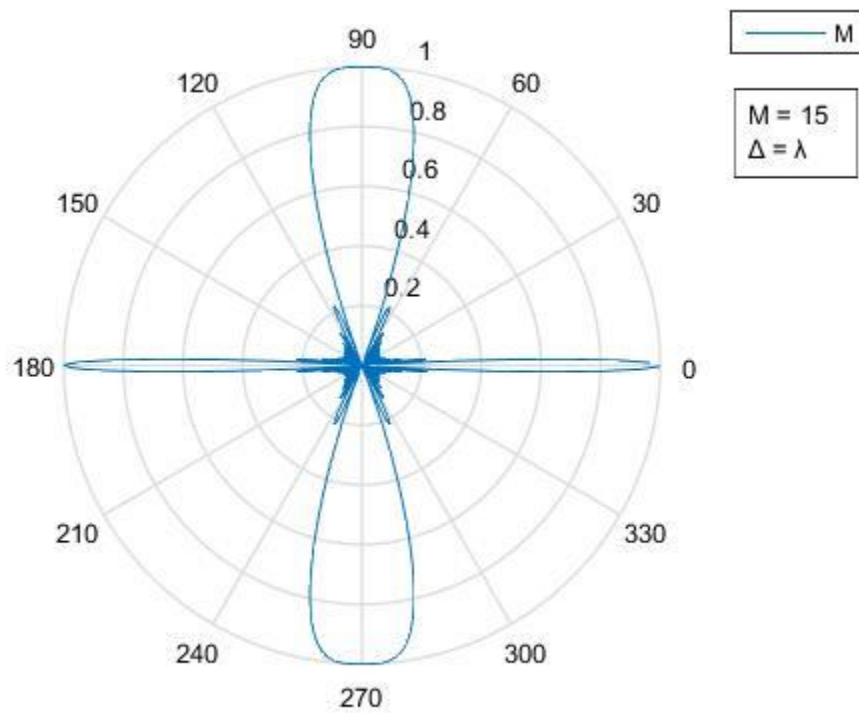
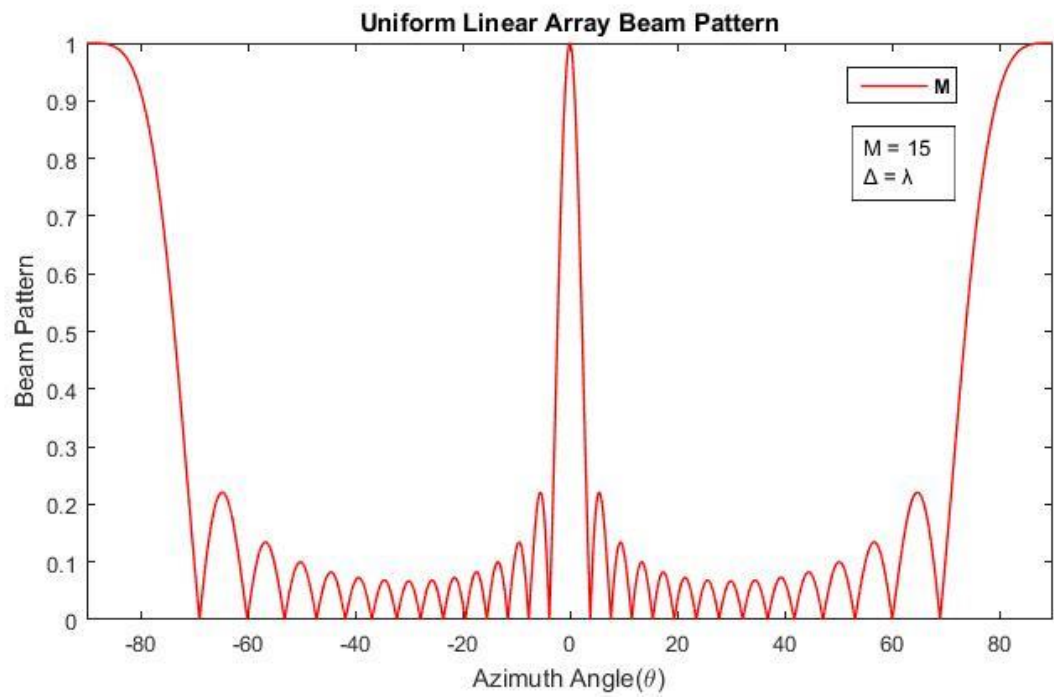


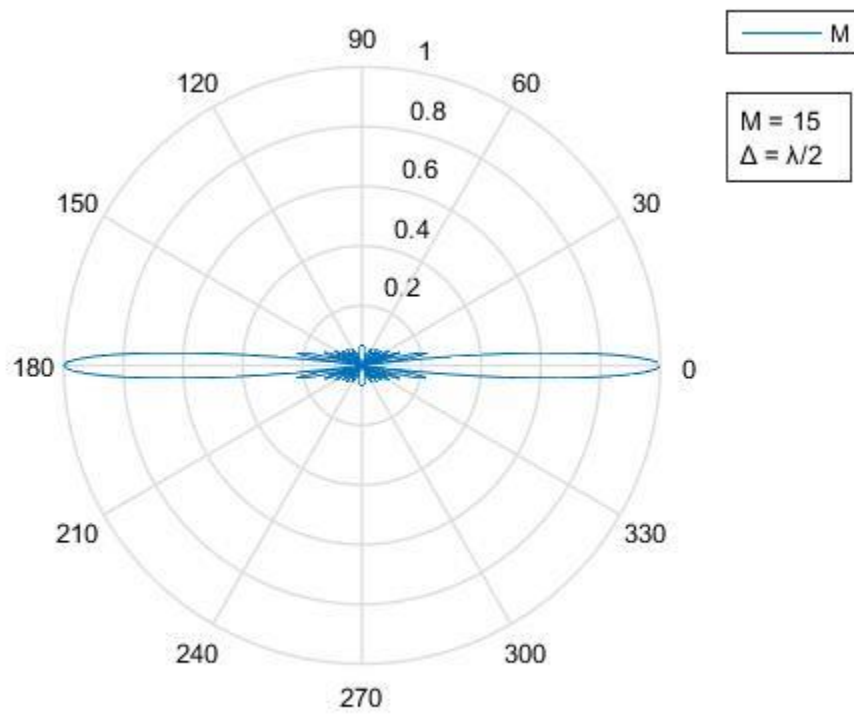
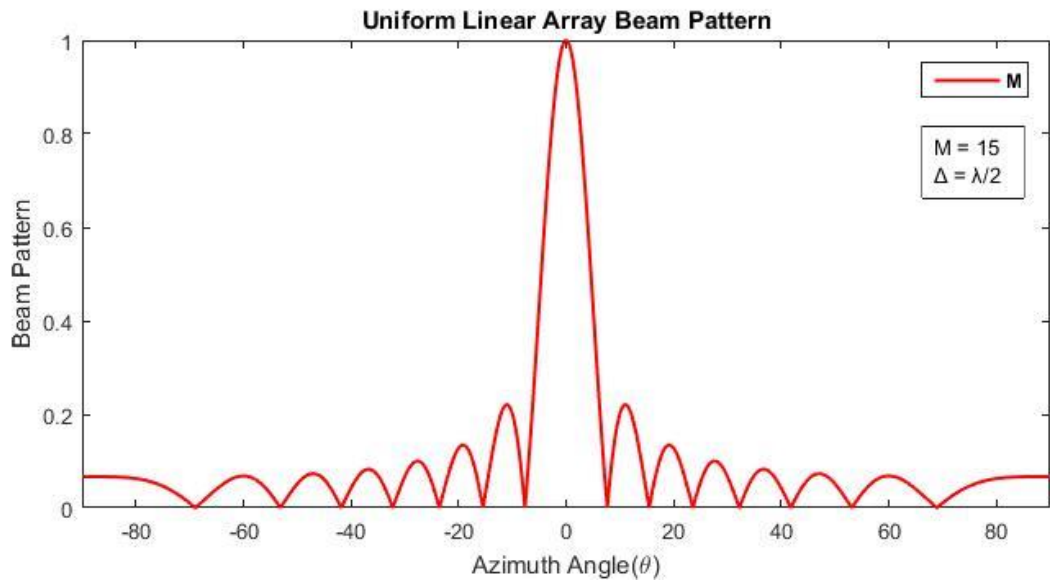


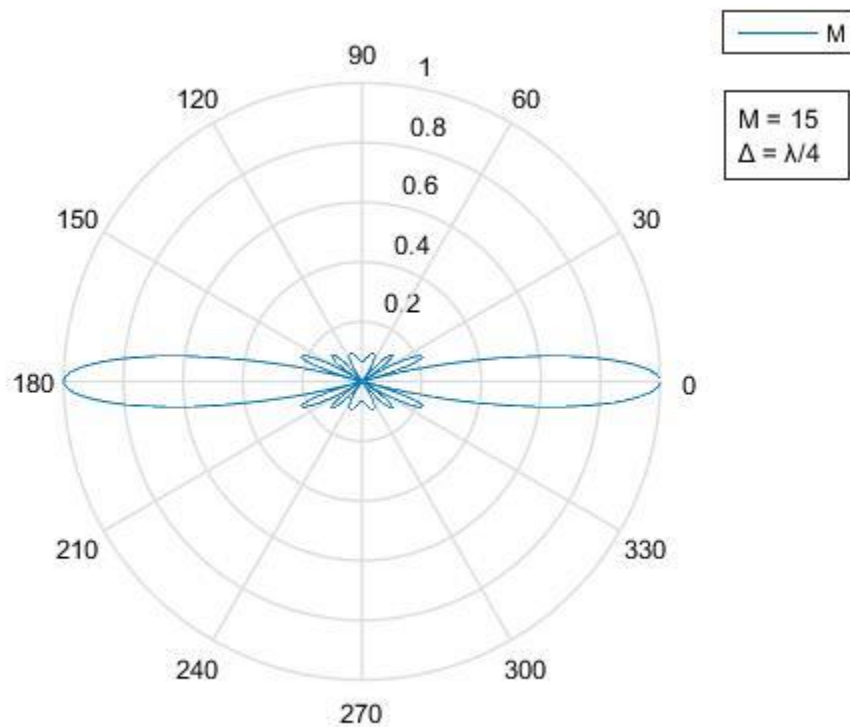
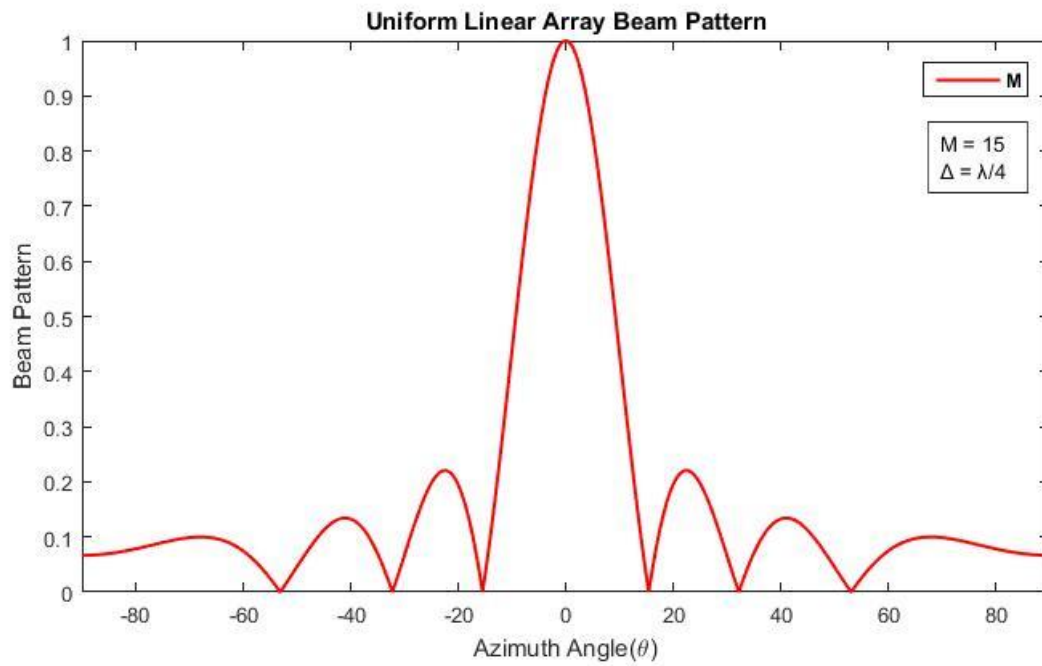


