RADIATION FROM PARABOLIC TYPE RADIO LINK ANTENNAS

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

RADIATION FROM PARABOLIC TYPE RADIO LINK ANTENNAS

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In this thesis, the fields scattering from parabolic reflectors with perfectly electric surface (PEC) have been investigated. The parabolic reflector surface illuminated by a point source located at focus. In order to find the surface integral, the modified theory of physical optics (MTPO) method was used and analyzed. The reflected geometrical optics (GO), transmitted fields and edge diffracted fields were evaluated by using asymptotic methods. One of these asymptotic methods was the stationary phase method (SPM), which was used to find the reflected geometrical optics and transmitted fields; and the other one was the edge point method which was used for edge diffracted fields. The scattered fields were plotted by MATLAB numerically and compared by various parameters such as angle of incidence and the distance between the sources.

Keywords:MTPO, Scattering, Diffraction Theory

ÖZ

PARABOLİK RADYO LİNK ANTENLERİNDEN YAPILAN IŞIMA

KILIÇ, Gamze

Yüksek Lisans, Elektronik ve Haberleşme Mühendisliği Anabilim Dalı

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Bu tezde, mükemmel elektrik iletken yüzeyi olan parabolik reflektörden saçılan alanlar incelenmiştir. Parabolik yüzey odakta yer alan noktasal kaynakla aydınlatılmıştır. Yüzey integralini bulmak için modifiye fiziksel optik teorisi metodu kullanılmıştır ve analiz edilmiştir. Yansıyan geometrik optik, iletilen alanlar ve köşe kırınım alanları asimptotik metotlar kullanılarak bulunmuştur. Bu asimptotik metotlardan birisi; yansıyan geometrik optiği ve iletilen alanları bulmada kullanılan sabit faz metodu ve diğeri de köşe kırınım alanları bulmada kullanılan kenar nokta yöntemi olmuştur. Kırınan alanlar MATLAB’da numerik olarak çizdirilmiştir Geliş açısı, kaynak ve reflektör arasındaki uzaklık gibi değişkenler açısından karşılaştırılmıştır.

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Anahtar Kelimeler: MTPO, Saçılma, KırınımTeorisi

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LIST OF ABBREVIATIONS

PTD	Physical Theory of Diffraction
PO	Physical Optics
CSP	Complex Source Point
MTPO	Modified Theory of Physical Optics
SPM	Stationary Phase Method
GO	Geometrical Optics
GTD	Geometrical Theory of Diffraction
PEC	Perfectly Electric Conducting
HF	High Frequency
SP	Stationary Phase

CHAPTER 1

INTRODUCTION

1.1 Background

Reflectors are mainly used in high-gain antennas. They can easily achieve gains of above 30 dB for microwave and higher frequencies. Hertz discovered the first reflector system back in 1888.This system is a cylindrical reflector fed by a dipole. On the other hand, the design of these antennas was developed mainly during the days of World War 2when a great many radar applications evolved. The simplest reflector antenna contains two components. The first of these is a reflecting surface and the other one is a much smaller feed antenna which often is located at the reflector’s focal point. Structures involve a secondary reflector that is sub reflector at the focal point. These are called dual reflector antennas. Other reflectors, which used in practice, are the cylindrical reflector, the corner reflector, spherical reflector, and others. The most known reflector is parabolic one. Parabolic reflector gathers an incoming parallel beam of electromagnetic waves and focuses them onto the antenna at the focal point or focus which is sometimes referred to as the antenna feed. Also parabolic reflectors form parabolic antennas this is used for long distance communication systems and radar applications such as a radio astronomy, microwave radar satellite, power transmission. That antenna is most common shape like a dish and is called a dish antenna.

Reflectors for scattering of waves are studied as the part of curved shapes [1]. Scattering of the waves are investigated by many researches. Cutleri researched that the design of parabolic antenna and the relation of phase polarization and amplitude of illumination to all radiation characteristics [2]. Kara; scattering of a plane wave coming with an arbitrary complex angle to the cylindrical parabolic reflector is investigated in his study[3].Asymptotic analysis of parabolic reflector antennas was researched by Hasselmann and Felsen [4]and they evaluated physical optics (PO) and Complex Source Point (CSP) in this study. Büyükaksoy and Uzgören, Akduman and Büyükaksoy studied that the scattering of the electromagnetic fields from the curved surfaces [5-6].Scattering from a cylindrical reflector which is fed by an offset electrical line source was researched by Yalçın [7].Başdemir obtained scattered fields of the inhomogeneous plane waves from a truncated cylindrical cap He used PO and Geometrical Theory of Diffraction (GTD) method to find reflected and diffracted fields [8].In literature, no research has been done about using physical optics to solve scattering wave on the impedance cylindrical parabolic. However, Umul has researched scattering waves by cylindrical parabolic impedance reflector [9].Also he applied the Modified Theory of Physical Optics (MTPO)/Malyughinetz hybrid method applies the scattering analysis of parabolic impedance reflectors [10].

