ISSN 2319 - 6629

Volume 2, No.1, December 2012 – January 2013
International Journal of Wireless Communications and Networking Technologies
Available Online at http://warse.org/pdfs/2013/ijwcnt03212013.pdf

Adaptive Array Algorithm For Electromagnetic Modeling

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Abstract: In this paper, the radiation pattern of array of isotropic elements, simple dipoles and half wave dipole elements were simulated using the MATLAB software. The adaptive algorithm has been used to steer the main beam in the desired direction and also to suppress the sidelobes to the desired level. From the results it is shown that to achieve the desired pattern the Signal to Interference- plus- Noise, (SINR) is maximized in desired direction and minimized in the interference direction.EMI/EMC affects for this issue are under investigation.

Keywords: MATLAB, SINR, Adaptive algorithm

1. INTRODUCTION

An antenna radiation pattern or antenna pattern is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates". A major lobe is defined as "the radiation lobe containing the direction of maximum radiation". A minor lobe is any lobe except a major lobe. A sidelobe is "a radiation lobe in any direction other than the intended lobe". Minor lobes should be minimized as they represent radiation in undesired directions and they should be minimized. Sidelobes are normally the largest of the minor lobes. The level of minor lobes is usually expressed as a ratio of power density in main lobe to that of major lobe. This ratio is often termed as the sidelobe ratio or sidelobe level [1]. In most of the communication systems, we need to suppress the sidelobe level to the desired level in order to achieve efficient communication by transmitting the information in desired direction which is nothing but steering the main beam in desired direction.

In the present paper, the sidelobes are suppressed to desired level and the main beam is steered in desired direction. The radiation pattern of an array of isotropic elements, an array of simple dipoles and an array of half wave dipoles were generated.

EMI/EMC is the current challenge of the circuit scenario. Its affects with reference to the stated problem are under investigation.

2. METHODOLOGY

For the given number of elements, if spacing between them and the element patterns are known, beam maximum can be steered in desired direction and sidelobe specification at other angles can be met using the adaptive theory principles. In order to achieve this, Signal to Interference-plus-Noise Ratio (SINR) is maximized in desired direction and minimized in the interference directions.

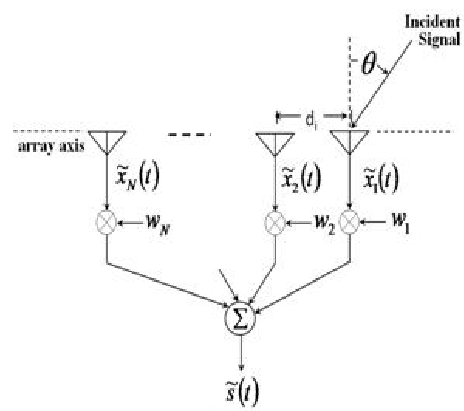

Figure 1: An n Element linear array [1]

The adaptive array principle introduces a null at the angle of arrival of interference signal to meet the desired specifications if the incident interference signal is only one. But if the number of interference signals increases, adaptive theory cannot place a null on each interference signal. So, this theory adjusts the powers of interference signals iteratively, until the desired sidelobe behavior is obtained.

In the examples illustrated below, first the main beam is steered in the required direction by choosing the steering vector which is a function of inter-element phase shifts and the element patterns in the array. Then the sidelobes are forced down to the desired level by assuming

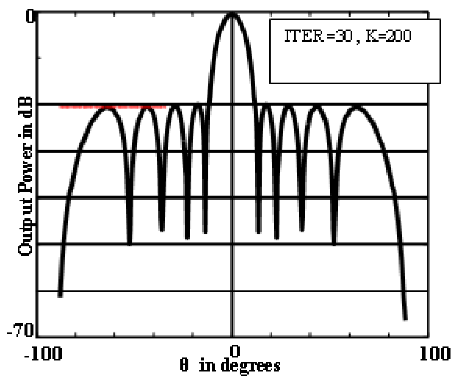

Figure 2 Radiation Pattern with N= 10, $\theta_d = 0^o$, D= 30 dB

that a large number of closely spaced interfering signals are incident on the array from the sidelobe region. Initially the powers of interference signals are set to zero. For the suppression of sidelobes to the desired levels, the powers of these interfering signals are then adjusted iteratively ensuring that the interference