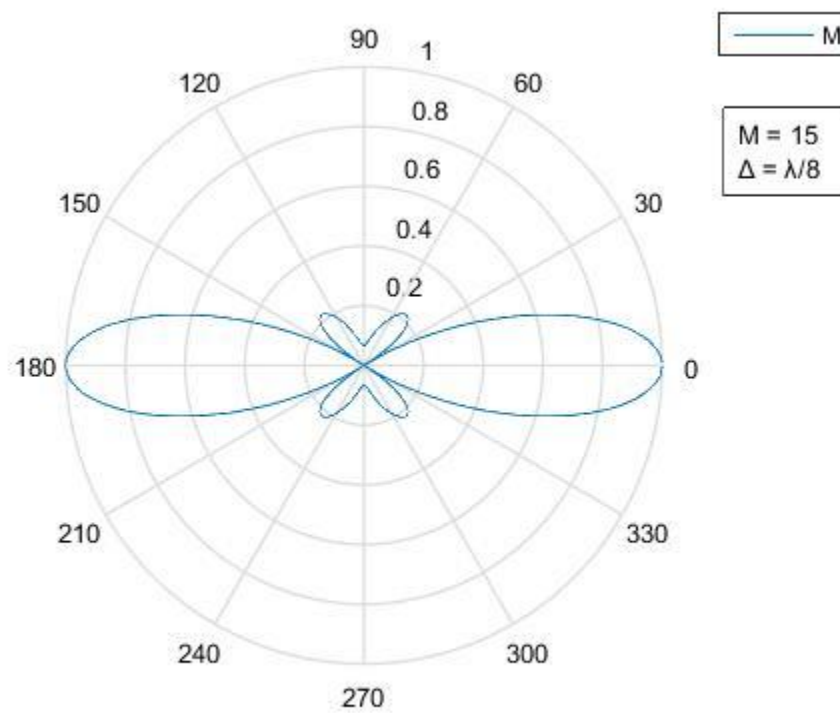
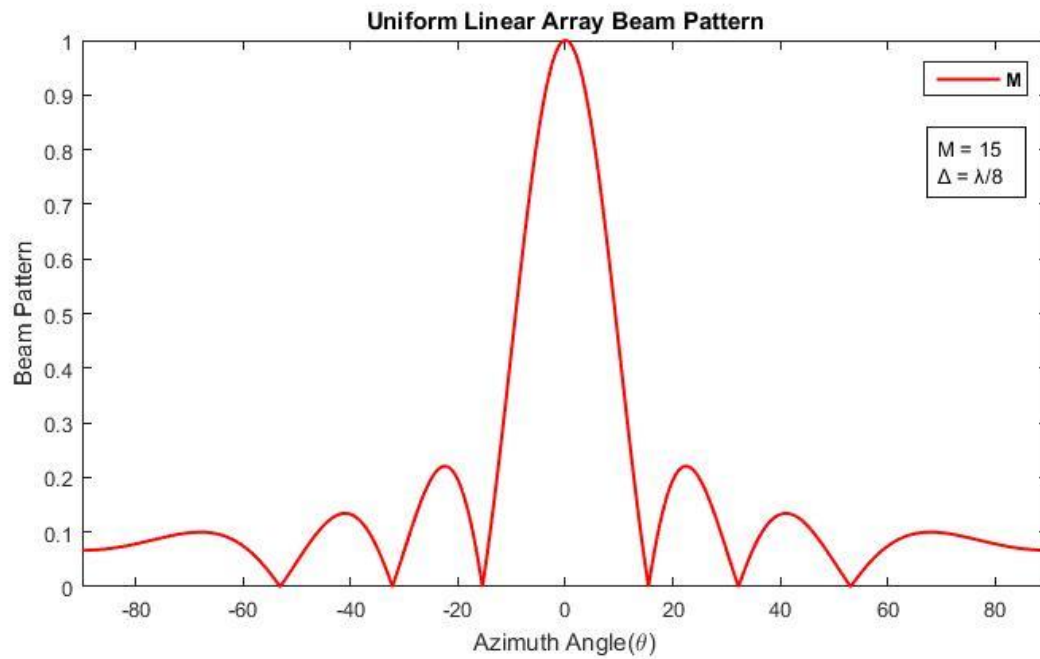
Beam Pattern for $M = 15$:



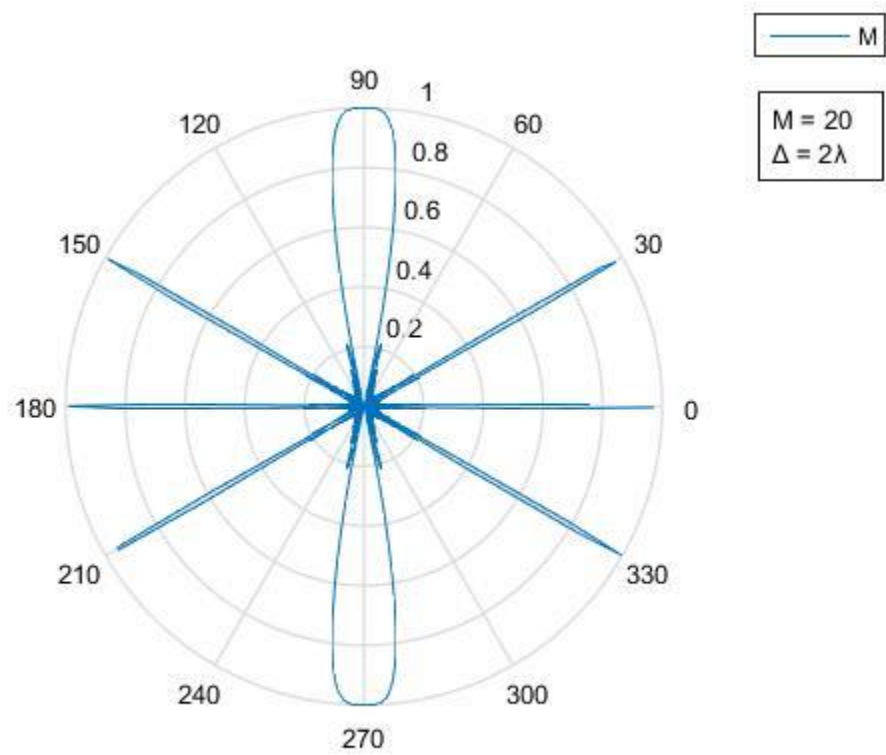
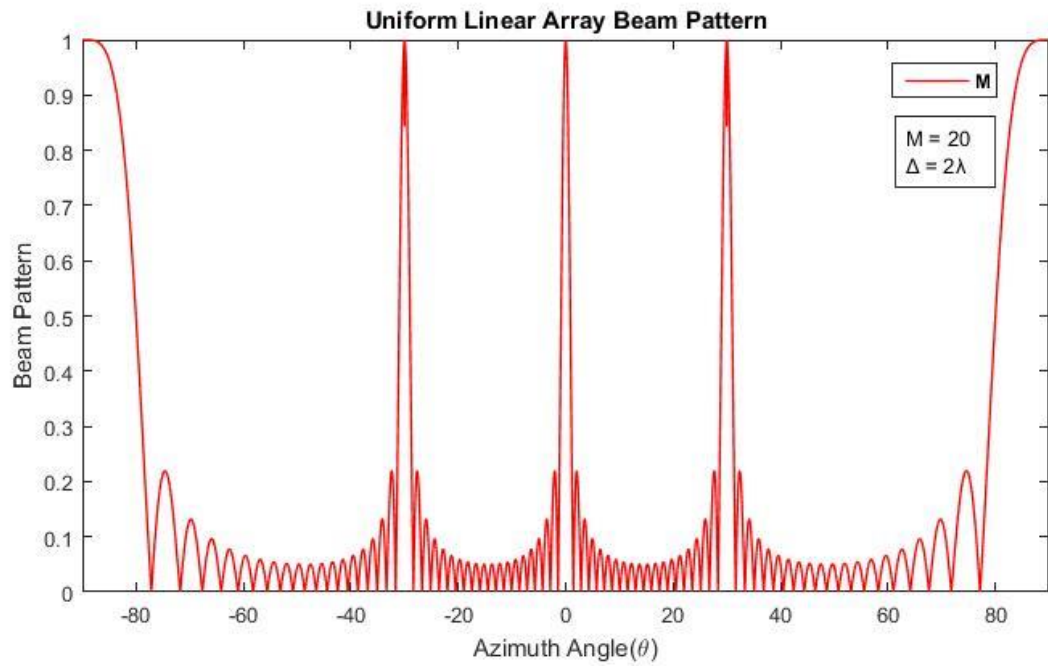


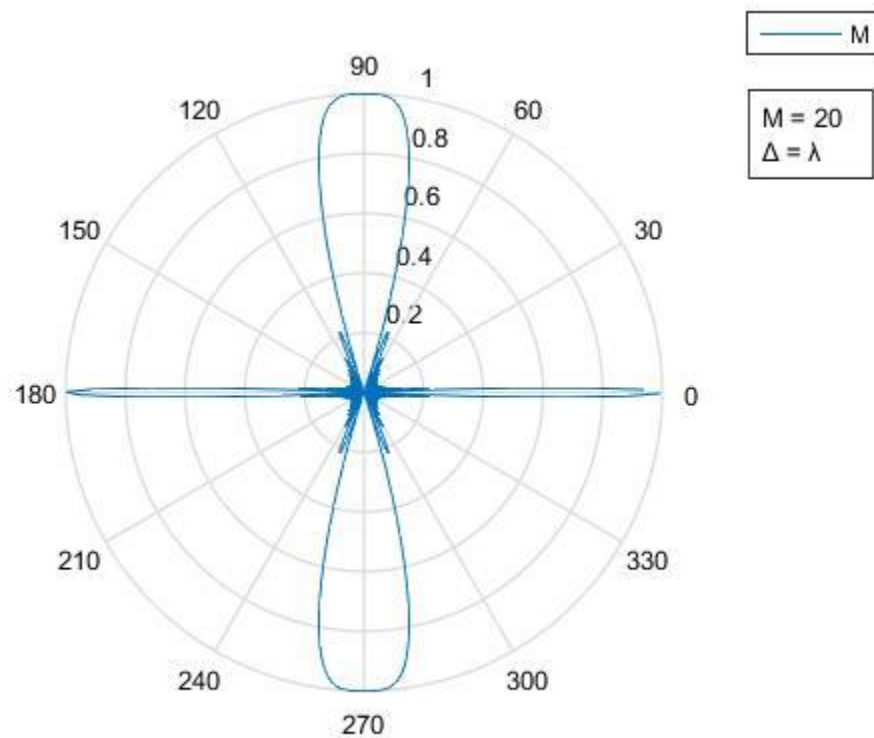
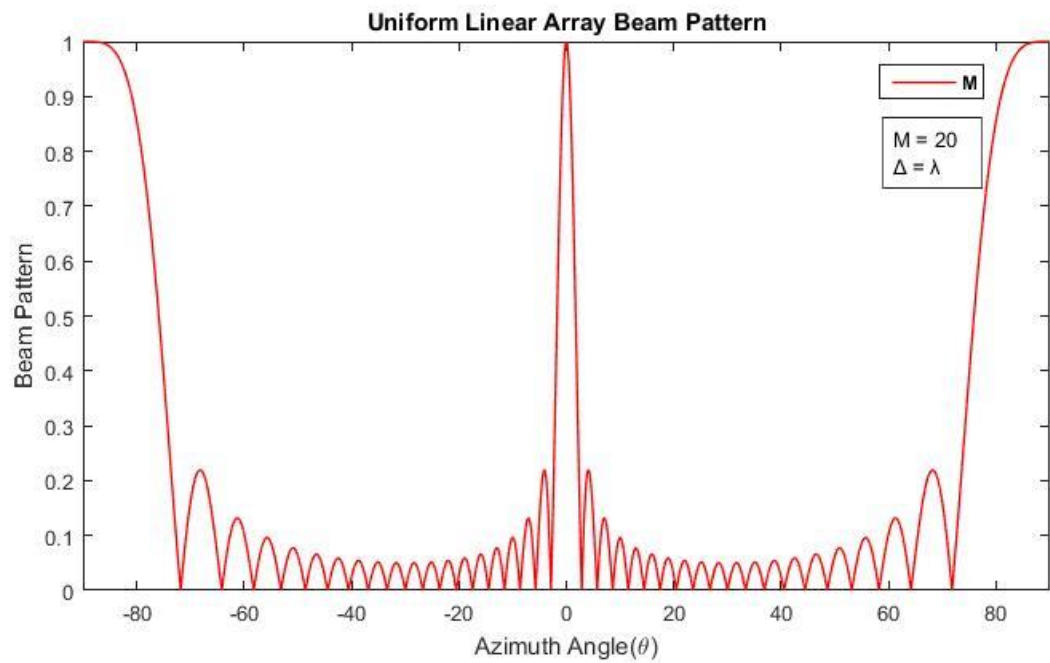