Parabolic reflectors are used for scattering of electromagnetic waves which has high frequency. One of high frequency techniques is physical optics (PO). Because the wavelength affects the size of the reflector surfaces. The surfaces have to be bigger for this reason and this procedure requires essential computer time. Some series approach to the radiation integral eliminates the some of these difficulties [11-12]. Alternatively one may evaluate ray method for examine the field in the reflector. One of ray method is which indicates that in the high frequency too, Geometrical Optics (GO). For determining the good and bad zones of communication, this method is used to show us by the help of incident and reflected fields. However; this method does not include diffraction phenomena. GO fields, directly reach the observation point and not affected by the scatters. But GO does not include the diffracted fields. There are two types of popular ray-based techniques for investigation of diffraction problems. They are Geometrical theory of diffraction (GTD) [13] and its uniform version of Uniform theory of diffraction (UTD) [14]. At the caustic regions these techniques have some problems as well They give infinite field values at those regions. For eliminating these problems current-based and integral-based techniques are used. McDonald is suggested the PO technique which is one of them [15]. It is based on the integrating current, which is induced on the scatterer’s surface. PO has the advantage of leading the exact geometrical optics (GO) waves, which reflect or transmit through the scattering surface. But on the other hand it has an important defect that restricts its usage. Incorrect diffracted waves occurred by the edge point of a PO scattering integral. There is a correction factor proper by James, which gave the exact diffracted wave when multiplied by the PO diffraction field [16]. However, for the rigorous solution of a related canonical problem it needs a good determination of the correction factor. It is shown that it is possible to obtain the exact solution of the diffraction problem of electromagnetic waves by the help of a conducting half-plane with an improved form of PO [17], in 2004. The resultant diffracted field expression was similar to the Sommerfeld [18] expression. After that, by a conducting wedge [19] and impedance half-plane [20], it is extended the improved PO for the diffraction of waves. For the evaluation of the induced surface current [21-22].The improved method which is based on the usage of the concept of the variable unit vectors instead of the static unit normal vector is used. For the analysis of scattering by various objects the modified theory of physical optics (MTPO) is also used by Shijo et al. [23] and Omaki et al. [24].Another approach is the direct evaluation of the exact surface current of PO using the rigorous solutions of some canonical diffraction problems, which is the result of the MTPO philosophy. With the concept of the variable scattering angle of MTPO [25], there is such an attempt can be realized using the edge point technique. This procedure does not require the evaluation of an extra correction field and leads directly to the rigorous surface current. The exact solutions of the canonical problems which involve the PO currents can be easily applied to more complex problems like scattering of waves by curved surfaces.

Young first supposed that the physical meaning of the scattering fields which was incident and edge diffracted fields, from a knife edge. His idea allowed to show the interferences characterizes of scattered fields, however his idea did not based mathematics [26]. Various definitions of elementary edge waves (Maggi, Rubinowicz, Mitzner, Michaeli) are discussed. Maggi and Rubinowitz improved Young’s idea by using Kirshoff’s integral. Hence, they derived mathematical expressions formula for scattering fields. [27-28].They reduces forms of surface integrals to line integrals, so this theory provides investigation of the diffracted fields independently from the total scattered fields. Mitzner and Michaeli also used this surface to edge reduction technique independently [29-30]. The result of the Mitzner’s work was formulated in terms of the incremental length diffraction coefficients and the Michaeli's work was formulated in terms of the equivalent edge currents for wedge like solutions. At the corners, PO gives wrong diffracted fields. Umul has overcome this corner problem with defining the exact form of the equivalent edge currents by using the axioms of the (MTPO) [31-32].

All these mentioned fields, which are scattered fields and diffracted fields, are analyzed numerically in the numerical parts of the Chap.3 by using MATLAB.