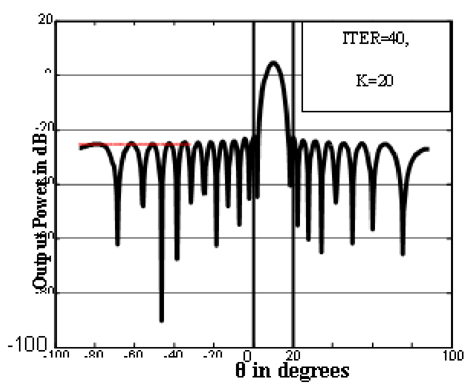

Figure 4 Radiation Pattern with N=20, $\theta_d = 10^o$, D= 30 dB.

power is zero in the beamwidth region of main beam[2-7].

For each succeeding iteration, the sidelobe level of the pattern is compared with the desired sidelobe level and the interfering signal powers are adjusted accordingly. If the sidelobe level of the pattern at an angle is above the desired sidelobe level, then the interference power at that angle is increased in order to suppress it and if the sidelobe level of the pattern at an angle is below the desired sidelobe level then power of the interference at angle is decreased in order to raise the sidelobe to the

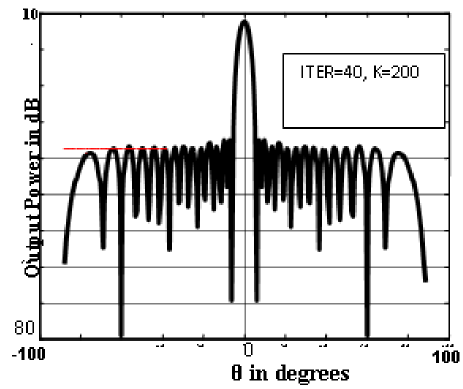

Figure 3 Radiation Pattern with N=30, $\theta_d = 0^o$, D= 35 dB.

desired level giving the suppression of sidelobes as required [8-12].

3. RADIATION PATTERNS OF AN ARRAY OF ELEMENTS

In this section the radiation patterns of different arrays of elements such as isotropic, simple dipoles and half wave dipoles are presented.

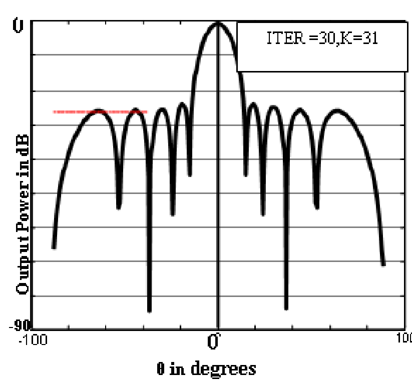

Figure 5 Radiation Pattern with N=10, $\theta_d = 0^o$, D= 25 dB.

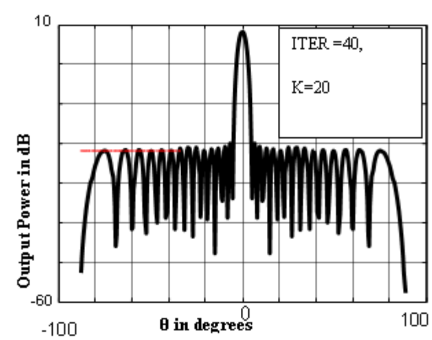

Figure 6 Radiation Pattern with N=30, $\theta_d = 0^o$, D = 30 dB.

