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Aperture Antenna with Low Side Lobe Level

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Abstract:

In this work the side lobes of the radiation pattern emitted by circular aperture antenna is reduced by controlling the current distribution function to higher order power equation of parabolic function. The results shows that one can be get a pattern of side lobe below -55 dB. Also we get that the side lobe levels can be reduce using the tapering current distribution across the aperture.

Introduction:

An aperture antenna is a part of structure of antenna is an aperture, or opening, through with electromagnetic waves flow. Aperture antenna is in common use at ultrahigh frequency UHF and above[1].

Mahony was found the directivity of the circular aperture depends on the aperture size[2]. A novel circular aperture pattern synthesis technique is presented by Adriaan J. Booysen, which enables a linear line-source distribution to be converted to a rotationally symmetric circular aperture distribution, of which any -cut radiation pattern is ideally the same as the principal plane pattern of the line-source distribution. Line source pattern synthesis techniques are numerous and versatile and the technique presented here allows these techniques to be applied to circular apertures as well. This new synthesis method is most compatible with line-source distributions which have zero edge illumination[3].

A high-gain low sidelobe level array antenna that is fed by a radial waveguide and designed to operate over a frequency range is considered. The effect of the tapering, for both paraboloidal and bell-shaped aperture amplitude distributions, and the consequences of the phase errors, caused by the variation with frequency of the electrical lengths in the radial waveguide feed structure, on the gain and side lobe level are studied in detail. Results obtained based on the proposed analysis are validated with respect to experimental data available in the literature. They are applicable to designs of arrays as well as aperture antennas[4].

The radiation field from a two dimensional aperture can be determined when the field and geometry of the aperture is specified[5].

An antenna that has a physical aperture opening with a circular shape is said to be circular aperture, various forms of circular aperture antennas are encountered in practice. The radiation pattern of the circular aperture antenna is determined by using the sufficient value of aperture's diameter and current distribution function on the aperture, this antenna my be excited uniformly or non-uniformly current distribution.

In this paper the field distribution on the aperture is taking into account to reduce the side lobe level.

Theory:

Figure (1) depicted the geometry of associated with circular aperture. Consider an aperture of circular shaped of radius *a*. the far-field at point *P* is denoted by vector $\vec{r}$ and source point is represented by vector $\vec{r'}$, so, the radiation field at point *P* is given by[6].

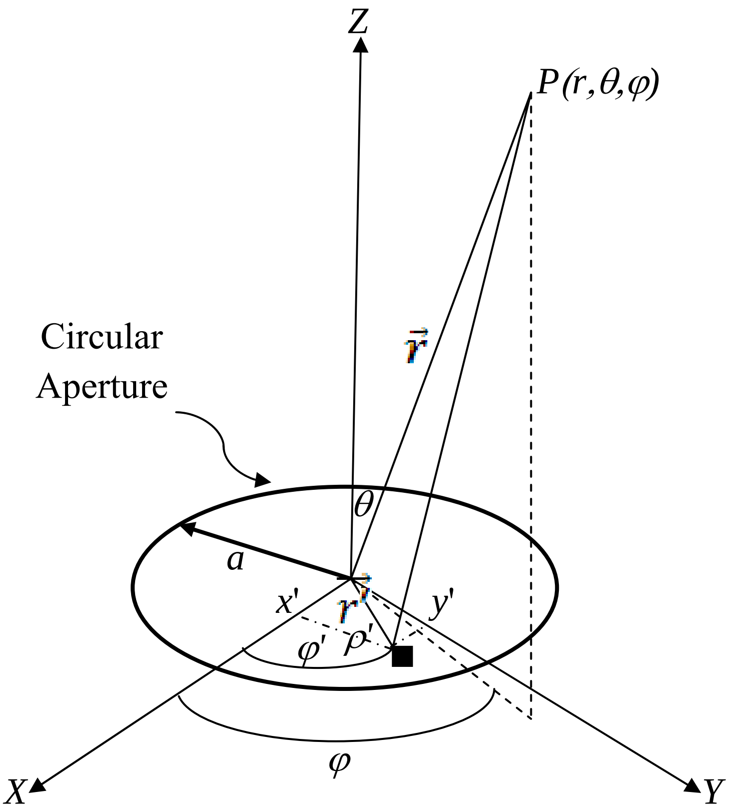


Fig.(1): Circular aperture geometry.

$$E_a(\theta,\varphi) = \iint D(x',y')e^{j\psi(x',y')}\,dx'dy' \quad \text{..........................} \quad (1)$$

Where a denotes aperture, and $\psi(x',y') = k\vec{r}.\vec{r'}(x',y')$, $k = {2\pi}/{\lambda}$, where is λ the wavelength, and $D(x', y')$ is the current distribution function is represented by parabolic function as[1],

$$E_a(\rho') - \left[1-\left(\frac{\rho'}{a}\right)^2\right]^n \quad \text{..} \quad (2)$$

Where n is an integer represent the distribution type, as an example *n=0* refers to uniform distribution and *n=1* means parabolic distribution and so on.

To simplifying eq.(1), some mathematical manipulations are done as

$\hat{r} = sin\theta cos\varphi\hat{x} + sin\theta sin\varphi\hat{y} + cos\theta\hat{z}$

$\vec{r'} = x'\hat{x} + y'\hat{y}\,, \qquad x' = \rho' cos\varphi' \; and \; y' = \rho' sin\varphi'$

So,

$\hat{r}.\vec{r'} = \rho' sin\theta cos\varphi cos\varphi' + \rho' sin\theta sin\varphi sin\varphi' = \rho' sin\theta cos\,(\varphi - \varphi')$ …(3)

In the cylindrical coordinate, and

$dx'\,dy' = \rho'\,d\rho'\,d\varphi'$

Then eq.(1) become,

$$E_a(\theta,\varphi) = \int_0^a \left[1 - \left(\frac{\rho'}{a}\right)^2\right]^n \rho' d\rho' \int_0^{2\pi} e^{jk\rho' sin\theta cos\,(\varphi-\varphi')} d\varphi' \ldots \qquad (4)$$

In case of uniform distribution (i.e. $n=0$) the current distribution function is unity, one can get

$$E_a(\theta,\varphi) = \int_0^a \rho' d\rho' \int_0^{2\pi} e^{jk\rho' sin\theta cos\,(\varphi-\varphi')} d\varphi' \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

The second integral of φ' is solve by using identity of Bessel's function as

$$\int_0^{2\pi} e^{jkz cos\xi} d\xi = 2\pi J_o(z) \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (5\text{-a})$$

Where $J_o(z)$ is the Bessel function of the first kind of the order zero. Because of the circular symmetry over aperture, the electric field independent of φ, hence, $E_a(\theta,\varphi) = E_a(\theta)$ and eq.(1), re-written as,

$$E_a(\theta) = \int_0^a \rho' J_o(k\rho' sin\theta) d\rho'$$

$$E_a(\theta) = \pi a^2 \frac{2J_1(k\rho' sin\theta)}{(k\rho' sin\theta)} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

In the general form (i.e. $n>0$) re-call that

$$\int_0^1 x[1-x^2]^n J_o(bx)dx = \frac{2^n n!}{b^{n+1}} J_{n+1}(b) \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6\text{-a})$$

Suppose, $x=\rho'/a$ and $b=k\rho' sin\theta$, eq.(5) is given by

$$E_a(\theta) - \frac{\pi a^2}{n+1} \frac{2^{n+1}(n+1)! J_{n+1}(k\rho' sin\theta)}{(k\rho' sin\theta)^{n+2}} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (7)$$

For taper on pedestal distribution function given by eq.(2) is represented as

$$E_a(\rho') = C + (1 - C)\left[1 - \left(\frac{\rho'}{a}\right)^2\right]^n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

In the same manner as done in case of uniform distribution, we get

$$E_a(\theta) = \frac{\pi a^2}{n+1} \frac{Cf(\theta, n=0) - \frac{1-C}{n+1} f(\theta, n)}{C + \frac{1-C}{n+1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

where

$$E_a(\theta) = \frac{2^{n+1}(n+1)!\,J_{n+1}(k\rho' \sin\theta)}{(k\rho' \sin\theta)^{n+2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

and C is the pedestal height defined as the edge (field) illumination relative to that at center.

Numerical Results:

In the term of reducing the side lobe levels the field distribution over an aperture is choosing as depicted in eq.(2) as

as n increased the normalized field distribution is becomes narrow and then the side lobe level is decreased, fig.(2) shows the field distribution over the aperture radius (r_o).

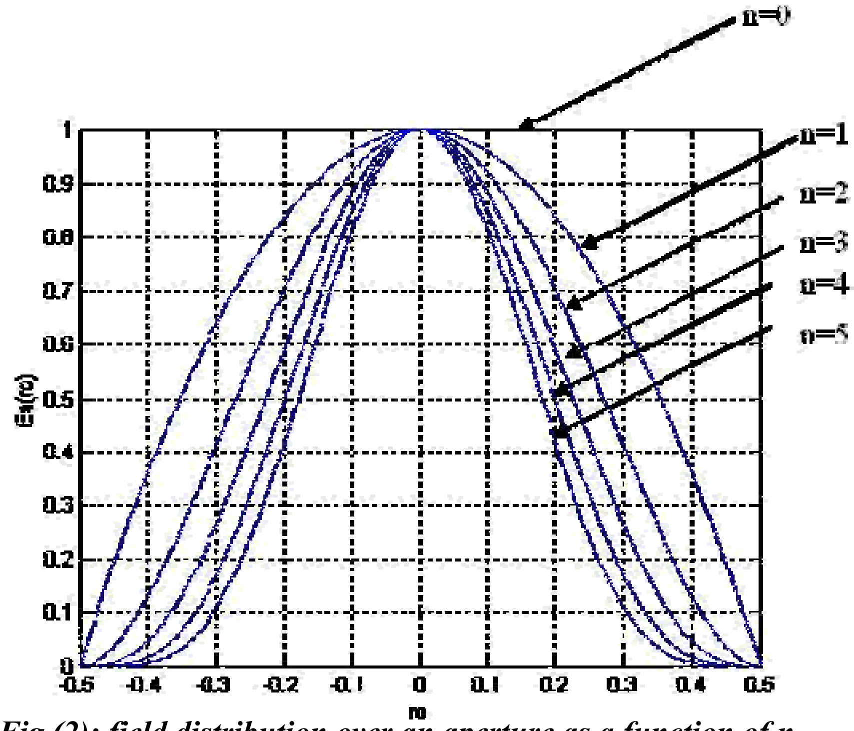
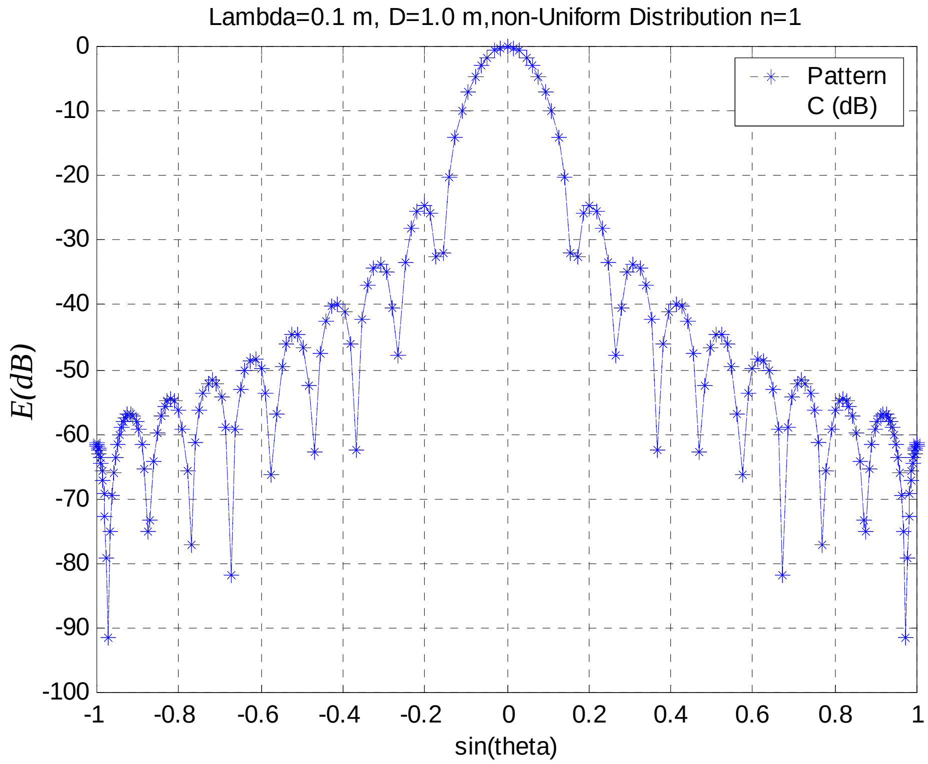
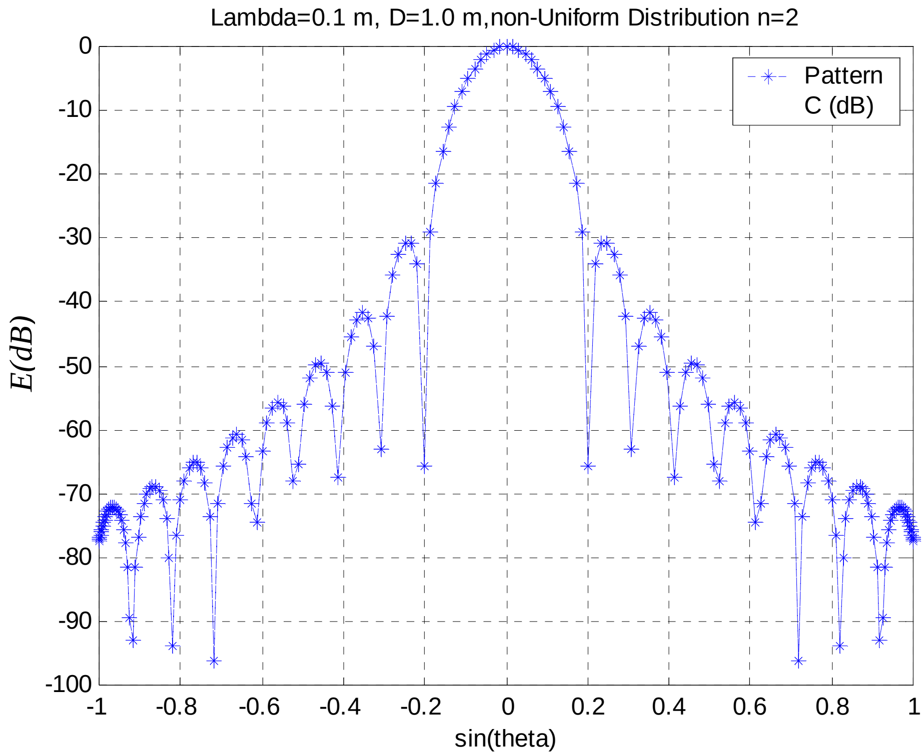


Fig.(2): field distribution over an aperture as a function of n.

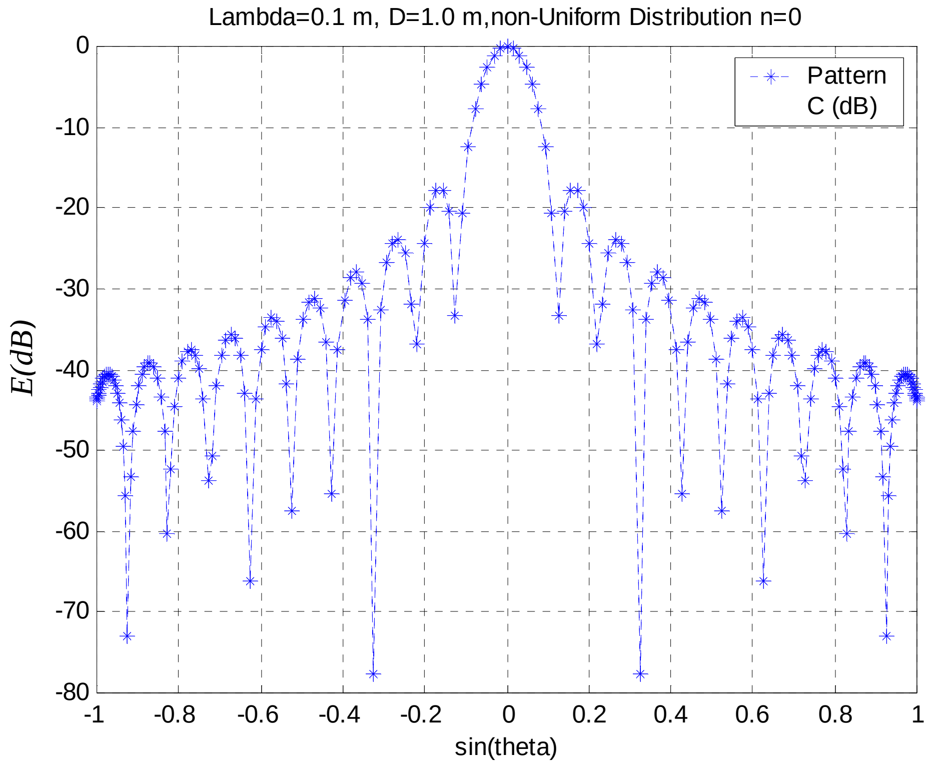
Figure (3) shows the radiation pattern of a circular aperture antenna of 1.0λ diameter as a function of field distribution function (n=0, 1, 2, 3, 4, 5).


Lambda=0.1 m, D=1.0 m,non-Uniform Distribution n=1
Pattern C (dB)
E(dB)
sin(theta)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

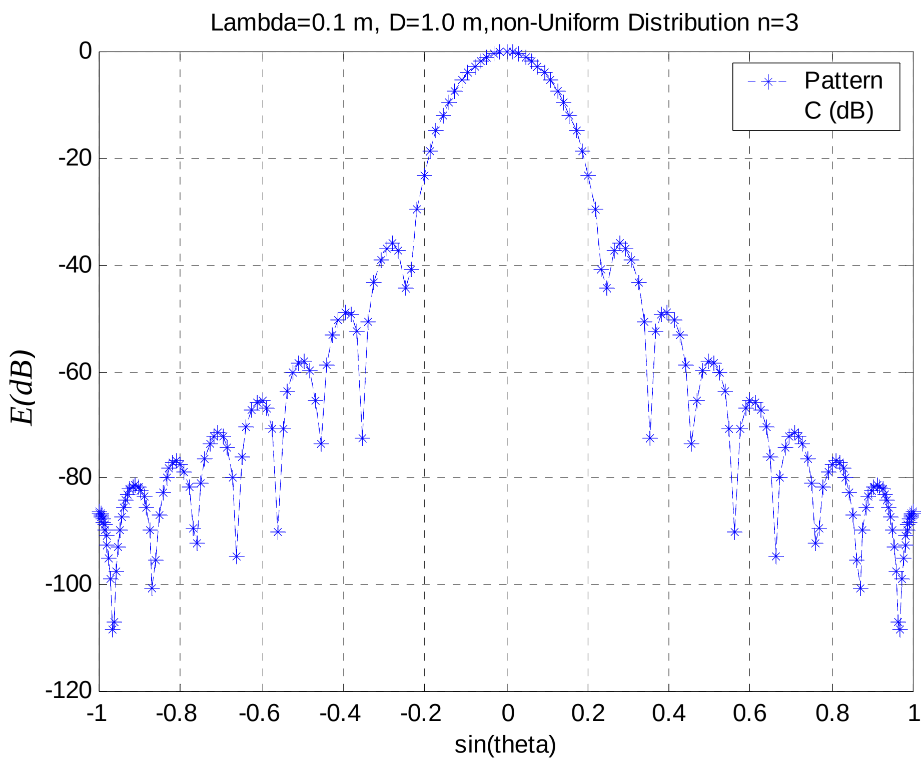
(a)


Lambda=0.1 m, D=1.0 m,non-Uniform Distribution n=2
Pattern C (dB)
E(dB)
sin(theta)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

(b)

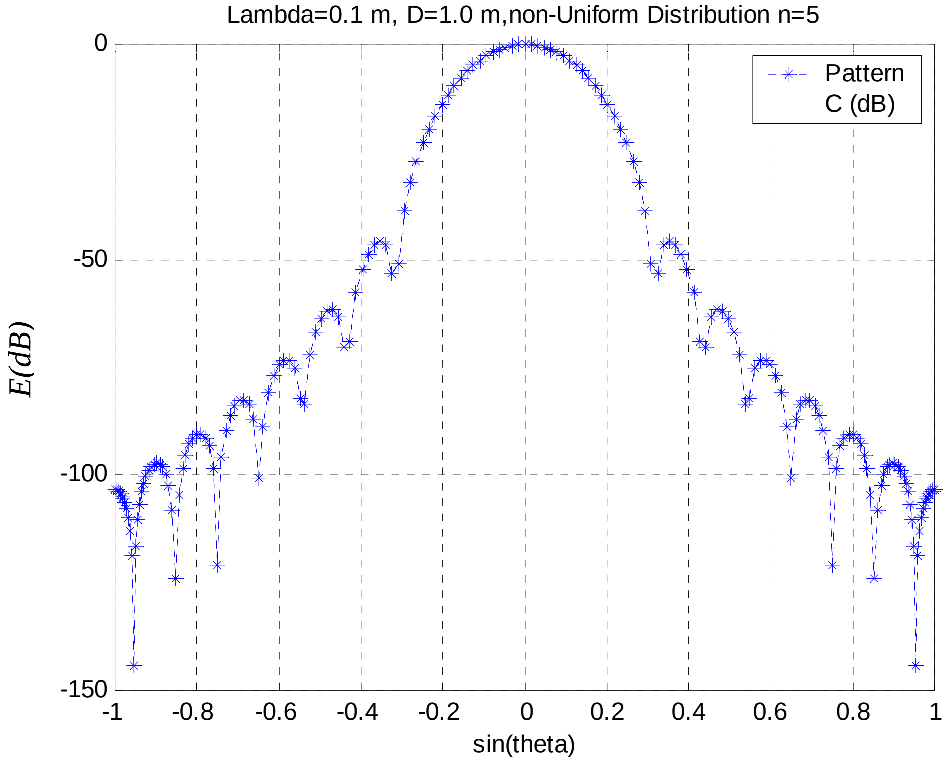

Lambda=0.1 m, D=1.0 m,non-Uniform Distribution n=0
Pattern C (dB)
E(dB)
sin(theta)
0
-10
-20
-30
-40
-50
-60
-70
-80
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

(c)


Lambda=0.1 m, D=1.0 m,non-Uniform Distribution n=3
Pattern C (dB)
E(dB)
sin(theta)
0
-20
-40
-60
-80
-100
-120
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

(d)

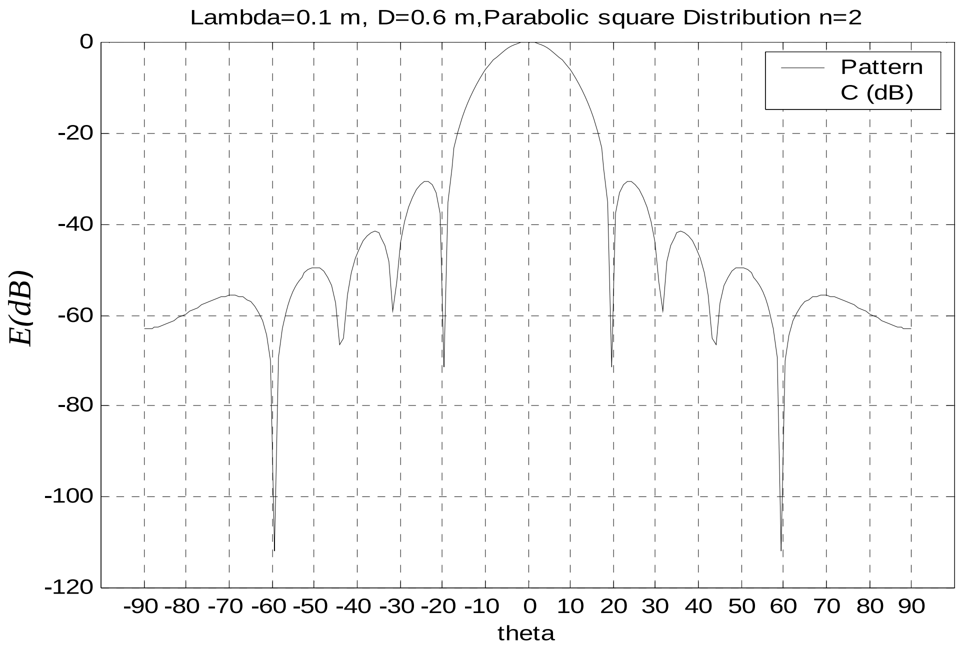
(continue)



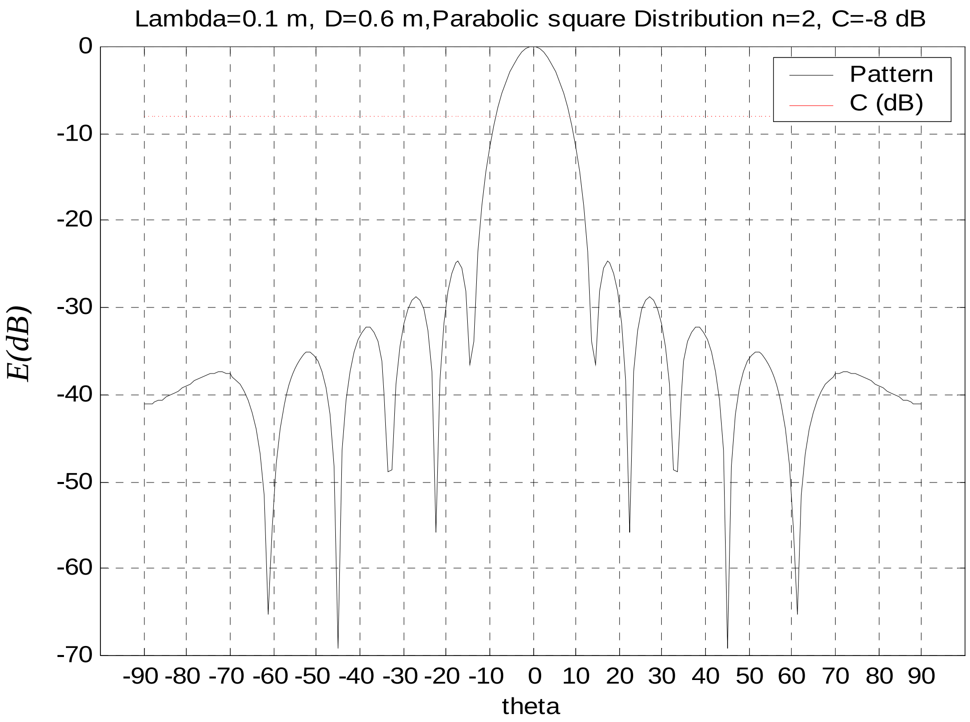
(e)

Fig.(3): Radiation pattern of 1.0l diameter as a function of n.

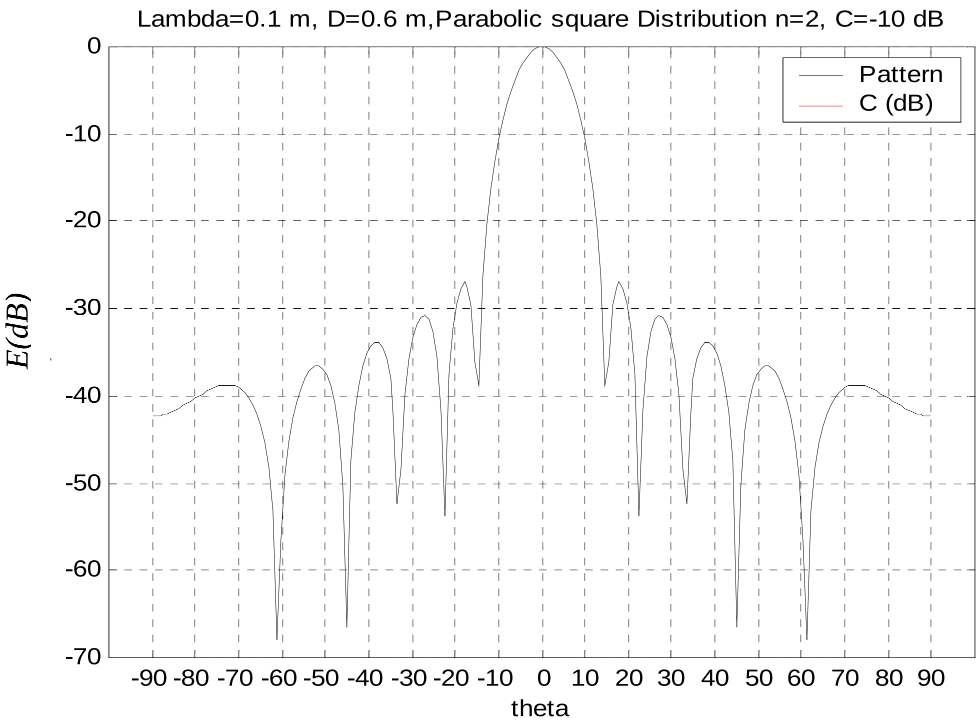
In term of studying the effect the tapering the case of 0.6□ diameter and in case of parabolic square distribution (i.e. *n=2*) the side lobe level when *n* increased or *C* decreased as shown in Fig.(4).



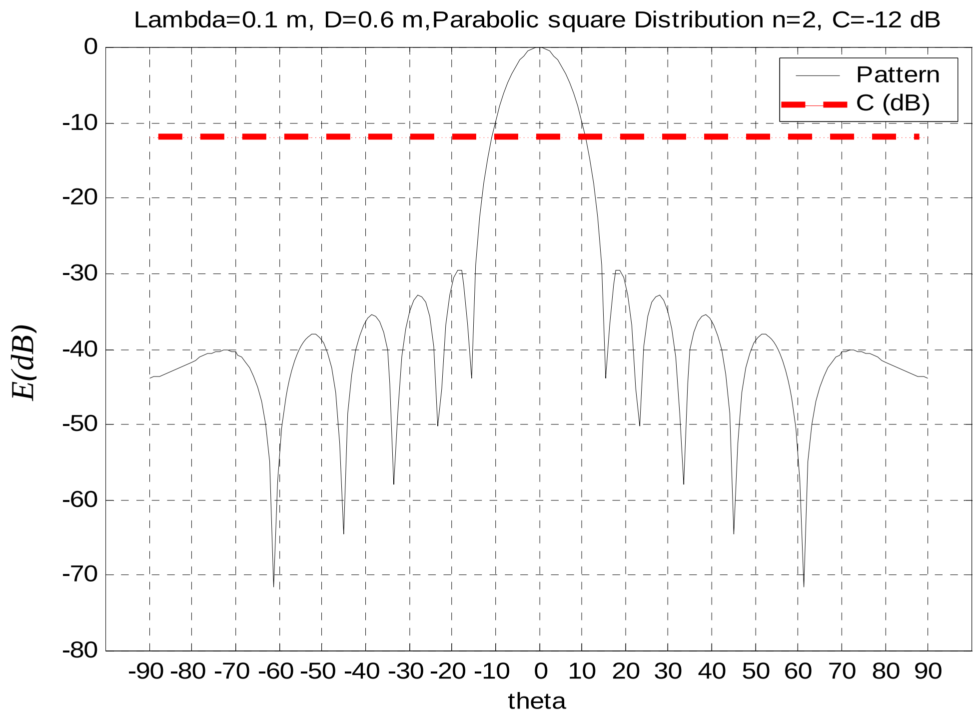
(a)


Lambda=0.1 m, D=0.6 m,Parabolic square Distribution n=2, C=-8 dB
Pattern
C (dB)
E(dB)
theta
0
-10
-20
-30
-40
-50
-60
-70
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90

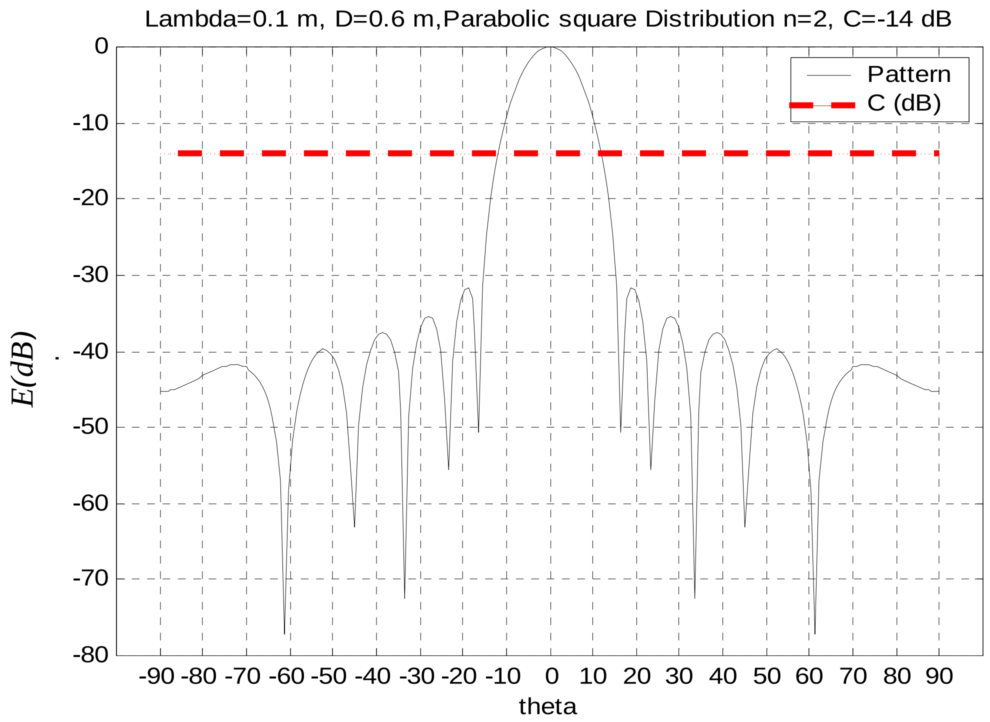
(b)


Lambda=0.1 m, D=0.6 m,Parabolic square Distribution n=2, C=-10 dB
Pattern
C (dB)
E(dB)
theta
0
-10
-20
-30
-40
-50
-60
-70
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90

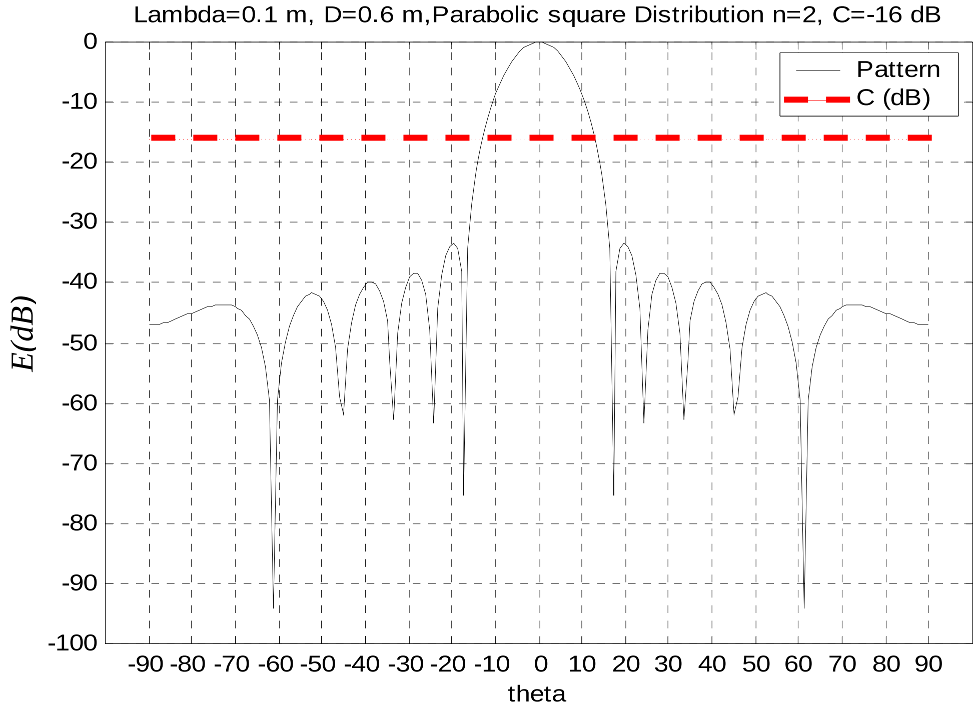
(c)


Lambda=0.1 m, D=0.6 m,Parabolic square Distribution n=2, C=-12 dB
Pattern
C (dB)
E(dB)
theta
0
-10
-20
-30
-40
-50
-60
-70
-80
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90

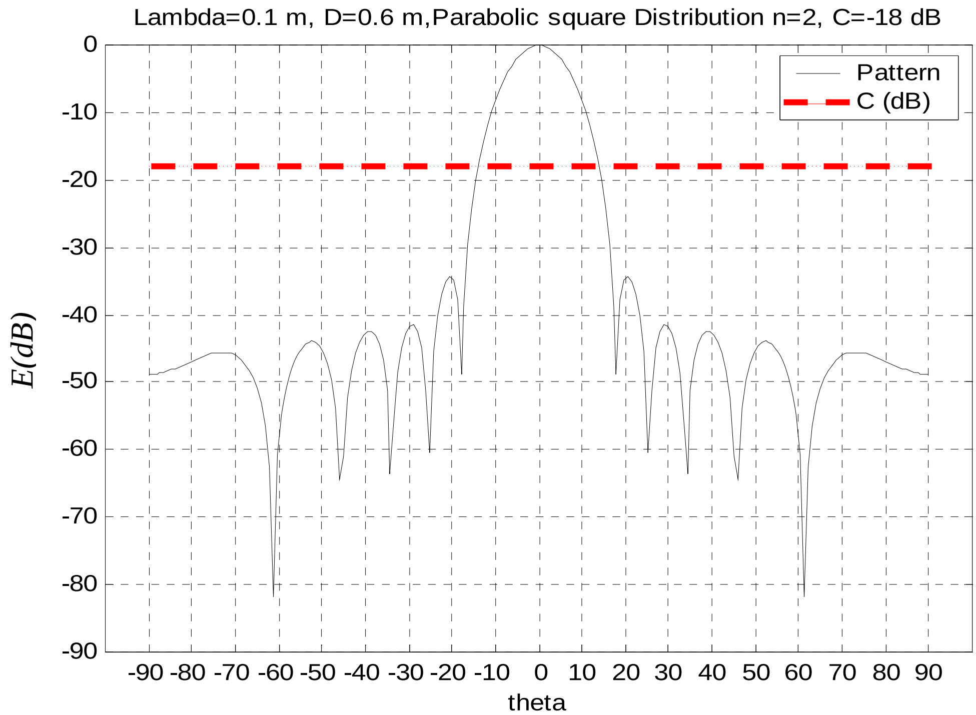
(d)


Lambda=0.1 m, D=0.6 m,Parabolic square Distribution n=2, C=-14 dB
Pattern
C (dB)
E(dB)
theta
0
-10
-20
-30
-40
-50
-60
-70
-80
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90

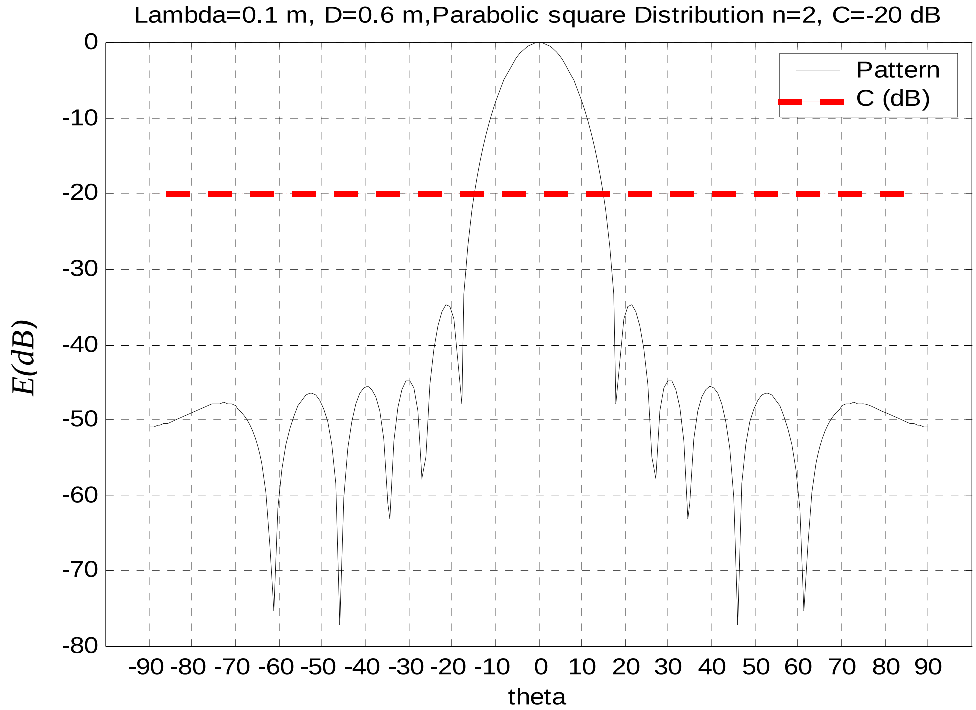
(e)


Lambda=0.1 m, D=0.6 m,Parabolic square Distribution n=2, C=-16 dB
Pattern
C (dB)
E(dB)
theta
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90

(f)


Lambda=0.1 m, D=0.6 m,Parabolic square Distribution n=2, C=-18 dB
Pattern
C (dB)
E(dB)
theta
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90

(g)



(h)

Fig.(4): Radiation pattern of 0.6 diameter as a function of C and n=2.

Discussed and Conclusions:

As shown in Fig.(3) the as *n* increased the side lobe level decreased up to -45dBas shown from Fig.(3-f) as n increased above this value the side lobe level decrease to -58.6dB as shown in Fig.(5)

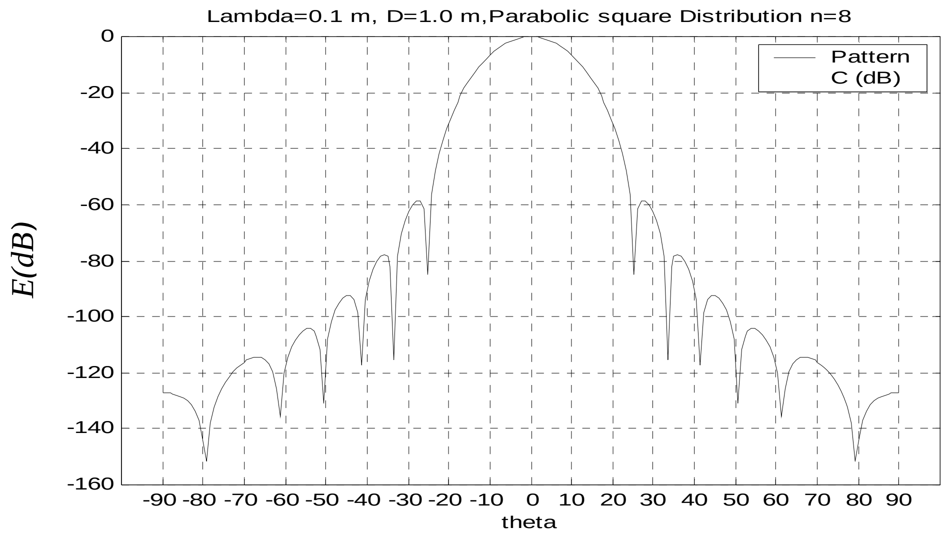


Fig.(5): Radiation pattern o f 1.0 diameter of n=8.

In term of tapering phenomenon the side lobe level is decreased with c decreased as shown in Table(1)

Table(1): Side lobe level as a function of C values with n=2

N	C	C (dB)	S.L.L present	Ref. 1
2	0.398	-8	-24.63	-24.7
2	0.316	-10	-27.00	-27.0
2	0.251	-12	-29.53	-29.5
2	0.200	-14	-31.71	-31.7
2	0.158	-16	-33.44	-33.5
2	0.126	-18	-34.41	-34.5
2	0.100	-20	-34.75	-34.7

From the above results one can conclude that:

1- The side lobe level can be controlled to reduce in term of increased *n*.
2- The directivity then decreased when side lobe decreased, this leads wide mean as shown in Fig.(6).
3- Through tapering the current distribution across the aperture, on can significantly reduce the side lobe levels.
4- By choosing the sufficient value of on can reach below -55 dB side lobe level.
5- According to the above conclusions this antenna is becomes low side lobe antenna.

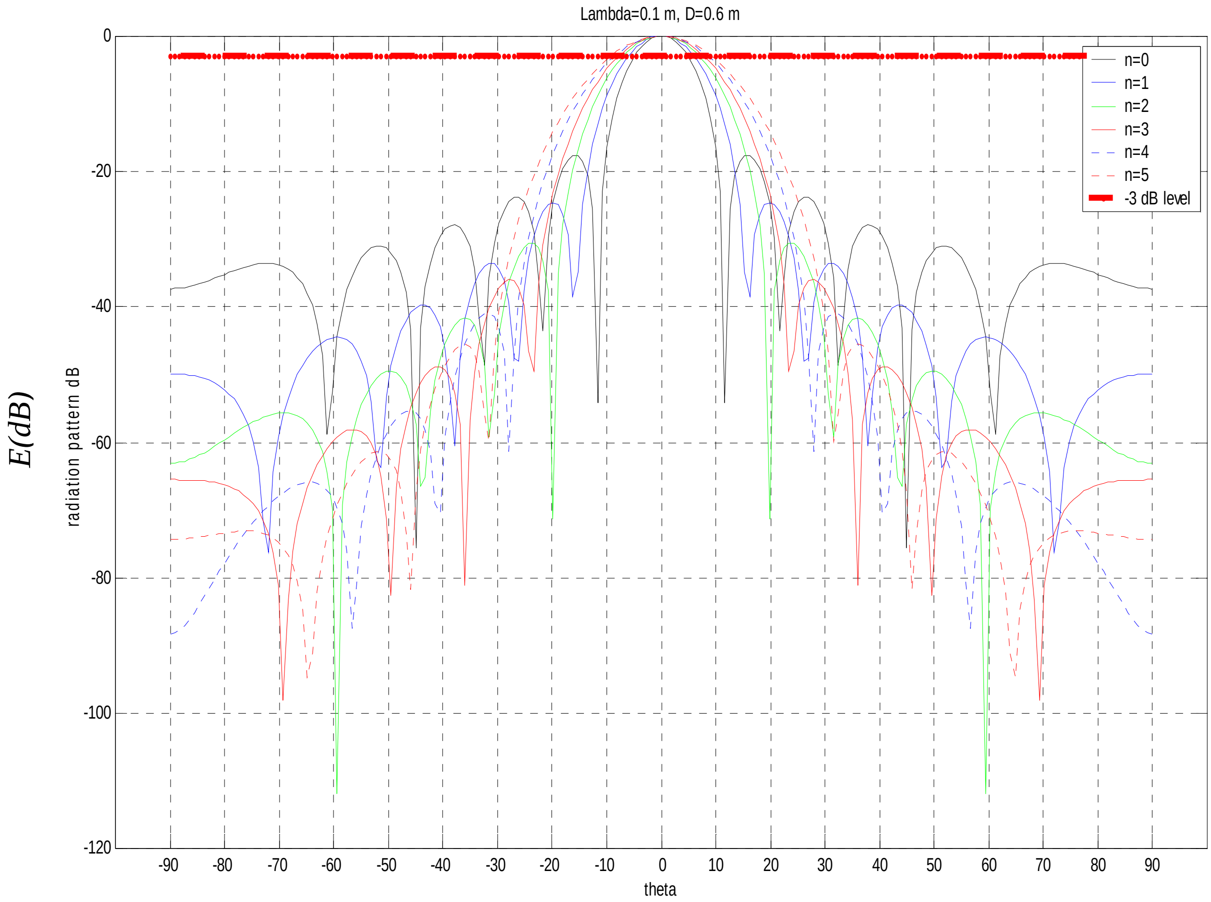


Fig.(5): compared results of different values of n

References:

1- Warren L. Stutzman and Gary A. Thiele, "Antenna Theory and Design", 2nd Ed., John Willey & Sons, Inc., New York, 1998.
2- John D. Mahony, "A note of the directivity od a uniformly excited circular aperture in an infinite ground plane", IEEE Trans. Anten. & Prapag., Vol. 47, No, 3, pp. 87-89, 2005.
3- Adriaan J. Boosyen, " Circular aperture pattern synthesis from collapsed equivalent line-source distribution", IEEE Trans. Anten. & Prapag., Vol. 52, No, 11, pp. 2904-2911, 2004.
4- L. Pazin and Y. Leviatan, " Effect of amplitude tapering and frequency phase errors on radiation characteristics of radial waveguide feed non-resonant array", IEE Proc.Microw. Anten. Propag. Vol. 151, No; 4, pp. 363-369, 2004
5- Wolf E. A., "Antenna Analysis", John Willey & Sons, Inc., New York, 1966.
6- Bassem R. Mahafza, "Radar Systems Analysis and Design Using MATLAB", Chapman & Hall/CRC, London, 2000.

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هوائي الفتحة الدائري ذي المستوى فلقات ثانوي واطئ

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الخلاصة

في هذا العمل مستوى الفلقات الثانوية لهوائي الفتحة الدائري تم تقليله بالسيطرة على قيم الأس العليا لمعادلة القطع المكافئ لمعادلة توزيع التيار. بينت النتائج انه يمكن الوصول إلى مستوى فلقـــات ثانوية اقل من 55 dB-. كما ويمكن أن نقلل مستوى الفلقات الثانوية باستخدام التوزيع المستدق لداله التيار عبر فتحة الهوائي.