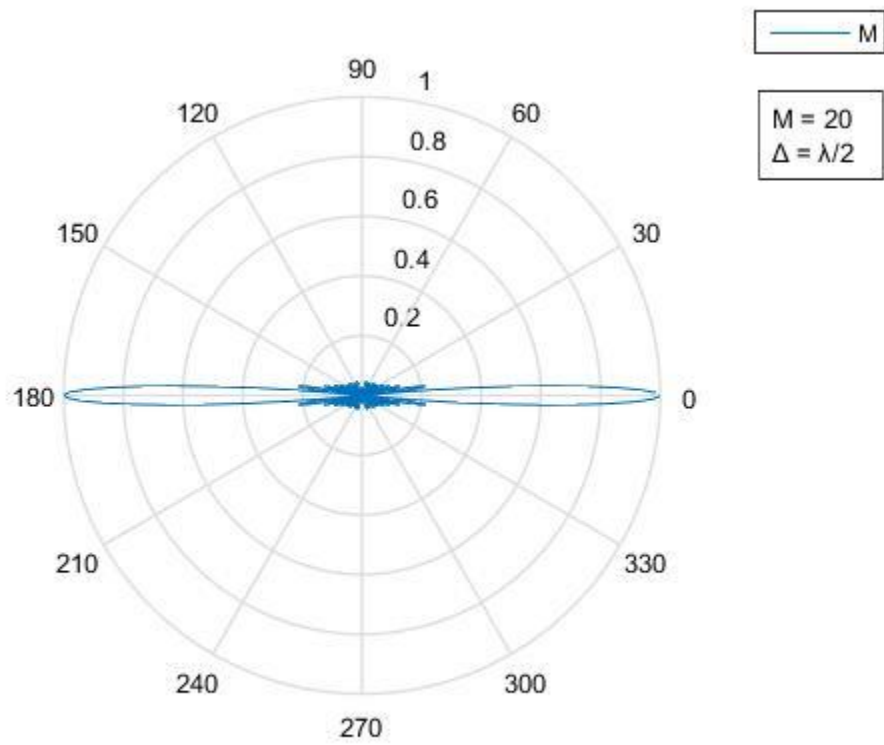
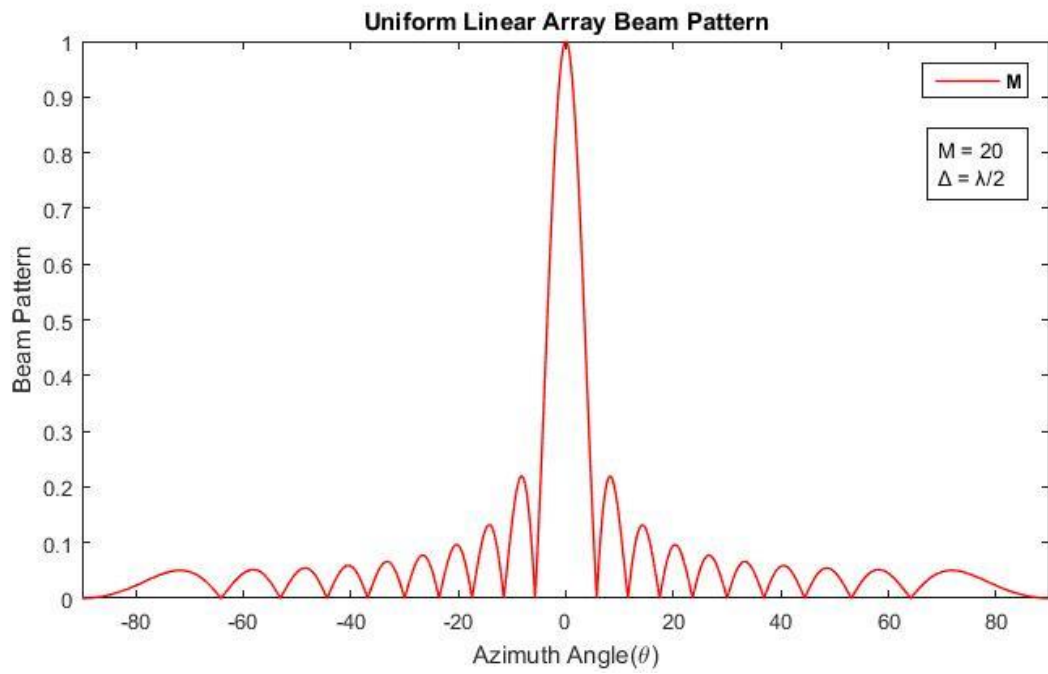


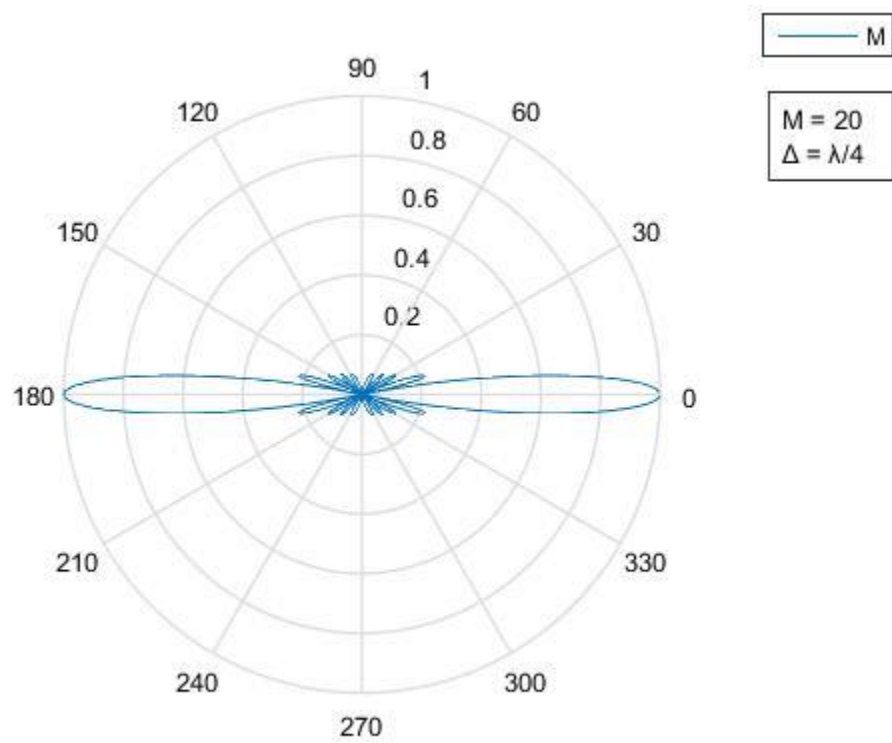
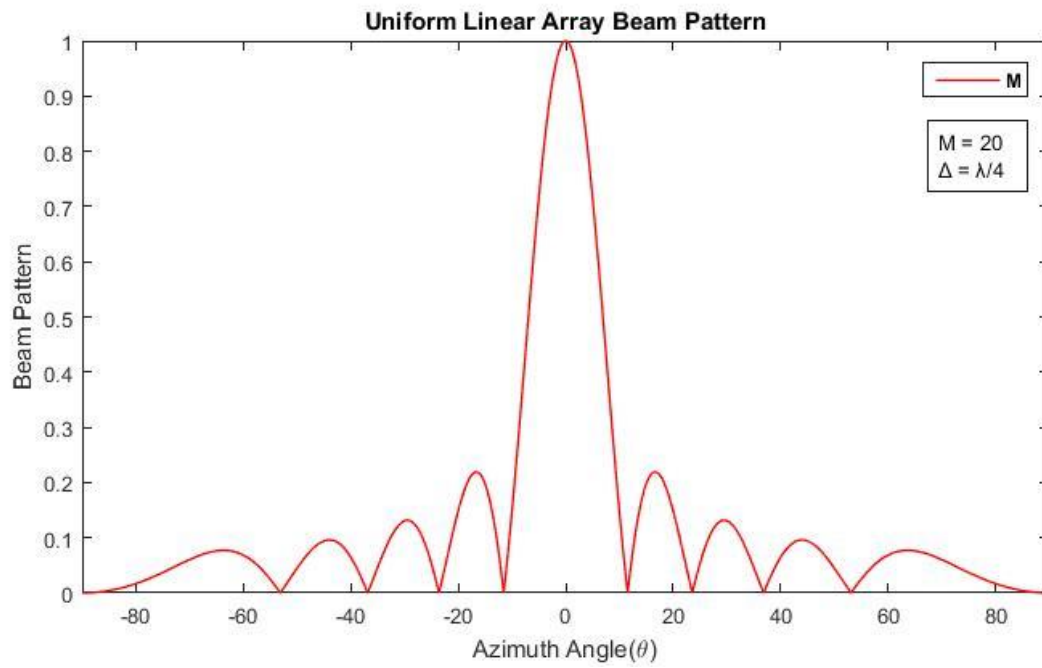


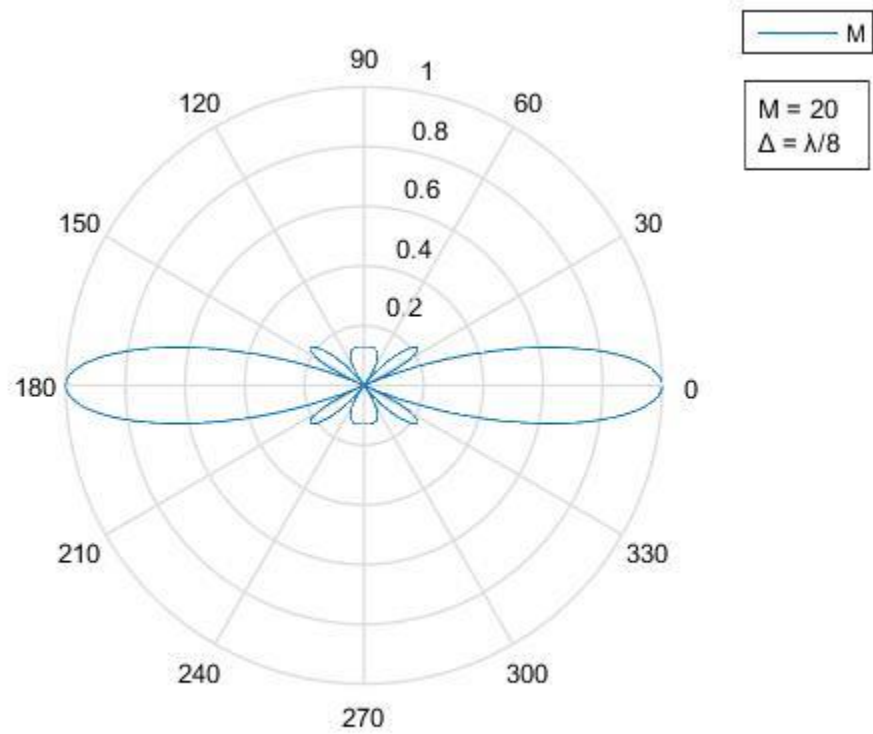
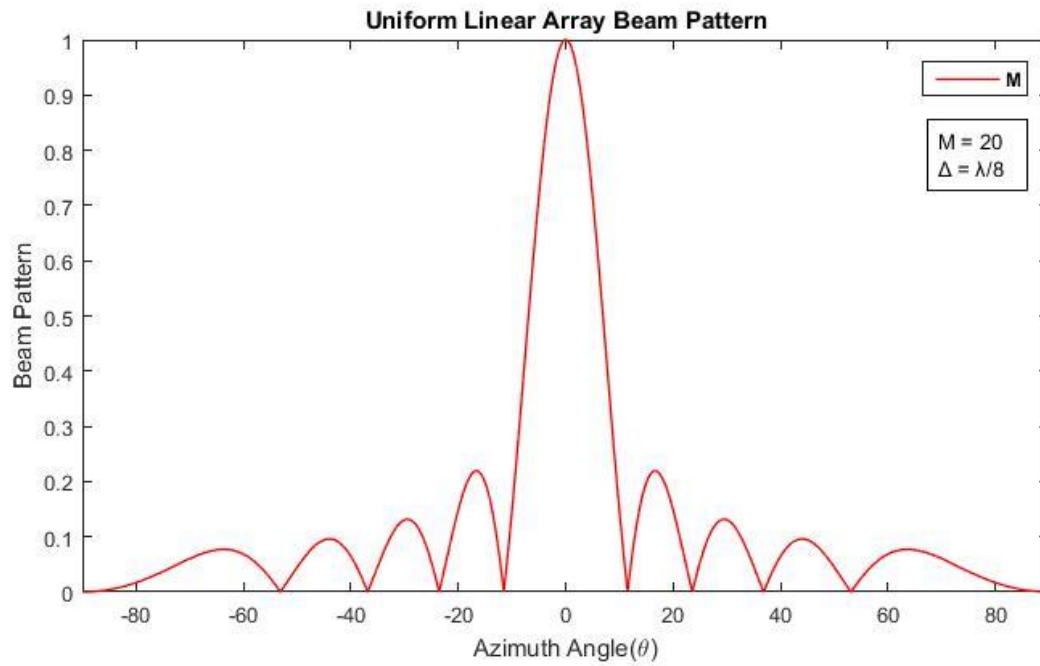
Beam Pattern for $M = 20$:









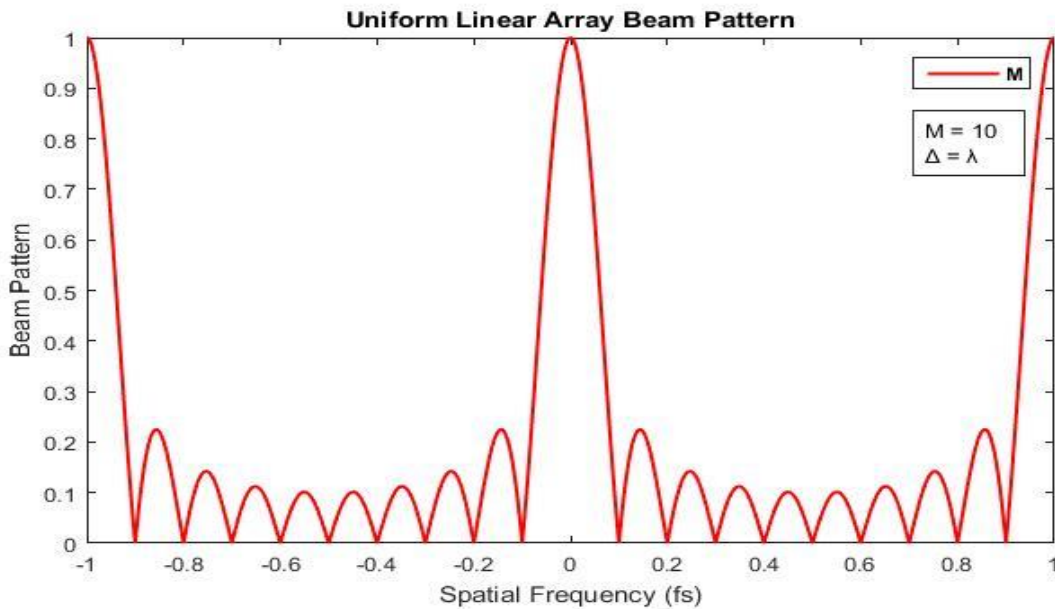
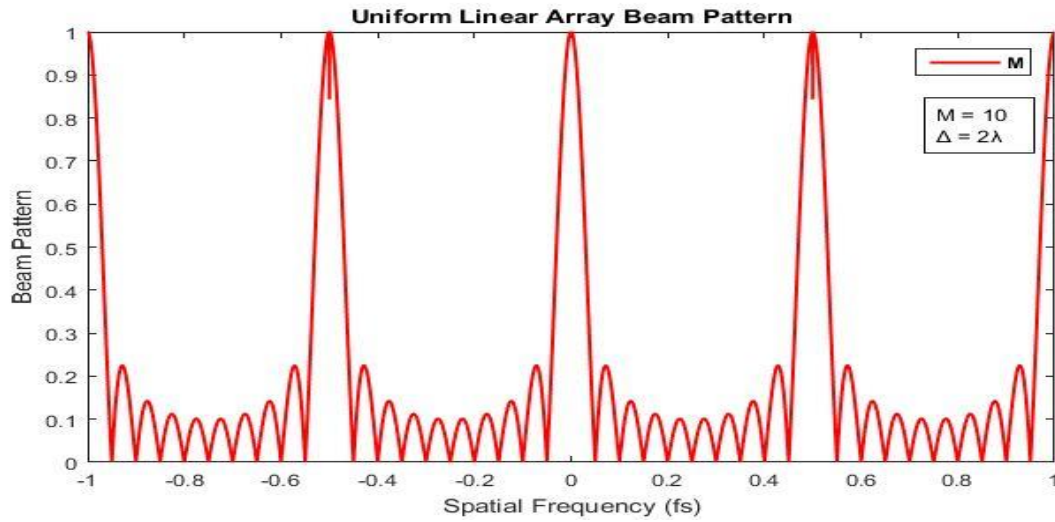


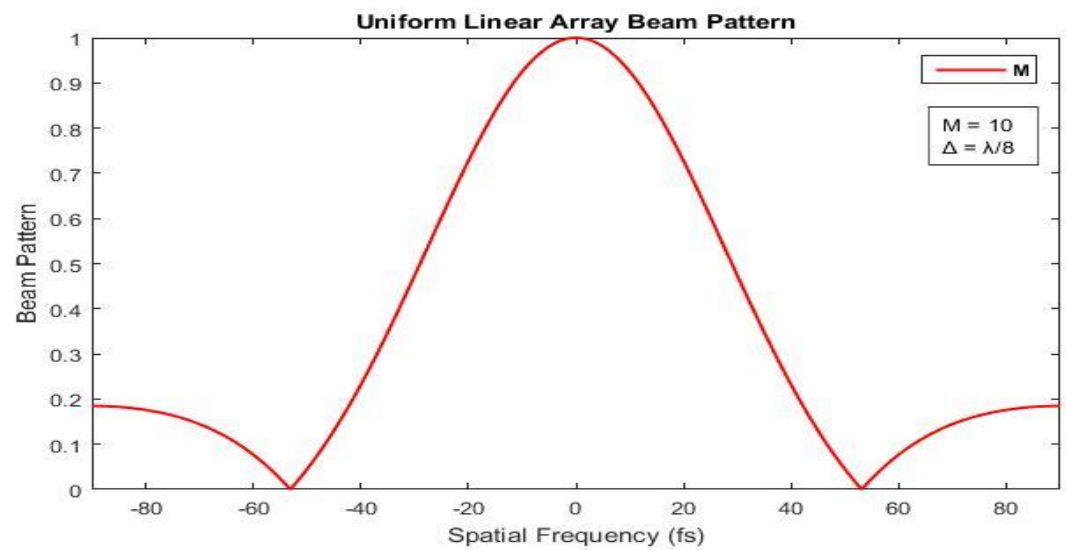
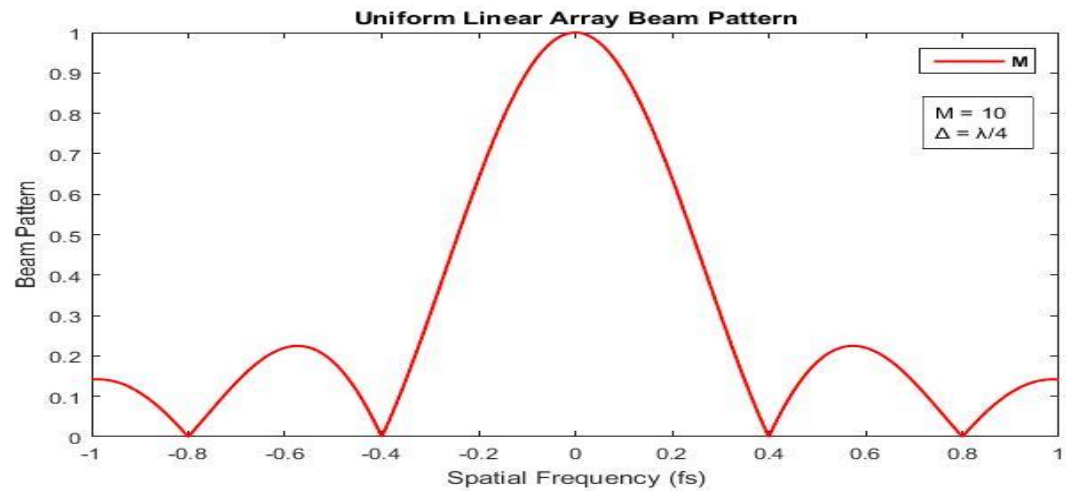
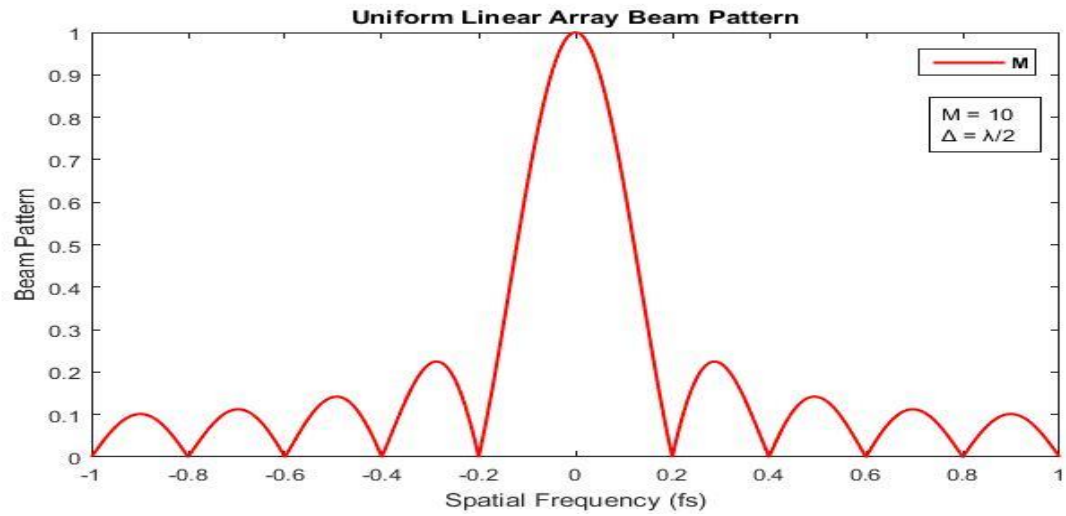
Analysis of Uniform Weighted Linear Array using Spatial Frequency

In Eq.1, we can replace the term $\frac{\Delta \sin \theta}{\lambda}$ by f_s , where f_s is the spatial frequency.

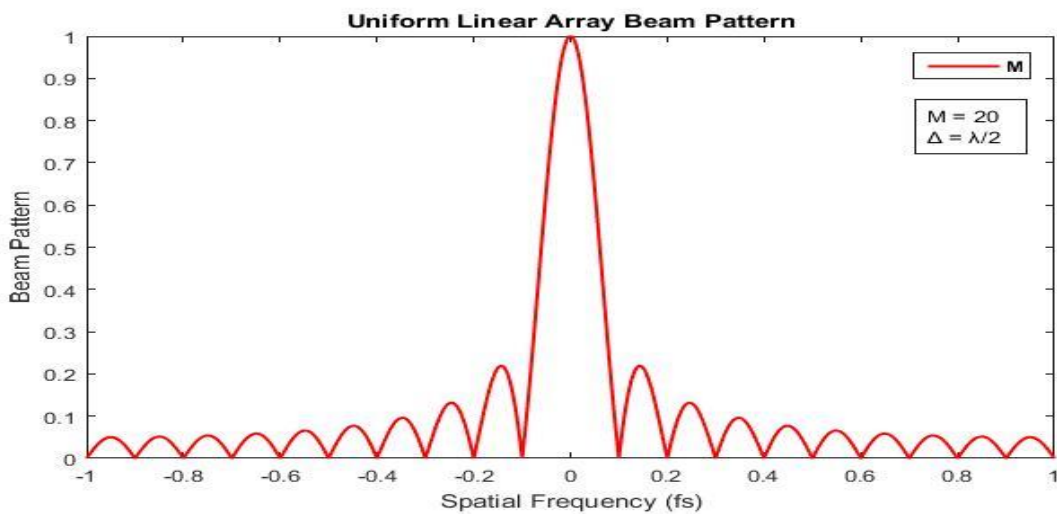
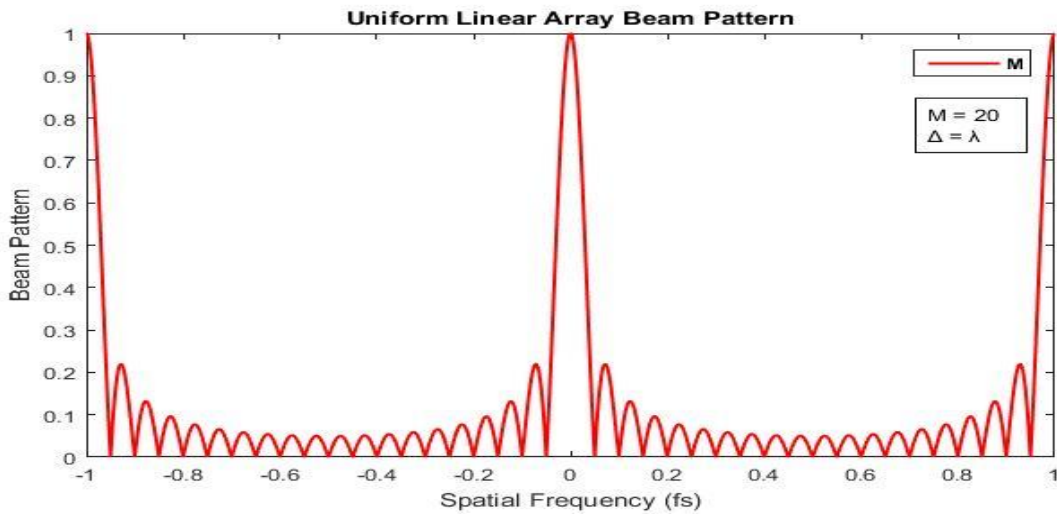
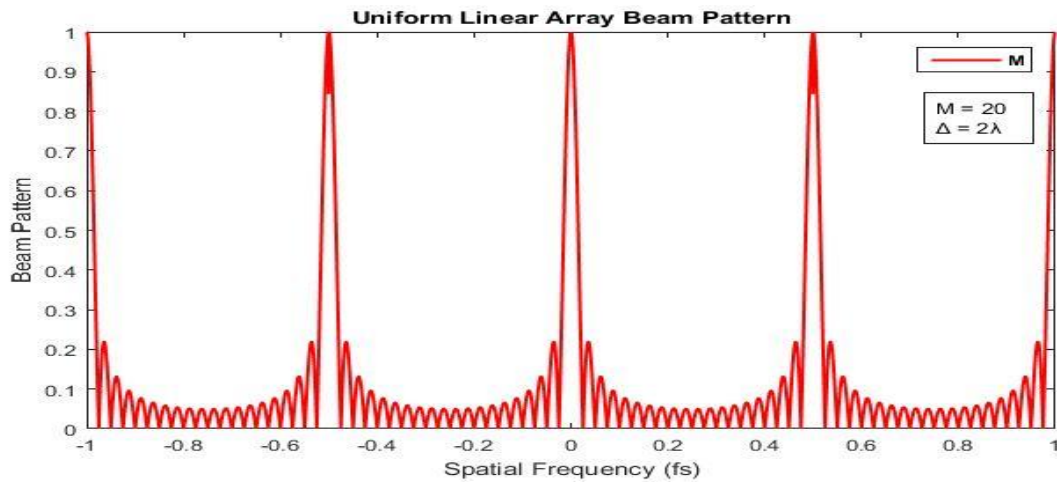
After replacing $\frac{\Delta \sin \theta}{\lambda}$ by f_s Eq.1 becomes $B(f, \theta, \phi) = \frac{1}{M} \frac{\sin(\pi M f_s)}{\sin(\pi f_s)}$