The radiation patterns of array of isotropic elements that are equispaced at a distance of half wavelength apart and steered to a desired angle by steering vector are presented in figures 2 to 8. The sidelobes are suppressed uniformly depending on the iteration gain and the number of iterations. Figure1 shows an array of linear elements [1].

The radiation patterns of array of isotropic elements, Simple dipoles and halfwave dipoles are shown in figures below with the number of iterations required and the iteration gains required to achieve the desired radiation pattern.

In the figures shown, the figures 9 to 16 are the radiation patterns of an array of dipoles where as figures 17 to 19 are the radiation patterns of an array of half- wave dipoles.

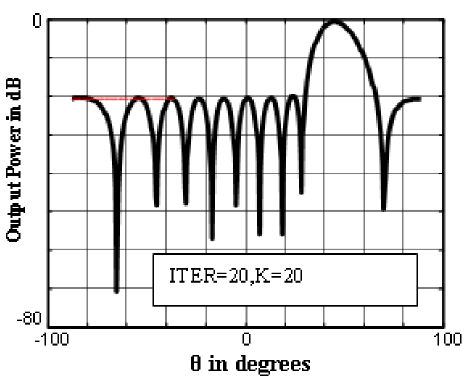

Figure 7 Radiation Pattern with N=10, $\theta_d = 45°$, D = 20 dB.

In the radiation pattern of figure 2 shown, first the main beam is steered in the required direction i.e 0° by choosing the steering vector which is a function of inter-element phase shifts and the element patterns in the array. Then the sidelobes are forced down to the desired level of 30 dB by assuming that a large number of closely spaced interfering signals are incident on the array from the side lobe region.

Initially the powers of interference signals are set to zero. For the suppression of sidelobes to the desired levels of 30 dB, the powers of these interfering signals are then adjusted iteratively ensuring that the interference power is zero in the beamwidth region of main beam[13-19]

For each succeeding iteration, the sidelobe level of the pattern is compared with the desired sidelobe level (30dB) and the interfering signal powers are adjusted accordingly. If the sidelobe level of the pattern at an angle is above the desired sidelobe level, then the interference power at that angle is increased in order to suppress it and if the sidelobe level of the pattern at an angle is below the desired sidelobe level then power of the interference at angle is decreased in order to raise the sidelobe to the desired level giving the suppression of sidelobes as required[21].

In Fig.2, for the array of 10 isotropic

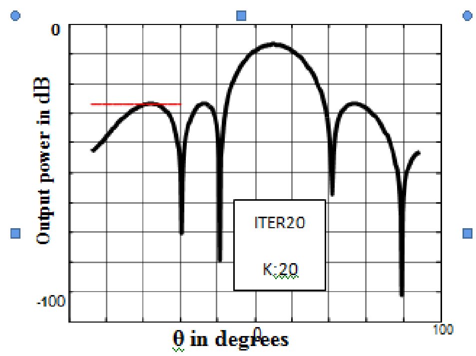

Figure 8 Radiation Pattern with N=5, $\theta_d = 10°$, D= 20 dB.

elements, the maximum sidelobe level is achieved at 30 dB at (-21,-31.8), the main beam is located at 0° at (0,-1.802).The iteration gain required to achieve this is 200 and number of Iterations required were 30.

In Fig9, for the array of 10 dipole elements, the maximum sidelobe level is achieved at 20 dB at (-18.5,-20.64), the main beam is at 0° at (0, -0.6387).The iteration gain required to achieve this is 20 and number of iterations required were 20.

In figure 17, for the array of 10 half-wave dipole elements, the maximum sidelobe level is 20 dB at (25.5,-11.55), the main beam is at 45° at (44.5, 8.434).The iteration gain required to achieve this is 2.5 and number of iterations required were 20.

For the remaining figures the description is tabulated as shown in Table 1.This table describes the maximum sidelobe level position along with the angle at which the main beam is available ie it indicates the location of the main beam as well as the position to which the side lobes are suppressed.

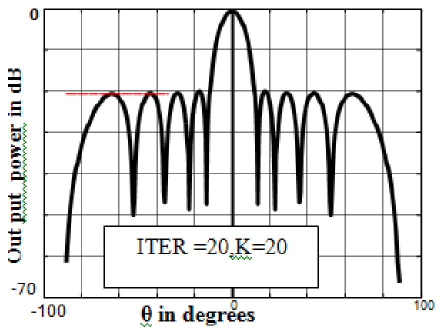

Figure 9: Radiation Pattern with N=10, $\theta_d = 0^{\circ}$, D= 20 dB.

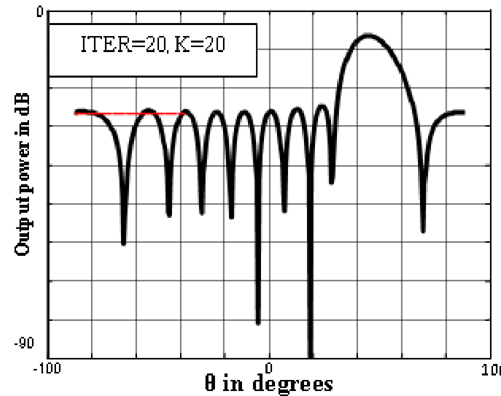

Figure 11 Radiation Pattern with

N=10, $\boldsymbol{\theta_d} = \mathbf{45^{\circ}}$, D= 20 dB.

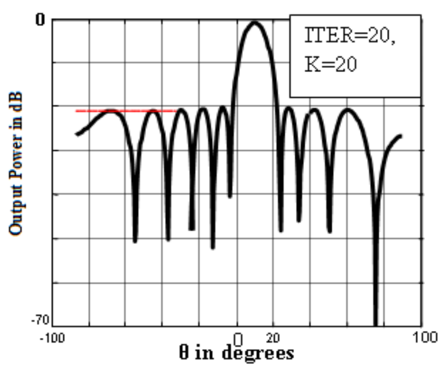

Figure 10 Radiation Pattern with N=10, $\boldsymbol{\theta_d} = \mathbf{10^{\circ}}$, D= 20 dB.

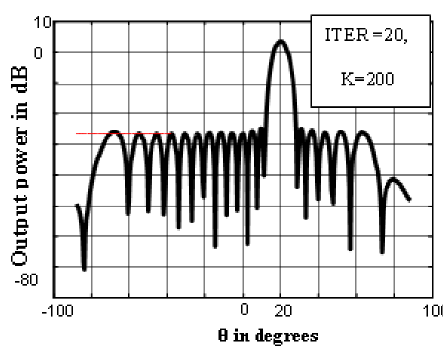

Figure 12 Radiation Pattern with N=20, $\boldsymbol{\theta_d} = \mathbf{20^{\circ}}$, D= 30 dB.

Table1: Description of the radiation patterns of isotropic, dipole and halfwave dipole elements

S. no	**Fig.no**	**Input Parameters**	**Radiation Pattern Description**
1	2	N=10, θ_d =0°, SLL=30dB, Iteration gain=200, N.o of iterations=30	Maximum SLL is 30 dB at (-21,-31.8), Main beam is at 0° at (0,-1.802).
2	3	N=30, θ_d =0°, SLL=30dB, Iteration gain=200, N.o of iterations= 40	Maximum SLL is 35 dB at (-21,-27.61), Main beam is at 0° at (0, 7.395).
3	4	N=20, θ_d =10°, SLL=30dB,Iteration gain= 20,N.o of iterations = 40.	Maximum SLL is 30 dB at (-8.5,-25.49), Main beam is at 10° at (10,4.514).
4	5	N=10, θ_d =0°, SLL=25dB, Iteration gain= 31,N.o of iterations = 30.	Maximum SLL is 25 dB at (-20,-26.23), Main beam is at 0° at (0, -1.231).
5	6	N=30, θ_d =0°, SLL=30dB, Iteration gain= 20,N.o of iterations = 40.	Maximum SLL is 30 dB at (-10,-21.82), Main beam is at 0° at (0, 8.18).
6	7	N=10, θ_d =45°,SLL=20dB, Iteration gain= 20,N.o of iterations = 20.	Maximum SLL is 20 dB at (24,-20.65), Main beam is at 45° at (45, -0.6489).
7	8	N=10, θ_d =10°,SLL=20dB, Iteration gain= 20,N.o of iterations = 20.	Maximum SLL is 20 dB at (-26.5,-26.99), Main beam is at 10° at (10.5, -6.996).
8	9	N=10, θ_d =0°, SLL=20dB, Iteration gain= 20,N.o of iterations = 20.	Maximum SLL is 20 dB at(-18.5,-20.64), Main beam is at 0° at (0, -0.6387)
9	10	N=10, θ_d =10°, SLL=20dB,Iteration gain= 20,N.o of iterations = 20.	Maximum SLL is 20 dB at (-6,-20.9), Main beam is at 10° at (10, -0.8971).
10	11	N=10, θ_d =45°, SLL=20dB,Iteration gain= 20,N.o of iterations = 20.	Maximum SLL is 20 dB at (22,-26.6), Main beam is at 45° at (44.5, -6.61).
11	12	N=20, θ_d =20°, SLL=30dB,Iteration gain= 200,N.o of iterations = 20.	Maximum SLL is 30 dB at (4.5,-26.46), Main beam is at 20° at (20, 3.354).
12	13	N=10, θ_d =40°, SLL=30dB,Iteration gain= 200,N.o of iterations = 30.	Maximum SLL is 30 dB at (15.5,-36.36), Main beam is at 40° at (40.5, -6.375).
13	14	N=30, θ_d =45°, SLL=35dB,Iteration gain= 200,N.o of iterations = 30.	Maximum SLL is 35 dB at (35,-33.45), Main beam is at 45° at (45, 1.546).
14	15	N=5, θ_d =10°, SLL=20dB,Iteration gain= 200,N.o of iterations = 20.	Maximum SLL is 20 dB at (-24.5,-27.26), Main beam is at 10° at (11, -7.276).
15	16	N=5, θ_d =0°, SLL=20dB,Iteration gain= 20,N.o of iterations = 50.	Maximum SLL is 20 dB at (-35,-26.96), Main beam is at 0° at (-0.5, -6.965).
16	17	N=10, θ_d =45°, SLL=20dB,Iteration gain= 2.5,N.o of iterations = 20.	Maximum SLL is 20 dB at (25.5,-11.55), Main beam is at 45° at (44.5, 8.434).
17	18	N=10, θ_d =35°, SLL=20dB,Iteration gain= 35,N.o of iterations = 20.	Maximum SLL is 20 dB at (16.5,-22.47), Main beam is at 35° at (34.5, -2.483).
18	19	N=10, θ_d =30°, SLL=20dB,Iteration gain= 350,N.o of iterations =30.	Maximum SLL is 20 dB at (10.5,-35.24), Main beam is at 30° at (30, -10.24).

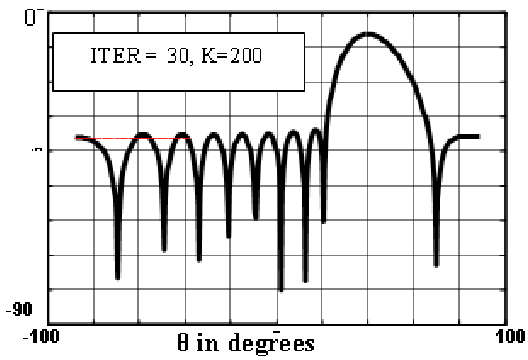

Figure 13 Radiation Pattern with

N=10, $\theta_d = 40^o$, D= 30 dB.