The time factor of $\exp(jwt)$ is assumed and suppressed throughout the thesis where ω is the angular frequency.

1.2 Objectives

The primary aim of this thesis is to construction of the scattering surface integral of MTPO. The feed of parabolic PEC reflector is a point source. Then the surface integrals are evaluated asymptotically. Thus, expression of reflected, transmitted and diffracted waves is determinated and then these waves are analyzed numerically for some parameters.

1.3 Organization of the Thesis

This thesis contains four chapters. All the necessary information about the reduction of the scattering surface integral to line integral representation, methods used for the derivation of the fringe fields and numerical analysis of these fields can be found for different geometries.

Chapter 1 is an introduction to the history of parabolic reflector and objectives of this thesis.

Chapter 2 includes an introduction of the MTPO, SPM to find reflected geometrical optics and transmitted fields and EP to find edge diffracted fields technique which will be used in this thesis.

In Chapter 3, the scattering waves from a parabolic reflector, which is a PEC surface, was investigated with MTPO.

Chapter 4 includes the conclusion part.

CHAPTER 2

CURRENT BASED TECHNIQUES

2.1 Modified Theory of Physical Optics

A new method for calculating the scattered fields from a perfectly conducting body is introduced. The method has three assumptions. One of them is the reflection angle which is taken as a function of integral variables, second one is a new unit vector, dividing the angle between incident and reflected rays into two equal parts is evaluated, and finally, the perfectly conducting (PEC) surface is considered with the aperture part, together. This integral is named as Modified Theory of Physical Optics (MTPO) integral. The method is applied to the reflection and edge diffraction from a perfectly conducting parabolic antenna. The reflected, transmitted and edge diffracted fields are evaluated by stationary phase method and edge point technique, asymptotically.

A general procedure will be given in order to find the total diffracted fields by taking into account these two surfaces. Three axioms can be introduced as;

1. Scattering fields from S_1 and S_2 are surface. A surface current on S_1 is induced the incident waves and integration of this current gives the incident and reflected fields as the PO. However this solution is not included incident waves. Because of this; S_2 is considered. Equivalent currents can be defined according to Equivalent Source Theorem and radiated fields can be obtained by integrations the related currents on S_2 .Radiated fields include incident waves. A surface current can be defined for S_1 as

$$\vec{J}_{es} = \vec{n}_1 \times \vec{H}_t \Big|_{S_1} \tag{2.1}$$

where $\vec{H}_t$ is the total magnetic field on the perfectly conducting surface. Equivalent Source Theorem can be applied to S_2 and equivalent surface currents can be defined as

$$\vec{J}_{es} = \vec{n}_2 \times \vec{H}_t \Big|_{S_2} \quad , \quad \vec{J}_{ms} = -\vec{n}_2 \times \vec{E}_t \Big|_{S_2} \tag{2.2}$$

2. The reflection and transmission angles (β) are variables which depend on the surface $(S_1 + S_2)$ coordinates.
3. A new unit vector $(\vec{n}_1, \vec{n}_2)$ which divides the angle between the reflected (or transmitted) and the incident rays into two equal parts can be defined.

$$\vec{n}_1 = \cos(u+\alpha)\vec{t} + \sin(u+\alpha)\vec{n} \tag{2.3}$$

and

$$\vec{n}_2 = \cos(v+\alpha)\vec{t} - \sin(v+\alpha)\vec{n} \tag{2.4}$$

for S_2 where α is the angle of incidence $\vec{t}$ and $\vec{n}$ are the actual tangential and normal unit vectors of the surface, respectively. u and v are equal to $\frac{\pi}{2} - \frac{\alpha+\beta}{2}$. The total scattered electric field can be defined as

$$\vec{E}_t = \vec{E}_{ts} + \vec{E}_{rs} \tag{2.4}$$

where

$$E_s(P) = -\frac{jk}{2\pi}\int_0^{\theta_0}\int_0^{2\pi}\frac{e^{-jkr'}}{r'}\frac{e^{-jkR}}{R}\left(\sin\frac{\beta-\alpha}{2} + \cos\frac{\beta+\alpha}{2}\right)\frac{r'^2\sin\theta'}{\cos\frac{\theta'}{2}}\,d\theta'\,d\phi' \tag{2.5}$$

2.2 Stationary Phase Method (SPM)

The invalidation of sinusoids with varying phase is the main idea of SPM. If the same phases of the sinusoids added together, they will act constructively but on the other hand if the same phases of the sinusoids changes rapidly with the frequency changes, they will act incoherently which differs at different times as constructive or incoherent. For example PO integral. As the elements are high frequency valued or very large scattered, the calculation of the PO integral can be very complex. In order to overcome this problem SPM can be used.