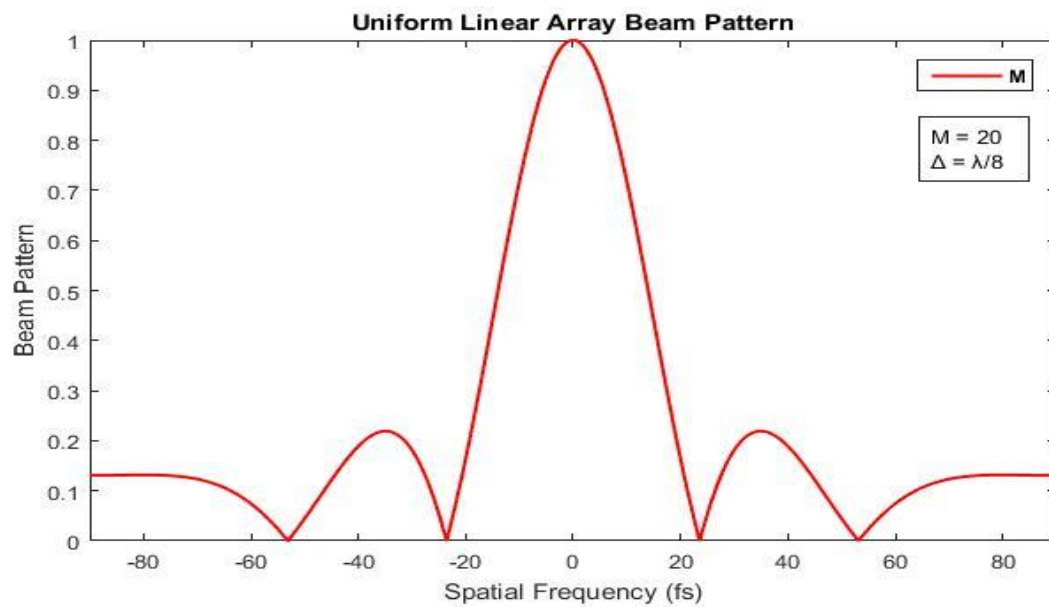
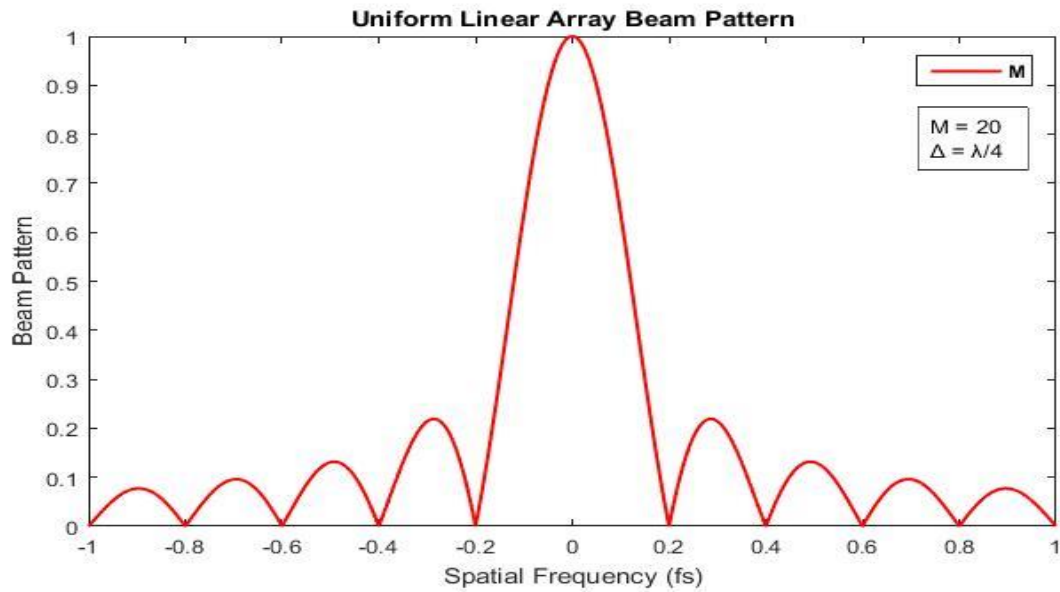
Beam Pattern for M = 10:





Beam Pattern for $M = 20$:





For fixed number of sensors, as the spacing between the sensors increases grating lobes appear in the pattern. When the sensor spacing is reduced then the grating lobe disappear from the pattern.

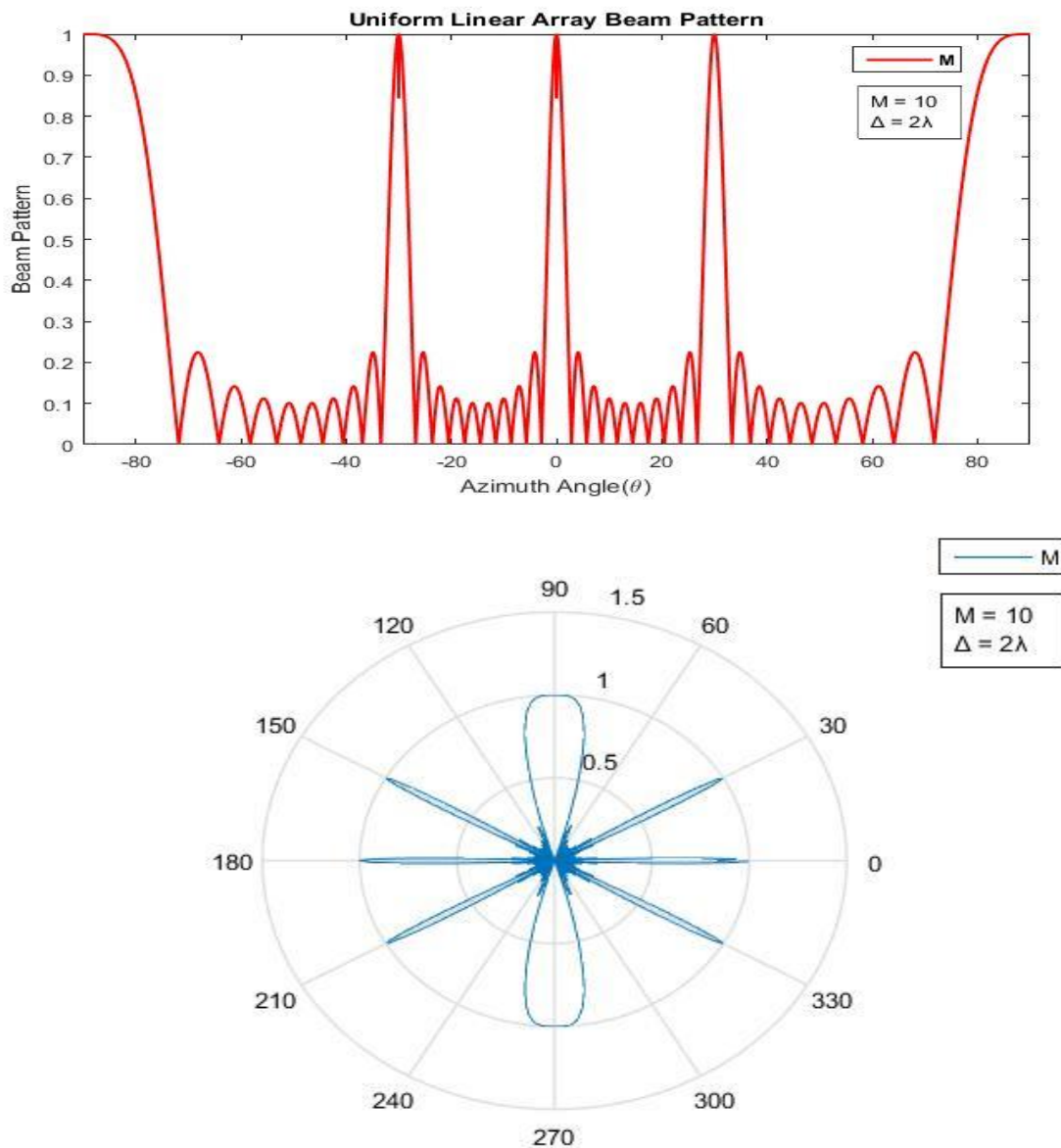
Array steering technique used to change the angle of the response of the array. Electronic array steering technique is preferably used over mechanical steering.

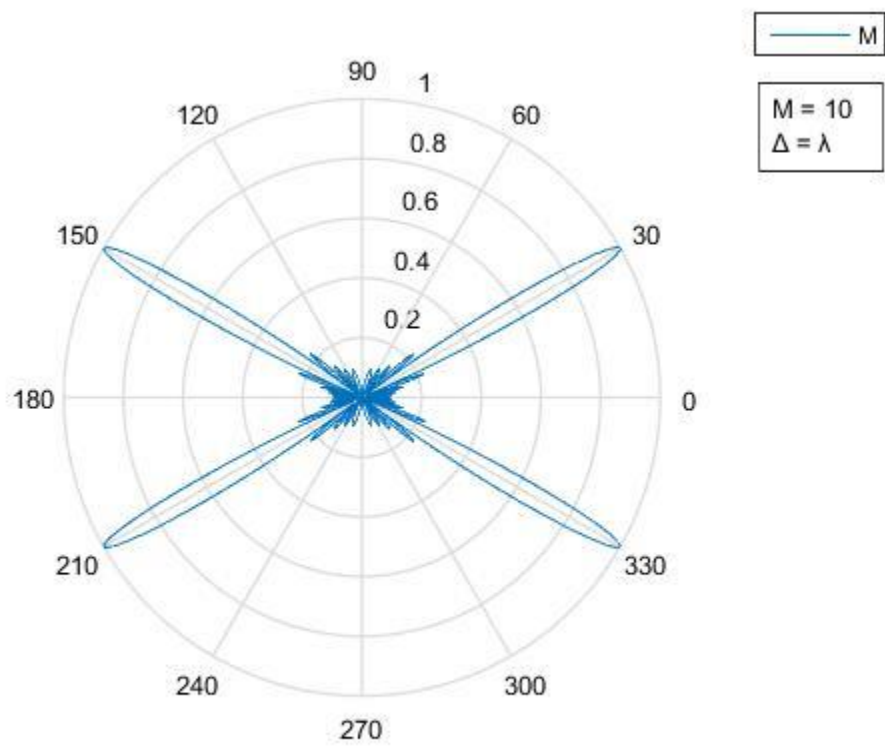
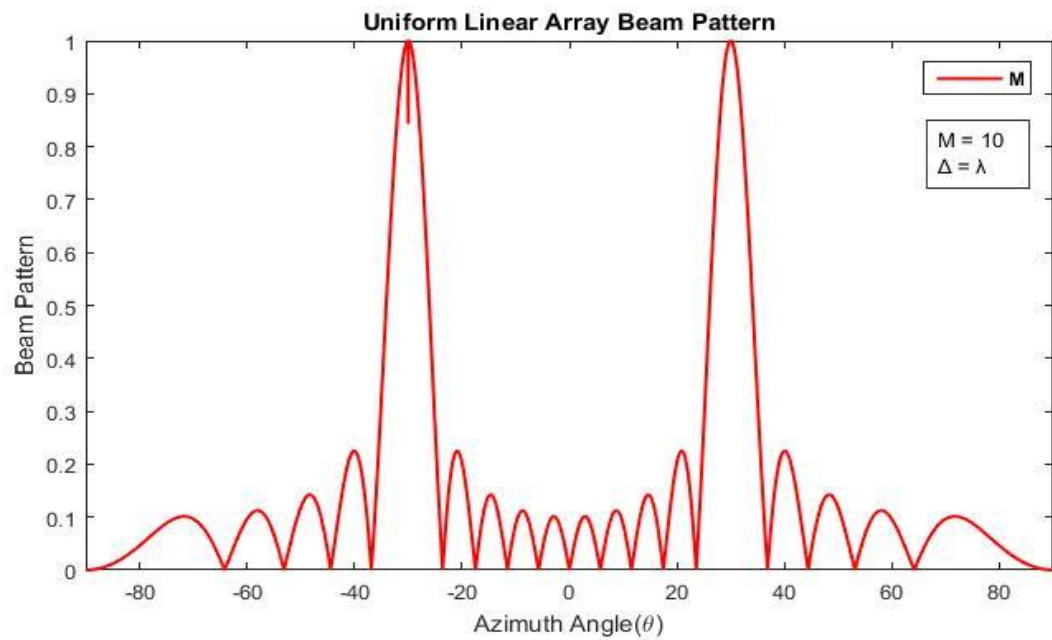
The beam pattern for array steering is given the following equation:

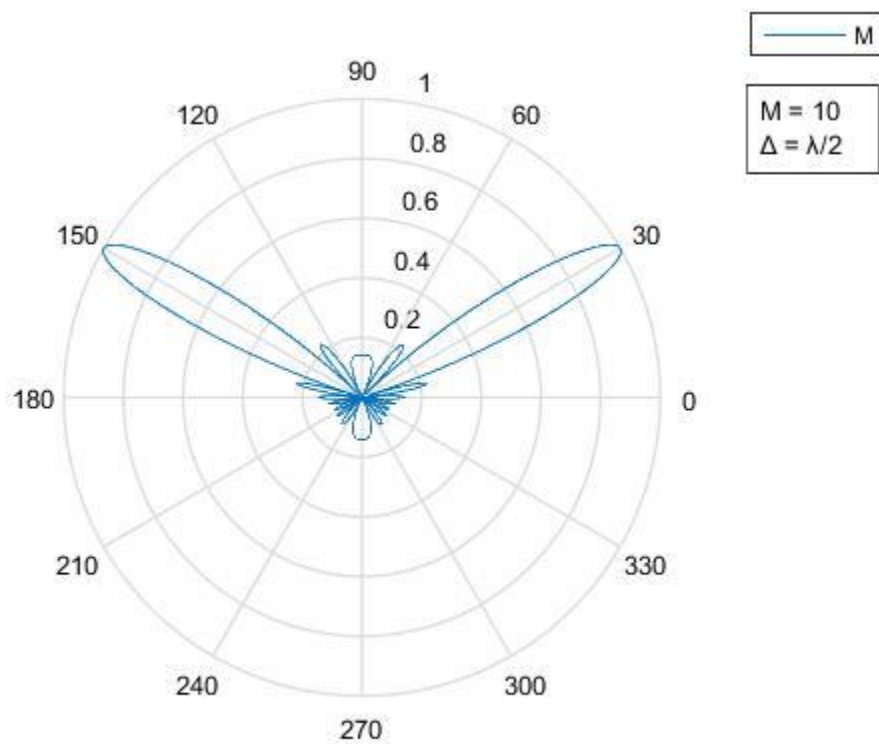
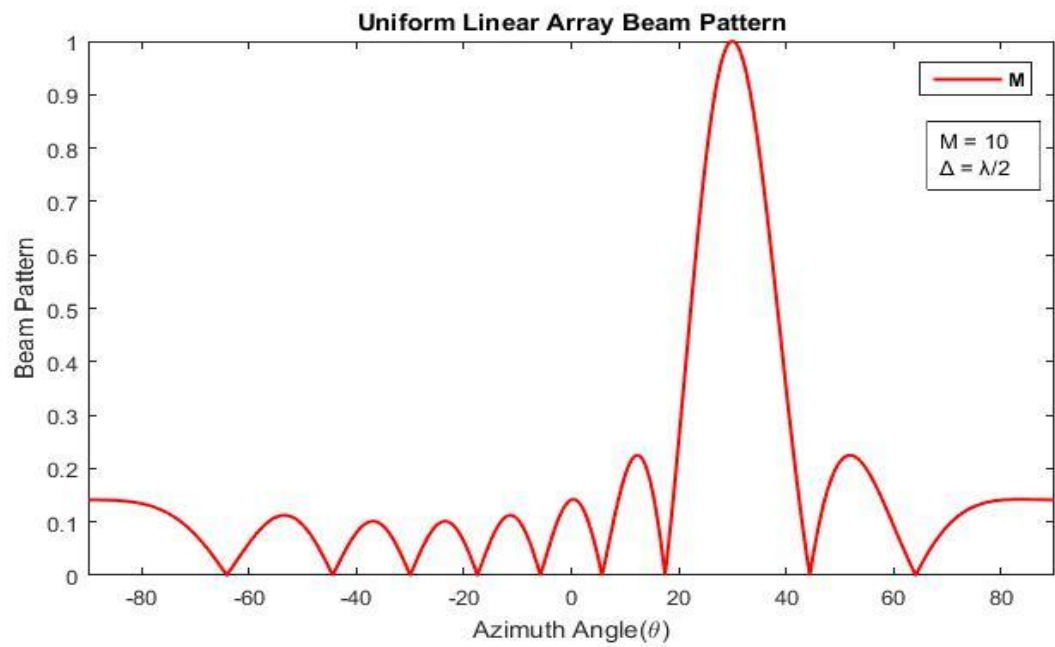
$$B(\theta, \theta_0) = \frac{1}{M} \frac{\sin\left(\frac{\pi M \Delta}{\lambda}(\sin\theta - \sin\theta_0)\right)}{\sin\left(\frac{\pi \Delta}{\lambda}(\sin\theta - \sin\theta_0)\right)} \dots\dots\dots \text{Eq.3}$$

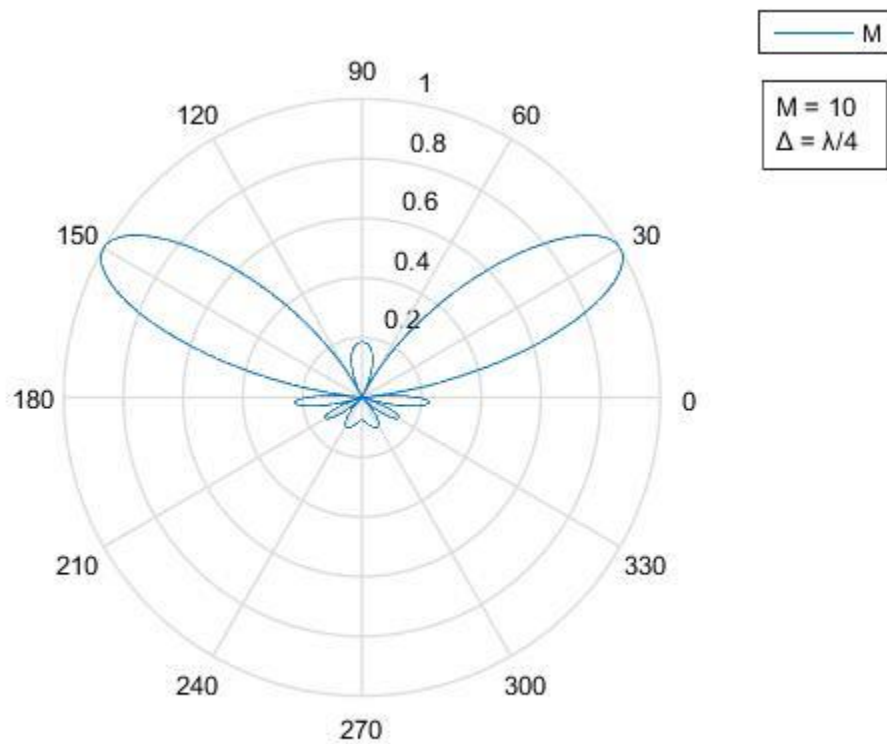
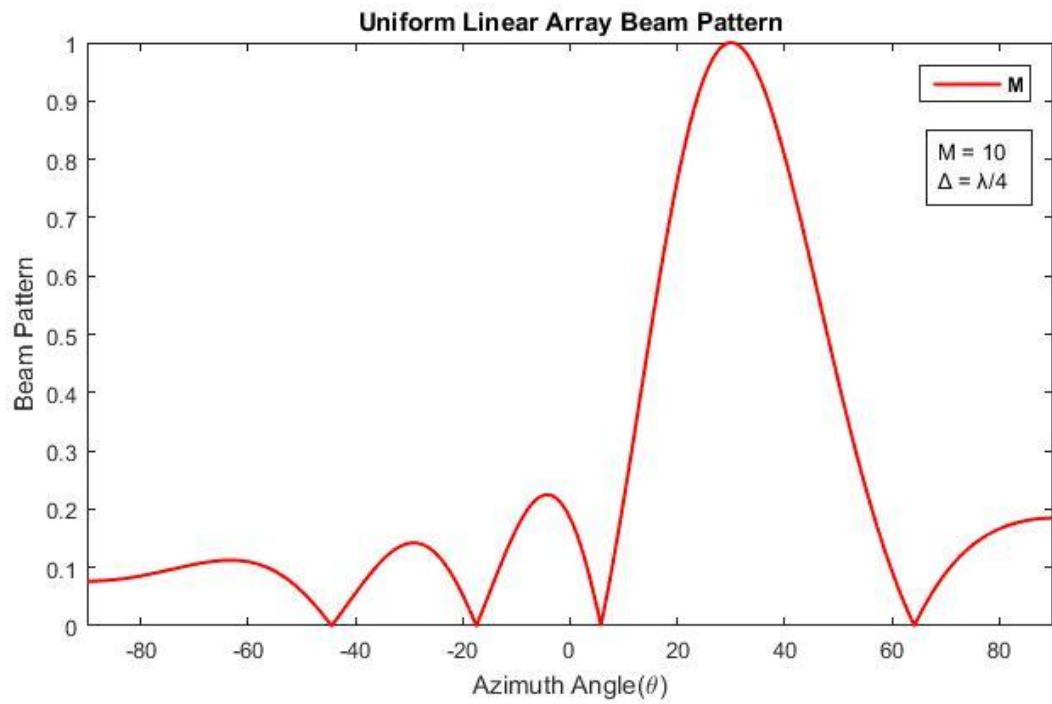
To analyze Eq.3, `ula_steering_pattern_1` and `ula_pattern_analysis_2` Matlab code files are used.

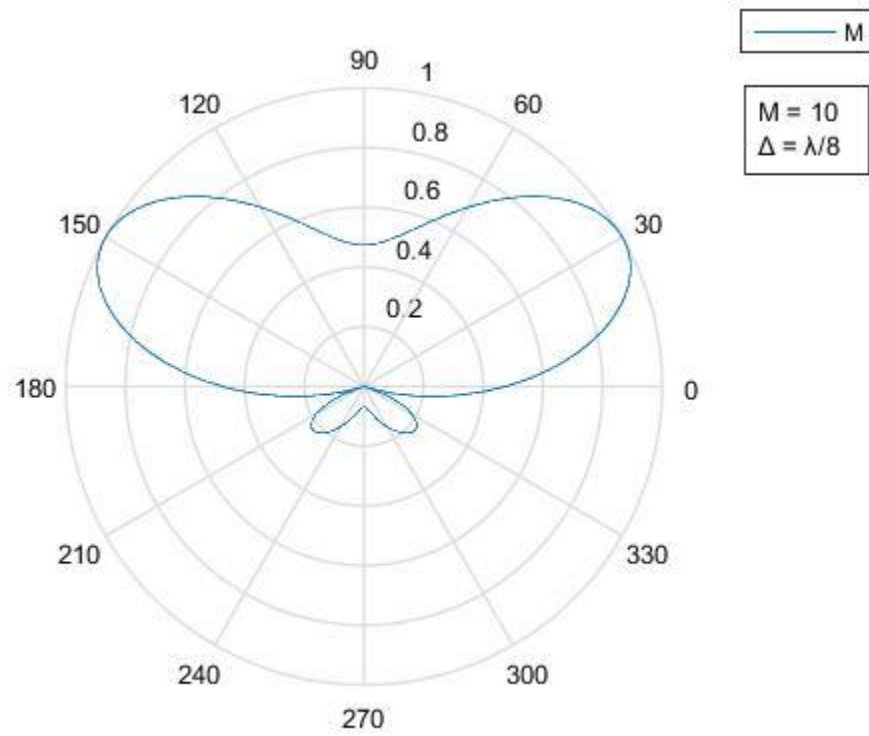
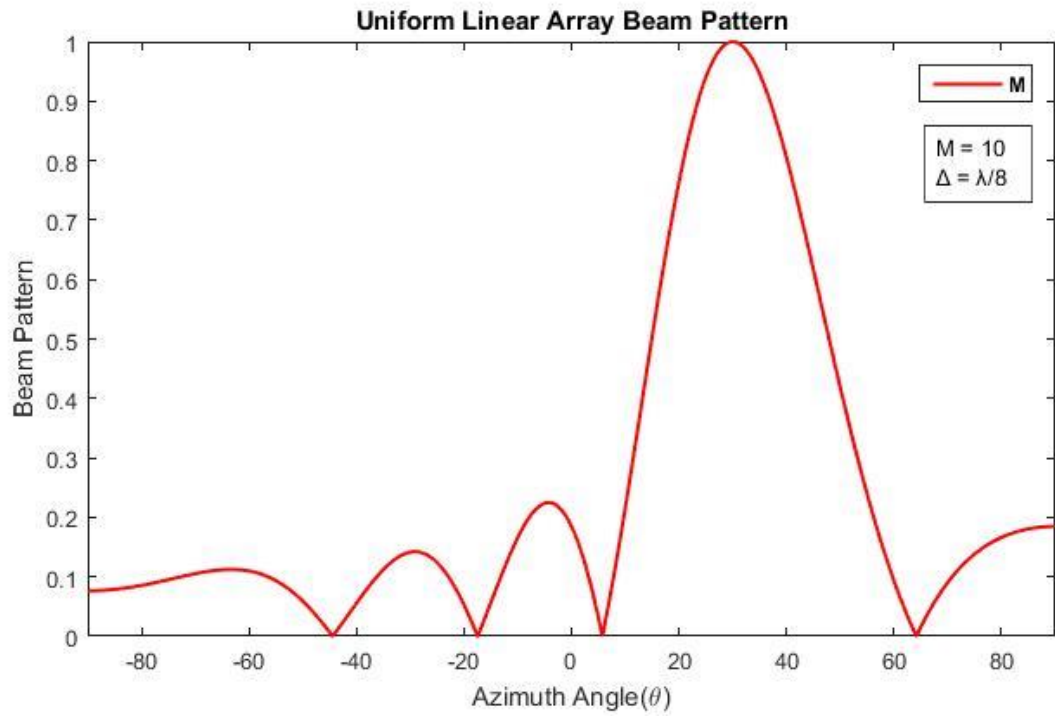
Beam Pattern for M = 10 and $\theta_0 = 30^\circ$:



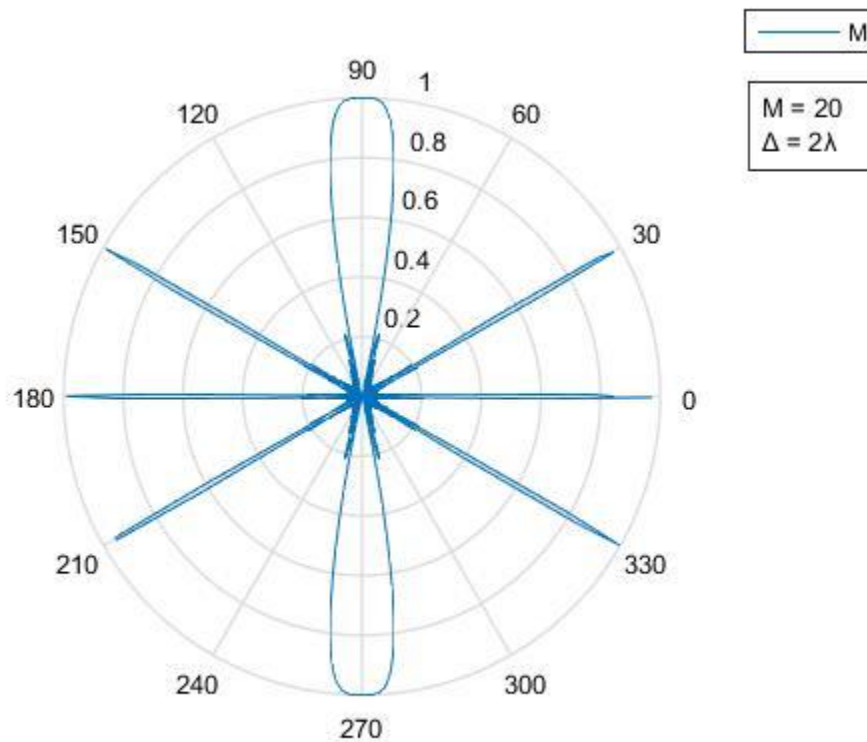
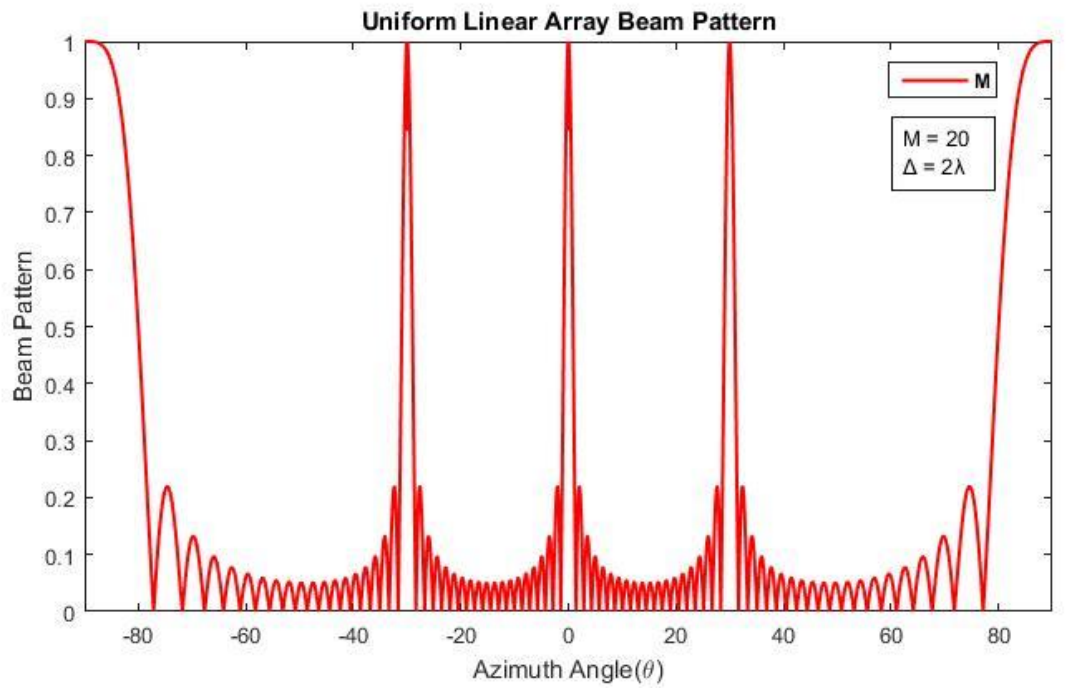


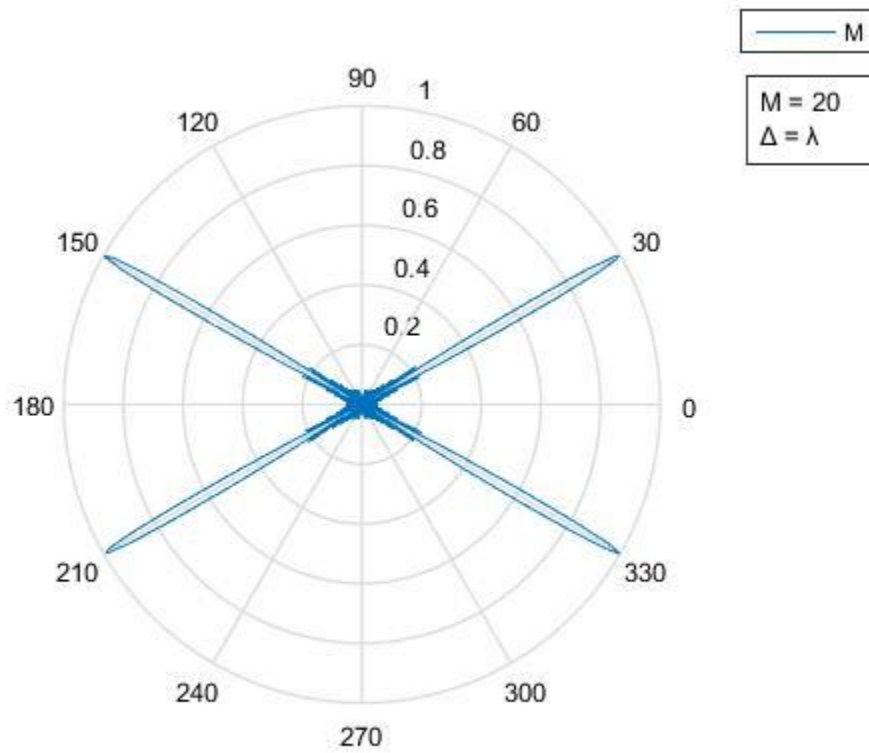
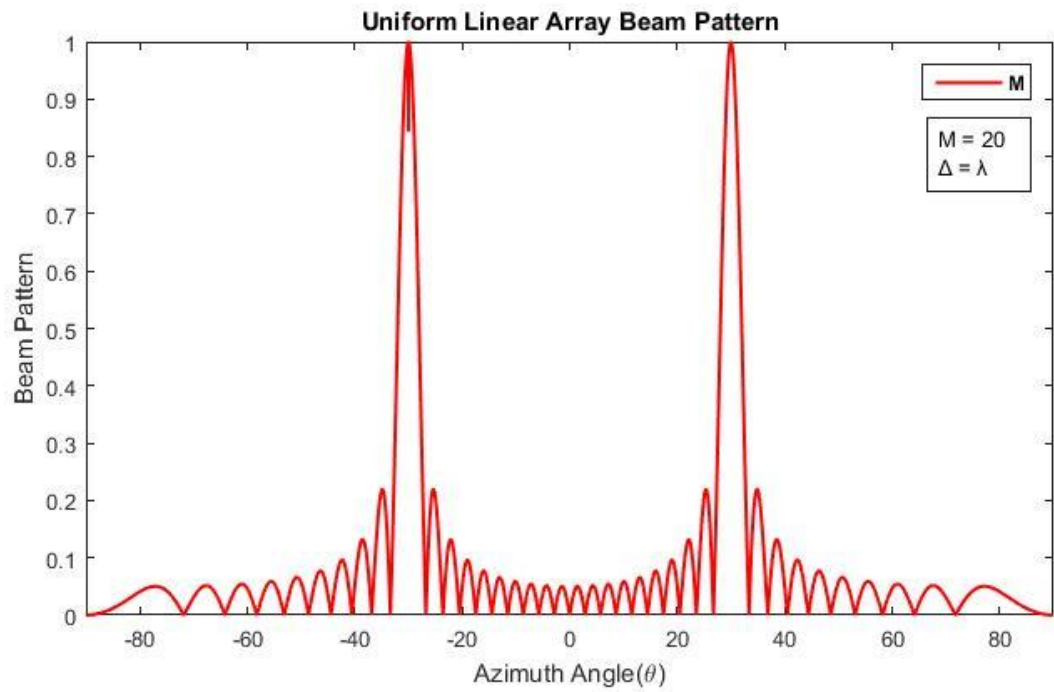


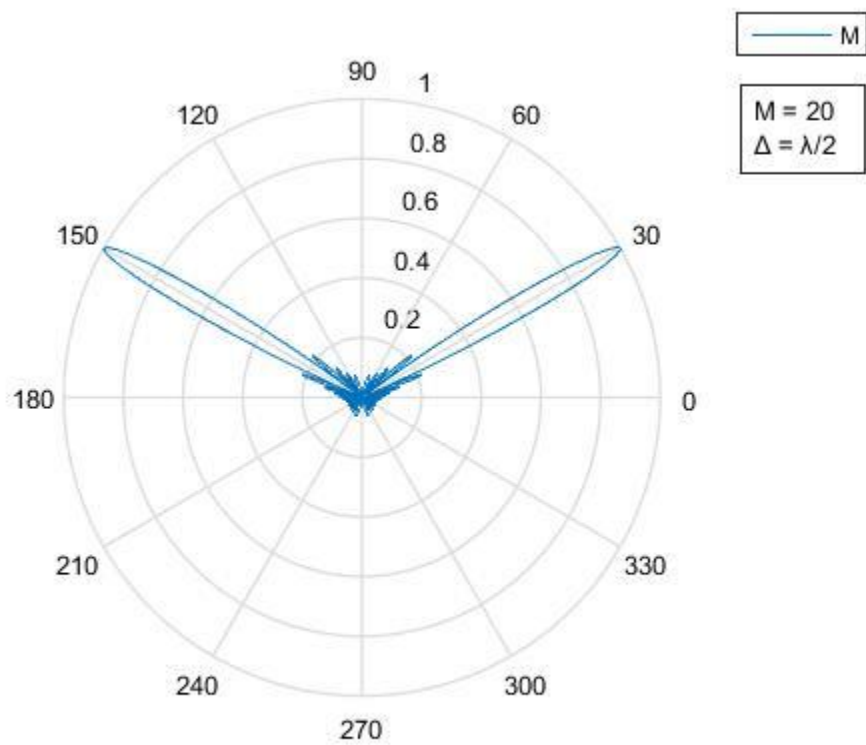
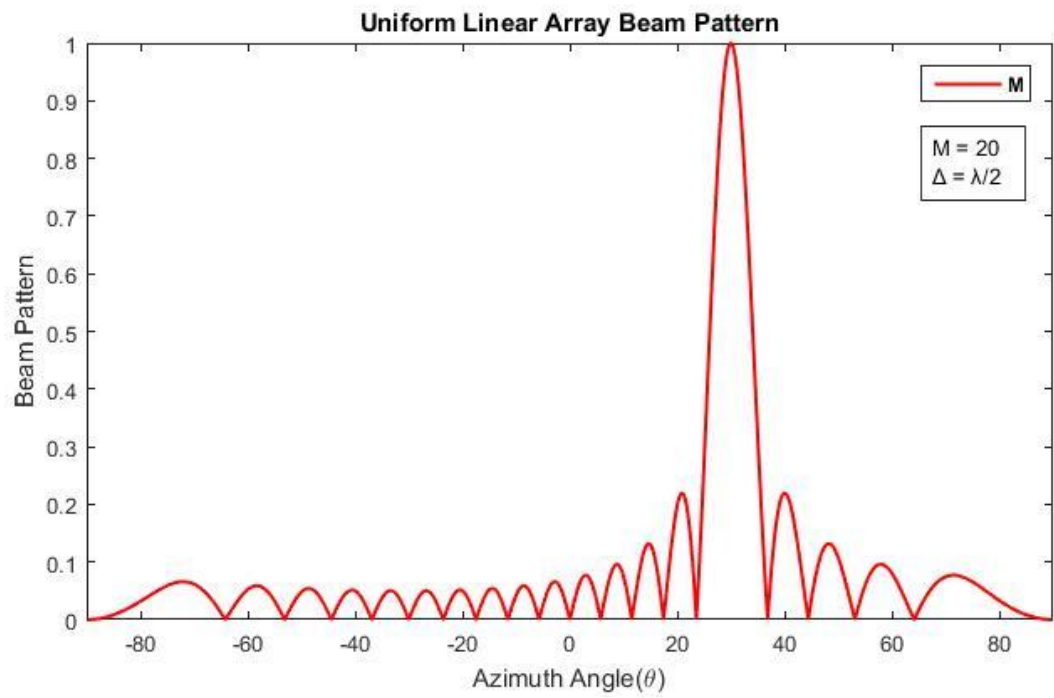