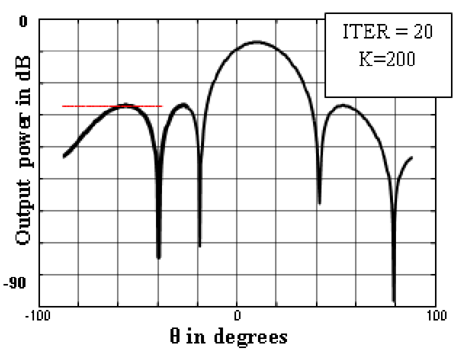

Figure 15 Radiation Pattern with
N=5, $\theta_d = 10^o$, D= 20 dB.

RESULTS AND DISCUSSION

The results were shown for the array of isotropic, dipole and half-wave dipole elements. The sidelobe control algorithm based on the adaptive array theory has been presented here. Using this algorithm, the weight vectors were chosen for a given set of array elements to meet a specified sidelobe criterion. This algorithm has used the array elements as the elements of an adaptive array and steered the main beam in the desired direction. Also suppressed the sidelobes to the desired level by injecting the interference in the array. In this algorithm, the weight vectors were adjusted iteratively until the desired sidelobe behaviour is achieved.

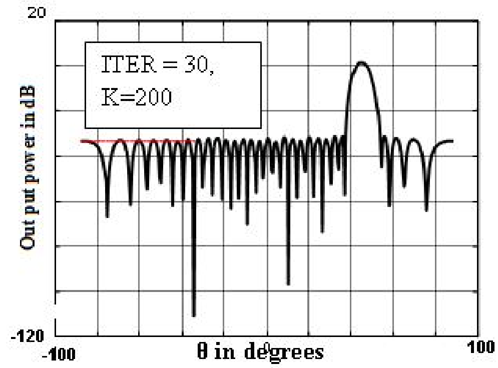

Figure 14 Radiation Pattern with

N=30, $\theta_d = 45^o$, D = 35 dB.

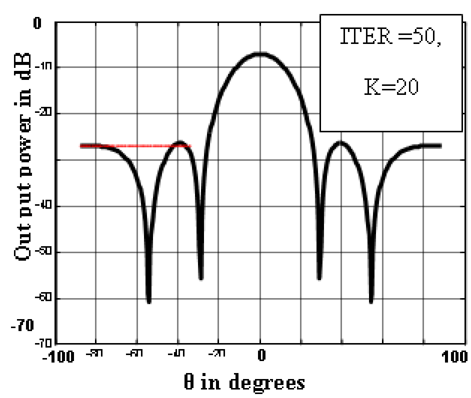

Figure 16 Radiation Pattern with N=5, $\theta_d = 0^o$, D= 20 dB.

To obtain the weight vectors to meet the sidelobe criterion, a large number of interfering signals were introduced. The response of an adaptive array to an interference signal depends on the strength of the interference signal. In order to achieve lower sidelobes, the strength of the interference signal should be more. The number of interference signals were chosen as 119.In order to achieve the desired sidelobe the strength of the interference signal will be either increased or decreased ie the powers of these interference signals were adjusted iteratively, until the desired sidelobe behaviour is achieved.

In the first step the powers of all the interference signals were set to zero and then for succeeding iterations, the sidelobes of pattern were compared with the desired sidelobe level and the powers of the interference signals were adjusted to meet the desired sidelobe level.

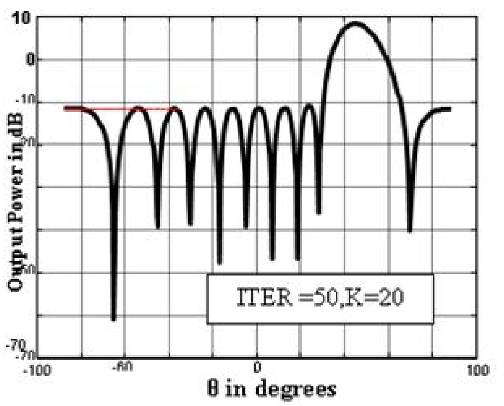

Figure.17: Radiation Pattern with N=5, $\theta_d = 0^o$, D= 20dB,

CON CLUSION

The sidelobe control algorithm was utilized to suppress the sidelobes and steer the main beam to the desired direction and also it was shown that by changing the number of iterations and the iteration gain, the sidelobes can be suppressed to the desired level.