SPM doesn’t depend on frequency. If frequency is higher, the solutions can be found very rapidly and accurately by SPM. İt is the one advantage method for high frequency method because SPM doesn’t depend on frequency. One of the disadvantage of this method that is only valid for high frequency.

The SPM is composed of PO integral which is given reflection and diffraction points. SPM is a method for evaluation of integrals of the form;

$$I = \int_a^{\infty} f(x) e^{-jkg(x)} dx \tag{2.6}$$

where $f(x)$ is amplitude function which is slowly varying, $g(x)$ is phase function which is rapidly varying function and a is the edge point of the integral. In the integrand I is approximately zero over the rapid oscillations of the exponential term regions. At the $dg(x)/d(x) = 0$, the only significant non-zero contributions to the integral occur in regions of the integration range. k is a large parameters.

Points of stationary phase are x_s and defined by;

$$g(x)' = 0\,. \tag{2.7}$$

Expanding $g(x)$ is a Taylor series near the point x_s and ;

$$g(x) \approx g(x_s) + \frac{1}{2} g''(x_s)(x - x_s)^2 \quad , \tag{2.8}$$

$f(x)$ is assumed to be slowly varying at the points where $f(x) = f(x_s)$ in the vicinty of the stationary phase, and also this term can be pulled outside the integral. Hence, the integral takes the form as;

$$I \approx f(x_s) e^{-jkg(x)} \int_a^{\infty} e^{-jkg''(x_s)(x-x_s)^2/2} dx\,. \qquad (2.9$$

If error function, which is defined as $\int_{-\infty}^{\infty} e^{-y^2/2} dy = \sqrt{2\pi}$, is written the Eq (2.8), stationary phase integral can be given by;

$$I_{SP} \approx e^{-j\frac{\pi}{4}} \sqrt{2\pi} \frac{f(x_s)}{\sqrt{kg''(x_s)}} e^{-jkg(x_s)}\,. \tag{2.10}$$

2.3 Edge Point Technique

When PO integral calculate on the edge diffracted waves, the edge point's results can be incorrect. A typical diffraction integral can be considered to be;

$$A = \int_a^b f(x) e^{-jkg(x)} dx \tag{2.11}$$

k is a large parameters. Eqn. (2.11) can be writing again as;

$$A = \int_a^b \frac{f(x)}{g'(x)} g'(x) e^{-jkg(x)} dx \tag{2.12}$$

This integral can be solved partial integral as;

$$A = \frac{1}{jk}\left[\frac{f(a)}{g'(a)} e^{-jkg(a)} - \frac{f(b)}{g'(b)} e^{-jkg(b)}\right] + \frac{1}{jk}\int_a^b \frac{f'(x)g(x) - f(x)g'(x)}{\left[g'(x)\right]^2} e^{-jkg(x)} dx \tag{2.13}$$

As the k is the very large number, the second integral can be neglected. Hence, the result of integration can be found;

$$A \approx \frac{1}{jk}\left[\frac{f(a)}{g'(a)} e^{-jkg(a)} - \frac{f(b)}{g'(b)} e^{-jkg(b)}\right] \tag{2.14}$$

CHAPTER 3

SCATTERING BY PARABOLIC REFLECTOR

3.1 Parabolic Reflector Application

The geometry of the problem is given by Fig.1.Where f is the focal length of the PEC reflector, P is the observation point and Q is the reflection points, θ' is the angle of incidence, r is the distance between the source and P, r' is the distance between the source and the reflector, $\vec{n}$ is the unit normal vector and R is the ray path. The angle between $\vec{n}$ and r', $\vec{n}$ and R are equal to α and β respectively. The PEC parabolic reflector is lying between the angles 0 and θ_0.

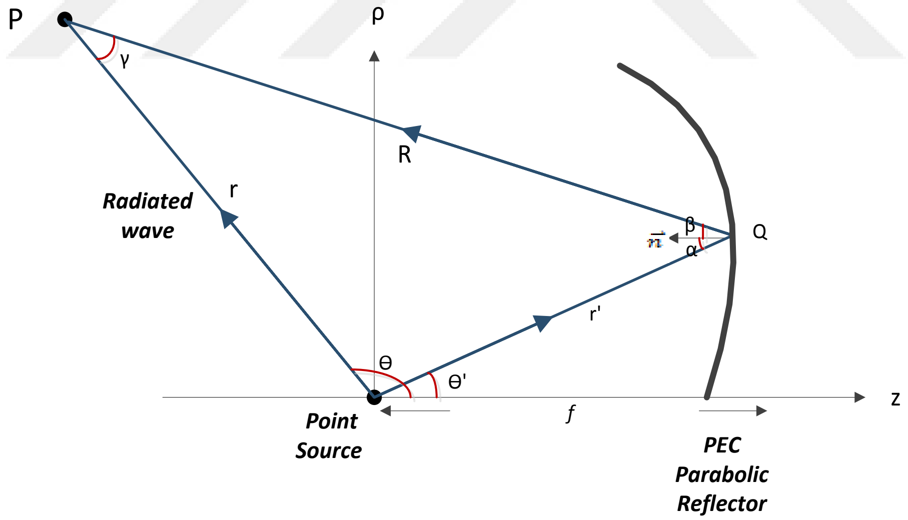

Figure 1 Geometry of the Parabolic Reflector

A parabolic reflector is fed by a point source. The radiated waves from the source can be given by

$$\vec{E}_i = \vec{e}_z E_0 \frac{e^{-jkr'}}{r'} \quad , \tag{3.1}$$

where E_0 is the complex amplitude and $\vec{e}_z$ is polarization of incident wave. The induced electric surface current can be defined as

$$\vec{J}_{PO} = 2\vec{n} \times \vec{H}_i \Big|_s , \tag{3.2}$$

where $\vec{n}$ is the unit vector and equal to $\cos\frac{\theta^{'}}{2}\vec{e}_r + \sin\frac{\theta^{'}}{2}\vec{e}_\theta$ and incident magnetic field is

.
$$\vec{H}_i = E_0 \frac{k}{\omega\mu_0} \sin\theta \frac{e^{-jkr}}{r} \vec{e}_\phi \tag{3.3}$$

By using the Maxwell-Faraday equations. PO scattering integral can be constructed by using the magnetic vector potential. Magnetic vector potential is written as

$$\vec{A} = \frac{\mu_0}{4\pi} \iint_S \vec{J}_{PO} \frac{e^{-jkR}}{R} dS , \tag{3.4}$$

for the PO current. PO current is inserted into Eq. (3.4) and the integral of magnetic vector potential is defined as;

$$\vec{A} = \frac{\mu_0}{4\pi} \int_0^{\theta_0} \int_0^{2\pi} \frac{e^{-jkr^{'}}}{r^{'}} \frac{e^{-jkR}}{R} (\sin\frac{\beta-\alpha}{2} + \cos\frac{\beta+\alpha}{2}) \frac{r^{'2} \sin\theta^{'}}{\cos\frac{\theta^{'}}{2}} d\theta^{'} d\phi^{'} \tag{3.5}$$

The expression of the uniform scattered electric field can be obtained from

$$\vec{E}_S \cong -jw\vec{A} , \tag{3.6}$$

where this notation is valid for the far field which is $k\rho >> 1$. So, scattered electric field expression is obtained as;

$$E_s(P) = -\frac{jk}{2\pi} \int_0^{\theta_0} \int_0^{2\pi} \frac{e^{-jkr^{'}}}{r^{'}} \frac{e^{-jkR}}{R} (\sin\frac{\beta-\alpha}{2} + \cos\frac{\beta+\alpha}{2}) \frac{r^{'2} \sin\theta^{'}}{\cos\frac{\theta^{'}}{2}} d\theta^{'} d\phi^{'} \tag{3.7}$$

3.2 Construction of the Scattering Integral

The scattering fields from the parabolic reflector can be obtained by using the surface integral, given by Eq. (3.7).The equation of the parabolic reflector can be written spherical coordinate system.

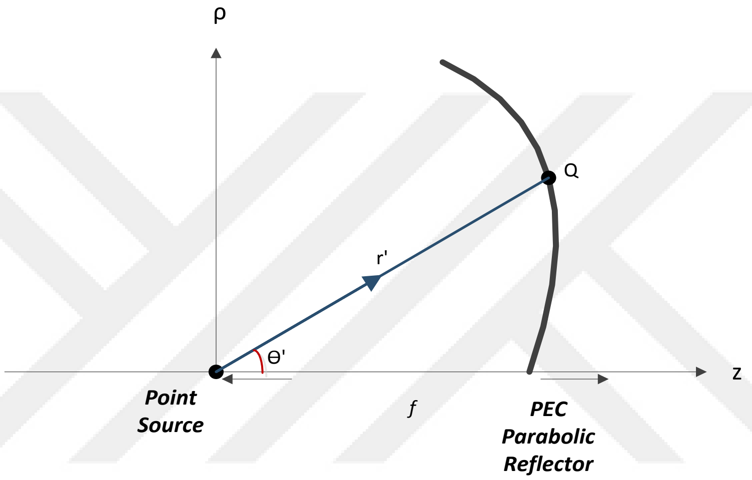

Figure 2 Geometry of the $r^{'}$

According to the distance between source and the reflection point as is given as;

$$\rho^{2} = 4f(f - z) \tag{3.8}$$

where ρ and z are $r^{'}\sin\theta^{'}$ and $r^{'}\cos\theta^{'}$ respectively. ρ and z is written at Eq. (3.8);

$$r^{'} = \frac{2f}{1+\cos\theta^{'}} = \frac{f}{\cos^{2}\dfrac{\theta^{'}}{2}}\,. \tag{3.9}$$

$r^{'}$ is found by Eq.(3.9) and R equal to $\left[r^{2} + r^{'2} + 2rr^{'}(\sin\theta\sin\theta^{'}\cos(\phi-\phi^{'})) + \cos\theta\cos\theta^{'}\right]^{1/2}$. α and β are described according to normal vector of the parabolic surface. The integral is evaluated asymptotically for large values of k .The $\phi^{'}$ part of integral can be calculated with using SPM. According to SPM the phase function is;

$$g(\phi^{'}) = R\,. \tag{3.10}$$

To find stationary phase (SP) point, firstly we will take derivative of the phase function according to $\phi^{'}$ which gives

$$\frac{dg}{d\phi^{'}} = \frac{-rr^{'}\sin\theta\sin\theta^{'}\sin(\phi-\phi^{'})}{R} . \tag{3.11}$$

We can find the SP point by equating to Eq. (3.11) to zero .Then stationary phase point is found as;

$$\phi_s^{'} = \phi \tag{3.12}$$

where R_s is the ray path at the $\phi_s^{'} = \phi$ and equal to $\left[r^2 + r^{'2} - 2rr^{'}\cos(\theta-\theta^{'})\right]^{1/2}$.

The second derivative of phase function is at stationary phase point;

$$\frac{d^2 g}{d\phi^{'2}} = R_s^{''} = -\frac{\sin\theta\sin\theta^{'} rr^{'}}{2R} . \tag{3.13}$$

The amplitude function takes the form as,

$$f(\phi_s) = \frac{e^{-jkr^{'}}}{r^{'}}\left(\sin\frac{\beta-\alpha}{2} + \cos\frac{\beta+\alpha}{2}\right)\frac{r^{'2}\sin\theta^{'}}{\cos\frac{\theta^{'}}{2}}\frac{1}{R} . \tag{3.14}$$

Hence the scattering integral takes the form as;

$$E_s = e^{-j\frac{\pi}{4}}\frac{-jk}{\sqrt{2\pi}}\frac{1}{\sqrt{r\sin\theta}}\int_0^{\theta_0}\frac{e^{-jk(r^{'}+R)}}{\sqrt{kR}}\left(\sin\frac{\beta-\alpha}{2} + \cos\frac{\beta-\alpha}{2}\right)\frac{\sqrt{r^{'}\sin\theta^{'}}}{\cos\frac{\theta^{'}}{2}}d\theta^{'} \tag{3.15}$$

with using Eq. (3.10), (3.11), (3.13) and Eq. (3.14). The stationary phase method can be used SPM can be used to for the evaluation of the $\theta^{'}$ part of the reflected and transmitted GO integral. And the method of the edge technique is also used for calculating the edge diffracted integral.

3.3-Asymptotic evaluation of the scattering integral

In this section, evaluating of the scattering integral;

$$E_s = e^{-j\frac{\pi}{4}} \frac{-jk}{\sqrt{2\pi}} \frac{1}{\sqrt{r\sin\theta}} \int_0^{\theta_0} \frac{e^{-jk(r^{'}+R)}}{\sqrt{kR}} \left(\sin\frac{\beta-\alpha}{2} + \cos\frac{\beta-\alpha}{2} \right) \frac{\sqrt{r^{'}\sin\theta^{'}}}{\cos\frac{\theta^{'}}{2}} d\theta^{'} \tag{3.16}$$

k is the very large number.

Reflected and transmitted waves are evaluated the SPM. Detailed information about this technique is given in Chap (2.2). According to Eq. (2.6) phase function is;

$$g(\theta^{'}) = r^{'} + R \tag{3.17}$$

And $R = r\cos\gamma + r^{'}\cos(\beta+\alpha)$ hence $g(\theta^{'})$ is also rewrite is that;

$$g(\theta^{'}) = r^{'}\left[1+\cos(\beta+\alpha)\right] + r\cos\gamma + \tag{3.18}$$

where γ is $\pi-\alpha-\beta-\theta+\theta^{'}$ according to Fig. 1 The first derivative of the phase function is found to be

$$\frac{dg}{dg^{'}} = \frac{r^2}{\cos\frac{\theta^{'}}{2}}\left[\sin\alpha - \sin\beta\right]. \tag{3.19}$$

when The SP point of the scattering integral can be found by equating the first derivative to zero The SP point find that $\beta_s = \alpha_s = \frac{\theta_s}{2}$ and $\beta_s = \pi - \alpha_s$ for the reflected and transmitted waves.

3.3.1 Reflected GO Waves

The geometry of the problem is given by Fig. 3. Where P is the observation point, θ_s is the SP value of $\theta^{'}$, r is the distance between the source and P, l_0 is the distance between the source and the reflector and l is the ray path. The angle between l_0 and l equal to θ_s. The PEC parabolic reflector is lying between the angles 0 and θ_0.

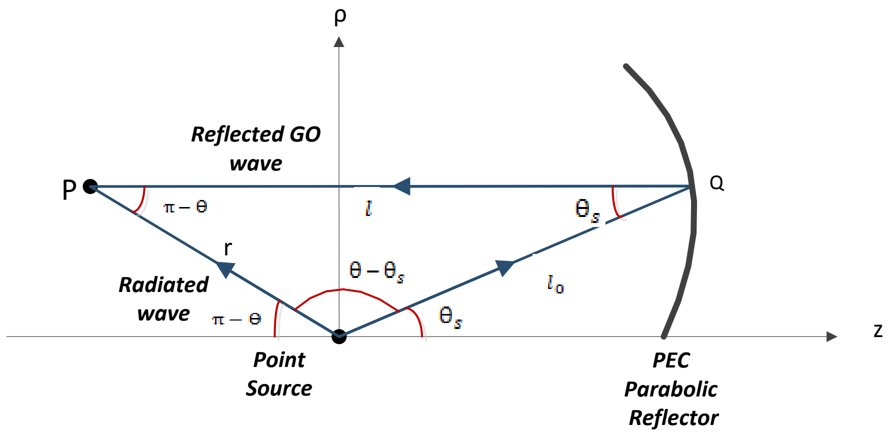

Figure 3 SP Geometry of the Reflected Wave

The second derivative of phase function can be evaluated as;

$$\frac{d^2 g}{d\theta'^2} = \frac{r'}{\cos\frac{\theta'}{2}}\left[\frac{1}{2}\cos\alpha - \cos\beta\frac{d\beta}{d\theta'}\right]. \tag{3.20}$$

The sine relation of

$$r'\sin(\alpha+\beta) = r\sin\gamma. \tag{3.21}$$

can be obtained from the triangle in Fig.3The expression of ;

$$\frac{d\beta}{d\theta'} = \frac{1}{2} - \frac{r'}{R}\frac{\cos\beta}{\cos\frac{\theta'}{2}}. \tag{3.22}$$

can be derived by using derivations of Eq. (3.21) and γ is $\pi - \alpha - \beta - \theta + \theta'$.