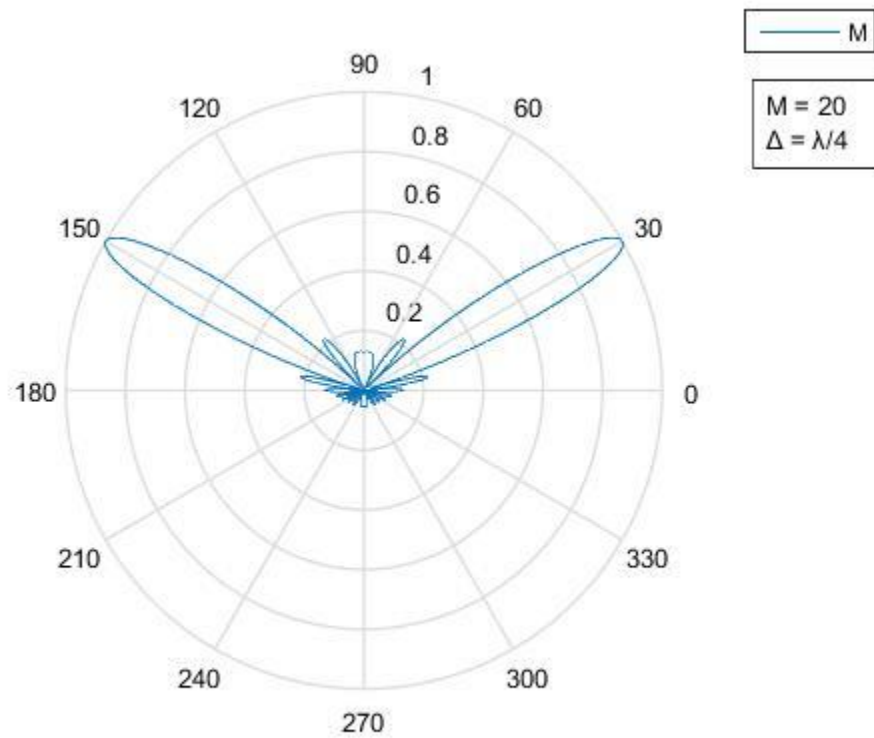
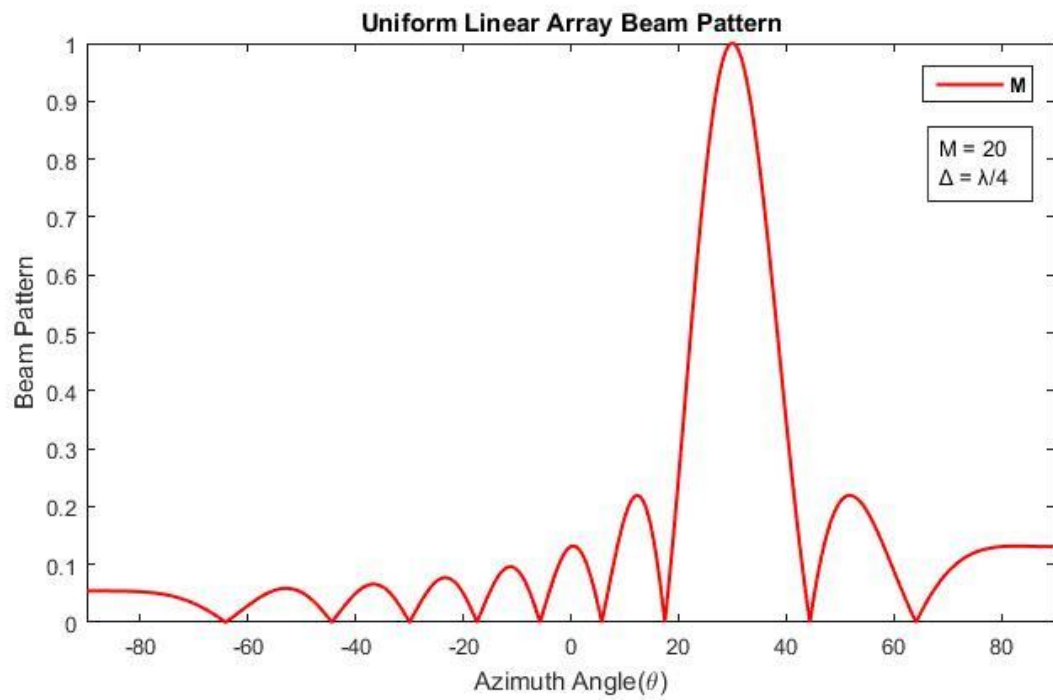


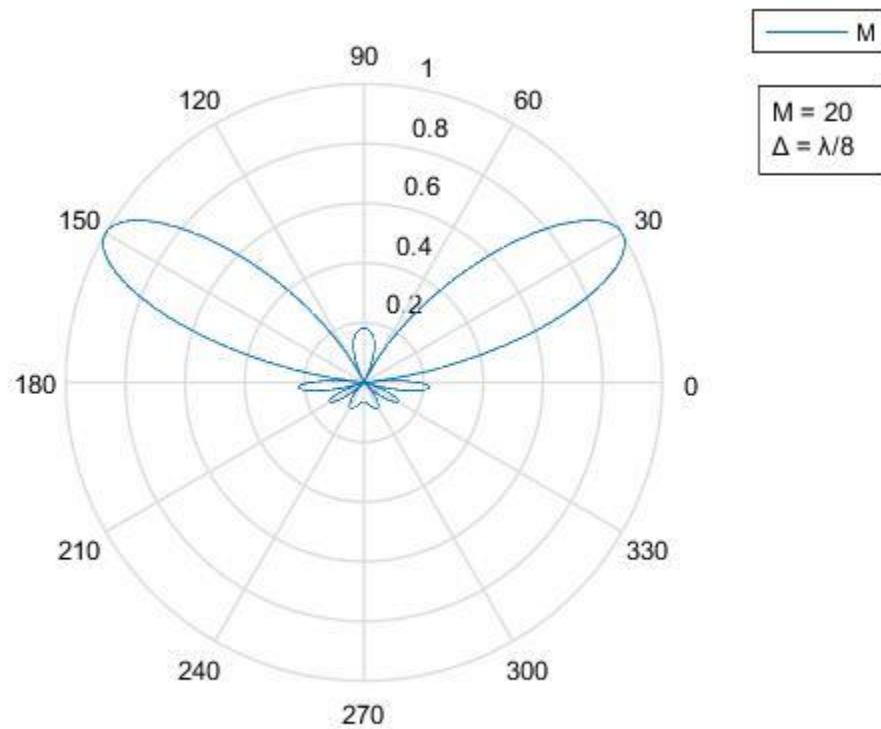
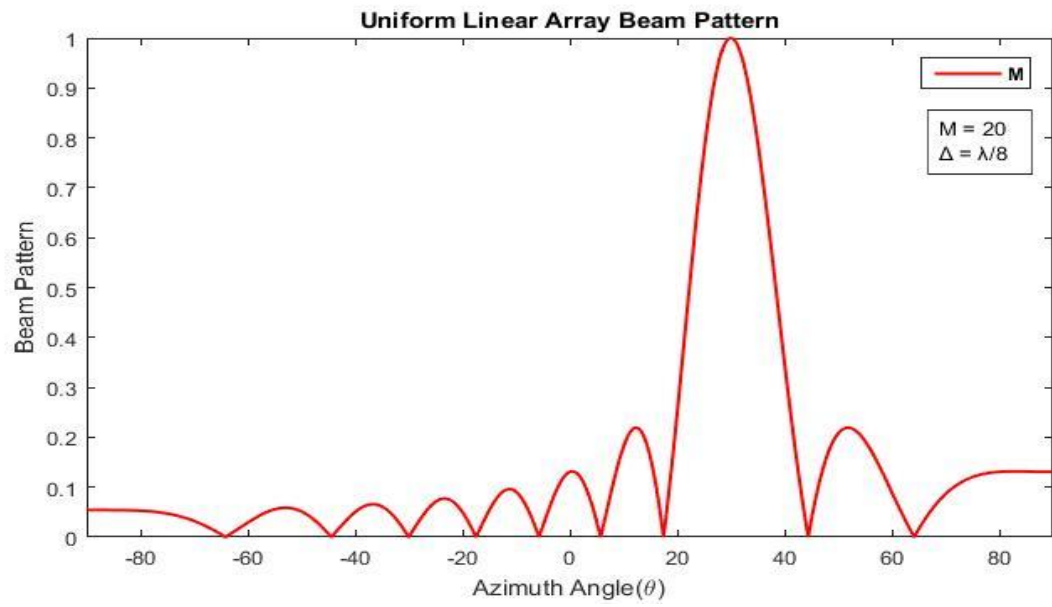
Beam Pattern for $M = 20$ and $\theta_0 = 30^\circ$:





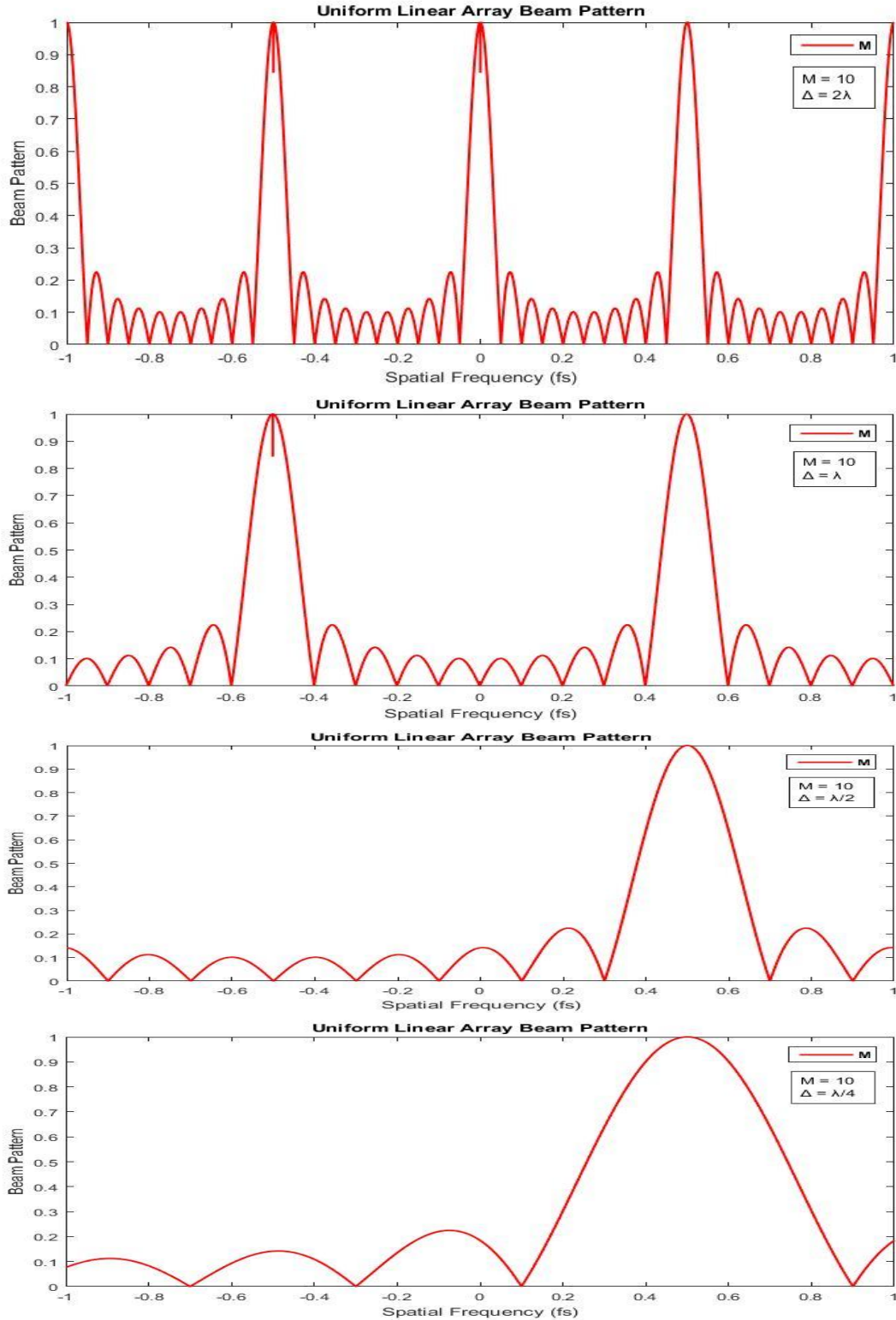






Analysis of Uniform Weighted Linear Array Using Electronic Steering With Spatial Frequency

Beam Pattern for $M = 10$ and $\theta_0 = 30^\circ$:



Beam Pattern for $M = 20$ and $\theta_0 = 30^\circ$:

