Assignment 1 (30% final grade)

5LPB0: Phased Arrays and Smart Antennas

Learning objective

You will develop your own Matlab tool for simulating phased arrays based on the theory provided in the lectures. In this way you will learn (hands-on) to apply the theory of array antennas. Each group will write a short report (2-3 pages) using the IEEE journal paper template, including abstract, overview of requirements, theory, results, conclusions and references. Use the book "Modern Antennas and Microwave Circuits: A complete master-level course, by A.B. Smolders" (see CANVAS chapters 2, 4 and 6) as background material.

Planning

- Hand-out: 21 April 2020
- Hand-in report (IEEE journal paper template): 19 May 2020 (send to: a.b.smolders@tue.nl)

Assignment per group

Each group will get an individually-tuned assignments, see table below.

Group	Assignment description	Deliverables
1	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$), Gain, beamwidth for the case: N_x=100, d_x=0.475λ, f=1 GHz, θ_0=35^0 • Extend the program with a non-uniform taper (window). Use a Taylor tapering with -22 dB sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the 2D radiation pattern in (u,v) coordinates for the case N_x=22, N_y=22, d_x=0.475λ, d_y=0.475λ, f=1 GHz, (θ_0, ϕ_0)=(35^0,45^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Taylor tapering. • Now introduce non-ideal radiating elements. Use electric dipoles along the $\phi=0^0$ axis (in the xy-plane)	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.

	(see book, chapter 4). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case.	
2	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$), Gain, beamwidth for the case: N_x=150, $d_x=0.55\lambda$, f=2 GHz, $\theta_0=-25^0$ • Extend the program with a non-uniform taper (window). Use a Chebyshev tapering with -27 dB sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the 2D radiation pattern in (u,v) coordinates for the case N_x=25, N_y=25, $d_x=0.45\lambda$, $d_y=0.45\lambda$ f=1.8 GHz, $(\theta_0, \phi_0)=(-25^0,90^0)$. Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Chebyshev tapering. • Now introduce non-ideal radiating elements. Use electric dipoles along the $\phi=45^0$ axis (in the xy-plane) (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case. What can you say about the polarization of the far-field pattern?	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.
3	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$), Gain, beamwidth for the case: N_x=115, $d_x=\lambda/2$, f=3 GHz, $\theta_0=45^0$ • Extend the program with a non-uniform taper (window). Use a Hamming taper with that provides a -25 dB peak sidelobe level. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the radiation pattern in (u,v) coordinates for the case N_x=22, N_y=22, $d_x=0.4\lambda$, $d_y=0.4\lambda$ f=3 GHz, $(\theta_0, \phi_0)=(45^0,-90^0)$. Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Hamming tapering.	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.

	• Now introduce non-ideal radiating elements. Use half-wavelength dipoles along the $\phi=-45^0$ axis (in the xy-plane) (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case. What can you say about the polarization of the far-field pattern?	
4	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0< \theta <90^0$), Gain, beamwidth for the case: N_x=98, $d_x=\lambda/2$, f=4 GHz, $\theta_0=-35^0$ • Extend the program with a non-uniform taper (window). Use a Gaussian tapering with -22 dB first sidelobe level. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the radiation pattern in (u,v) coordinates for the case N_x=18, N_y=18, $d_x=0.45\lambda$, $d_y=0.45\lambda$ f=4 GHz, $(\theta_0, \phi_0)=(-20^0,-45^0)$. Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Gaussian tapering. • Now introduce non-ideal radiating elements. Use half-wavelength dipoles the along the $\phi=90^0$ axis (in the xy-plane) (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case. What can you say about the polarization of the far-field pattern?	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.
5	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0< \theta <90^0$), Gain, beamwidth for the case: N_x=112, $d_x=\lambda/2$, f=5 GHz, $\theta_0=-45^0$ • Extend the program with a non-uniform taper (window). Use a Taylor tapering with -35 dB sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result.	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.

	• Extend the program to a two-dimensional planar array. Plot the radiation pattern in (u,v) coordinates for the case N_x=24, N_y=24, d_x=λ/2, d_y=λ/2 and f=5 GHz, (θ_0, ϕ_0)=(-45^0,135^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Taylor tapering. • Now introduce non-ideal radiating elements. Use a horn antenna with size a=0.45λ and b=0.3λ and electric field in the aperture directed in the y-direction (modeled as a uniform magnetic current distribution along the x-direction), (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case.	
6	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern (-90^0< θ <90^0), Gain, beamwidth for the case: N_x=88, d_x=0.6λ, f=6 GHz, θ_0=-35^0 • Extend the program with a non-uniform taper (window). Use a cosine-squared ($\cos^2(\pi x/Kd)$, with $\|x\|$<Kd/2) tapering. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the radiation pattern in (u,v) coordinates for the case N_x=19, N_y=19, d_x=0.55λ, d_y=0.55λ and f=6 GHz, (θ_0, ϕ_0)=(-35^0,45^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and cosine-squared tapering. • Now introduce non-ideal radiating elements. Use a horn antenna with size a=0.45λ and b=0.25λ and electric field in the aperture directed in the x-direction (modeled as a uniform magnetic current distribution along the y-direction), see course Microwave Engineering and Antennas. Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case.	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.
7	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern (-90^0< θ <90^0), Gain, beamwidth for the case: N_x=100, d_x=0.65λ, f=1 GHz, θ_0=35^0	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.