The results shown were obtained by utilizing the adaptive array theory and MATLAB. Several examples of pattern synthesis have been presented based on the adaptive array theory, minimization of noise or maximization of

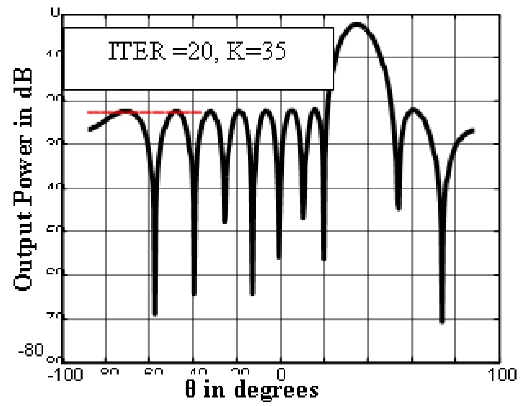

Figure 18 Radiation Pattern with N=10, $\theta_d = 35^o$, D= 20 dB.

SNR. In many cases the approach is simpler, better, and physically more meaningful than conventional synthesis. The EMI/EMC affects of this problem are under progress.

The simulation of array antenna pattern was carried out to steer the main beam in desired direction by using the steering vector which is a function of the element patterns and the inter element phase shifts. The sidelobes were suppressed to the specified level by adjusting the interference signal power.

The pattern synthesis was carried out using the adaptive array algorithm and MATLAB to generate the weight vectors that will yield desired radiation pattern. The radiation pattern for the specified antenna can be obtained by substituting the weight vectors in the IE3D software [1].The IE3D software is a powerful integrated Full wave Electro Magnetic Simulation and optimization package for the analysis and design of High frequency.[19]

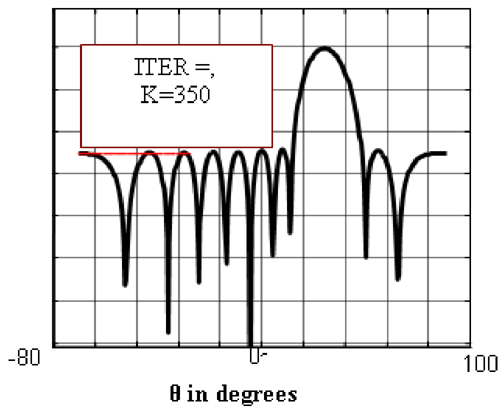

Figure 19 Radiation Pattern with N=10 $\theta_d = 30^\circ$, D= 20dB,

APPENDIX A
MATLAB PACKAGE

MATLAB is an interactive, matrix based system for scientific and engineering calculations. We can solve complex numerical problems without actually writing a program. The name MATLAB is an abbreviation for MATrix LABoratory.

MATLAB includes tools for:

1. Data acquisition
2. Data analysis and exploration
3. Visualization and image processing
4. Algorithm prototyping and development
5. Modeling and Simulation
6. Programming development.

These broad set of capabilities makes MATLAB an ideal home base for developing solutions to technical problems.

APPENIDIX-B
GLOSSARY

ACKNOWLEDGEMENT

Part of the work reported in this paper is carried out as post graduate research work by Kum.Kavitha at center for excellence in Electronics and communications Engineering, University college of Engineering, of Osmania University. Hyderabad. Shri Yerram Ravinder, Dr.V.M.Pandhari pande deserves best of the acknowledgements for their intensive care in carrying out the work in their valuable guidance. Also, the directors of CVR Engineering college thankful for their unmemorable interest in our work.

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