	• Extend the program with a non-uniform taper (window). Use a Taylor tapering with -32 dB sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the 2D radiation pattern in (u,v) coordinates for the case N_x=20, N_y=20, d_x=0.55λ, d_y=0.55λ f=1 GHz, (θ_0, ϕ_0)=(25^0,45^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Taylor tapering. • Now introduce non-ideal radiating elements. Use half-wavelength dipoles along the ϕ=45^0 axis (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case.	
8	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$), Gain, beamwidth for the case: N_x=160, d_x=0.6λ, f=2 GHz, θ_0=-25^0 • Extend the program with a non-uniform taper (window). Use a Chebyshev tapering with -36 dB sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the 2D radiation pattern in (u,v) coordinates for the case N_x=25, N_y=25, d_x=0.55λ, d_y=0.55λ f=2 GHz, (θ_0, ϕ_0)=(-15^0,90^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Chebyshev tapering. • Now introduce non-ideal radiating elements. Use half-wavelength dipoles along the ϕ=-90^0 axis (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case. What can you say about the polarization of the far-field pattern?	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.
9	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$),	Paper (IEEE format), max 4 pages with plots and explanation of your

	Gain, beamwidth for the case: N_x=118, d_x=0.575λ, f=5 GHz, θ_0=-45^0 • Extend the program with a non-uniform taper (window). Use a Taylor tapering with -28 dB sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the radiation pattern in (u,v) coordinates for the case N_x=24, N_y=24, d_x=0.55λ, d_y=0.55λ and f=5 GHz, (θ_0, ϕ_0)=(-45^0,135^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Taylor tapering. • Now introduce non-ideal radiating elements. Use magnetic dipoles (small loop antenna) along the z-axis (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case.	results. Add the Matlab code in the appendix.
10	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern (-90^0< θ <90^0), Gain, beamwidth for the case: N_x=85, d_x=0.6λ, f=6 GHz, θ_0=-35^0 • Extend the program with a non-uniform taper (window). Use a cosine-squared ($\cos^2(\pi x/Kd)$, with $\lvert x\rvert<Kd/2$) tapering. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the radiation pattern in (u,v) coordinates for the case N_x=19, N_y=19, d_x=0.625λ, d_y=0.625λ and f=6 GHz, (θ_0, ϕ_0)=(-35^0,45^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and cosine-squared tapering. • Now introduce non-ideal radiating elements. Use electric dipoles along the ϕ=135^0 axis (in the xy-plane) (see course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case.	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.
11	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering.	Paper (IEEE format), max 4 pages with plots and

		Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$), Gain, beamwidth for the case: N_x=140, d_x=0.625λ, f=2 GHz, θ_0=-15^0 • Extend the program with a non-uniform taper (window). Use a Chebyshev tapering with -32 dB sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the 2D radiation pattern in (u,v) coordinates for the case N_x=25, N_y=25, d_x=0.525λ, d_y=0.525λ f=2.75 GHz, (θ_0, ϕ_0)=(15^0,90^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Chebyshev tapering. • Now introduce non-ideal radiating elements. Use half-wavelength dipoles along the ϕ=180^0 axis (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case. What can you say about the polarization of the far-field pattern?	explanation of your results. Add the Matlab code in the appendix.
12		• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$), Gain, beamwidth for the case: N_x=98, d_x=0.625λ, f=6.5 GHz, θ_0=35^0 • Extend the program with a non-uniform taper (window). Use a cosine-squared ($\cos^2(\pi x/Kd)$, with $\|x\|<Kd/2$) tapering. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the radiation pattern in (u,v) coordinates for the case N_x=21, N_y=21, d_x=0.5λ, d_y=0.5λ and f=5 GHz, (θ_0, ϕ_0)=(35^0,45^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and cosine-squared tapering. • Now introduce non-ideal radiating elements. Use a horn antenna with size a=0.45λ and b=0.35λ and electric field in the aperture directed in the x-direction (modeled as a uniform magnetic current distribution along the y-direction), see course Microwave Engineering and Antennas. Again calculate the	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.

	radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case.	
13	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$), Gain, beamwidth for the case: N_x=125, d_x=0.575λ, f=2 GHz, θ_0=25^0 • Extend the program with a non-uniform taper (window). Use a Taylor tapering with -26 dB sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the 2D radiation pattern in (u,v) coordinates for the case N_x=25, N_y=25, d_x=0.525λ, d_y=0.525λ f=2 GHz, (θ_0, ϕ_0)=(45^0,0^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Taylor tapering. • Now introduce non-ideal radiating elements. Use half-wavelength dipoles along z-axis (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case. What can you say about the polarization of the far-field pattern?	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.
14	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$), Gain, beamwidth for the case: N_x=110, d_x=0.625λ, f=10 GHz, θ_0=35^0 • Extend the program with a non-uniform taper (window). Use a Taylor tapering with -24 dB sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the radiation pattern in (u,v) coordinates for the case N_x=18, N_y=20, d_x=0.625λ, d_y=0.55λ and f=10 GHz, (θ_0, ϕ_0)=(35^0,45^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Taylor tapering. • Now introduce non-ideal radiating elements.	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.

	Use a horn antenna with size a=0.6λ and b=0.3λ and electric field in the aperture directed in the x-direction (modeled as a uniform magnetic current distribution along the y-direction), see course Microwave Engineering and Antennas. Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case.	
15	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$), Gain, beamwidth for the case: N_x=160, d_x=0.6λ, f=2 GHz, θ_0=-25^0 • Extend the program with a non-uniform taper (window). Use a Chebyshev tapering with -36 dB sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the 2D radiation pattern in (u,v) coordinates for the case N_x=25, N_y=25, d_x=0.45λ, d_y=0.45λ f=7 GHz, (θ_0, ϕ_0)=(60^0,0^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Chebyshev tapering. • Now introduce non-ideal radiating elements. Use half-wavelength dipoles along the -z axis (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case. What can you say about the polarization of the far-field pattern?	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.
16	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0 < \theta < 90^0$), Gain, beamwidth for the case: N_x=112, d_x=0.625λ, f=11 GHz, θ_0=60^0 • Extend the program with a non-uniform taper (window). Use a cosine-squared ($\cos^2(\pi x/Kd)$, with $\|x\|<Kd/2$) tapering. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the radiation pattern in (u,v) coordinates for the	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.

	case N_x=21, N_y=21, d_x=0.625λ, d_y=0.5λ and f=11 GHz, (θ_0, ϕ_0)=(60^0,45^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and cosine-squared tapering. • Now introduce non-ideal radiating elements. Use a horn antenna with size a=0.6λ and b=0.3λ and electric field in the aperture directed in the x-direction (modeled as a uniform magnetic current distribution along the y-direction), see course Microwave Engineering and Antennas. Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case.	
17	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0< \theta <90^0$), Gain, beamwidth for the case: N_x=124, d_x=0.45λ, f=12 GHz, θ_0=65^0 • Extend the program with a non-uniform taper (window). Use a cosine-squared ($\cos^2(\pi x/Kd)$, with $\lvert x\rvert<Kd/2$) tapering. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the radiation pattern in (u,v) coordinates for the case N_x=20, N_y=20, d_x=0.45λ, d_y=0.6λ and f=12 GHz, (θ_0, ϕ_0)=(65^0,45^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and cosine-squared tapering. • Now introduce non-ideal radiating elements. Use a horn antenna with size a=0.4λ and b=0.45λ and electric field in the aperture directed in the x-direction (modeled as a uniform magnetic current distribution along the y-direction), see course Microwave Engineering and Antennas. Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case.	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.
18	• Develop a matlab program to simulate a linear phased array of isotropic elements with uniform tapering. Determine the 1D radiation pattern ($-90^0< \theta <90^0$), Gain, beamwidth for the case: N_x=130, d_x=0.65λ, f=15 GHz, θ_0=20^0 • Extend the program with a non-uniform taper (window). Use a Chebyshev tapering with -28 dB	Paper (IEEE format), max 4 pages with plots and explanation of your results. Add the Matlab code in the appendix.

	sidelobes. Determine the Gain, Beamwidth and maximum sidelobe level and compare this with the case of uniform tapering. Explain results. • Determine the frequency for which the first grating lobe appears in the radiation pattern. Explain result. • Extend the program to a two-dimensional planar array. Plot the 2D radiation pattern in (u,v) coordinates for the case N_x=25, N_y=25, d_x=0.6λ, d_y=0.45λ f=15 GHz, (θ_0, ϕ_0)=(20^0,-90^0). Determine the Gain, beamwidth, max sidelobe level (SLL) in case of uniform tapering and Chebyshev tapering. • Now introduce non-ideal radiating elements. Use half-wavelength dipoles along the ϕ=-180^0 axis (see book and course Microwave Engineering and Antennas). Again calculate the radiation pattern, gain, beamwidth and max. SLL for the planar array. Compare and explain results with the isotropic case. What can you say about the polarization of the far-field pattern?	