Hence, the second derivative of the phase function can be rewritten as;

$$\frac{d^2 g}{d\theta'^2} = \frac{r'}{\cos\frac{\theta'}{2}}\left[\frac{1}{2}\cos\alpha - \cos\beta - \frac{2r'}{R}\frac{\cos^2\beta}{\cos\alpha}\right]. \tag{3.23}$$

Eq.(3.23) is showed that the reflected GO ray is parallel to x axis. The second derivative is at SP;

$$\left.\frac{d^2 g}{d\theta'^2}\right|_s = \frac{l_0^2}{l} \tag{3.24}$$

l_0 and l are the SP values of $r^{'}$ and R at respectively. The amplitude function is;

$$f(\theta_s) = e^{-j\frac{\pi}{4}} \frac{-jk}{\sqrt{2\pi}} \frac{\sqrt{r^{'}\sin\theta^{'}}}{\cos\frac{\theta^{'}}{2}} \sqrt{\frac{l_0}{l}} \tag{3.25}$$

at the SP point. As a result GO can be evaluated as;

$$\vec{E}_{rGO} = u_0 \frac{e^{-jk(l_0+l)}}{l_0} U(\pi - \theta - \theta_1) \tag{3.26}$$

for $k >> 1$.The angles θ_s varies between 0 and θ_0 . θ_1 is $\sin^{-1}(\frac{r_0}{r}\sin\theta_0)$ and r_0 equal to $\frac{2f}{1+\cos\theta_s}$ be defined. From Eq.(3.9) and Eq.(3.13) l_0 and l can be written as l_0 and l are $\frac{2f}{1+\cos\theta_s}$ and $\sqrt{r^2 + l_0^2 - 2rl_0\cos(\theta - \theta_0)}$ respectively and θ_s is found that $\tan^{-1}\frac{r\sin\theta}{2f}$ in Fig.3. İt's obvious that the reflected wave is plane wave and the source fed focus at parabolic reflector.

3.3.2 Transmitted Waves

The geometry of the problem is given by Fig. 4. Where P is the observation point and Q is the reflection points , θ_s is the SP value of $\theta^{'}$, r is the distance between the source and P , l_0 is the distance between the source and the reflector and l is the ray path. The angle between l_0 and l equal to θ_s. The PEC parabolic reflector is lying between the angles $-\theta_0$ and θ_0.

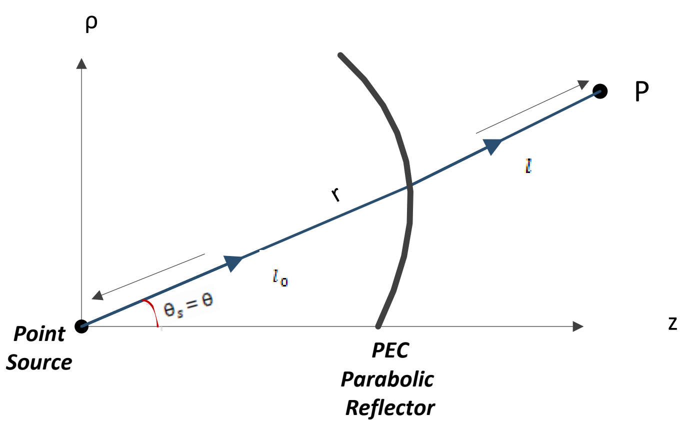

Figure 4 SP Geometry of the Transmitted Wave

The transmitted GO field can be evaluated by using the SP at $\beta_s = \pi - \alpha_s$. At that point θ_s is also equal to θ.If transmitted SP is examined in Eq.(3.20), the second derivative can be found as

$$\left.\frac{d^2 g}{d\theta^{2}}\right|_s = l_0 (1 + \frac{l_0}{l}) . \tag{3.27}$$

The amplitude function is given in Eq.(3.14).When SPM is applied transmitted GO can be evaluated as;

$$E_{tGO} = u_0 \frac{e^{-jkr}}{r} \left[u(-\theta_0 - \theta \right], \tag{3.28}$$

by taking into account Eq.(3.16), (3.14) and Eq.(3,27). $U(x)$ is the unit step function that is equal to 1 for $x > 0$ and to zero, otherwise. These functions are used in the field because there is no transmitted waves between the angles $\left[-\theta_0, \theta_0\right]$.The transmitted field is same as incident field and the parabolic surface blocking for this wave the same for the angle values which is θ_s equal to θ.

3.3.3 Edge Diffracted waves

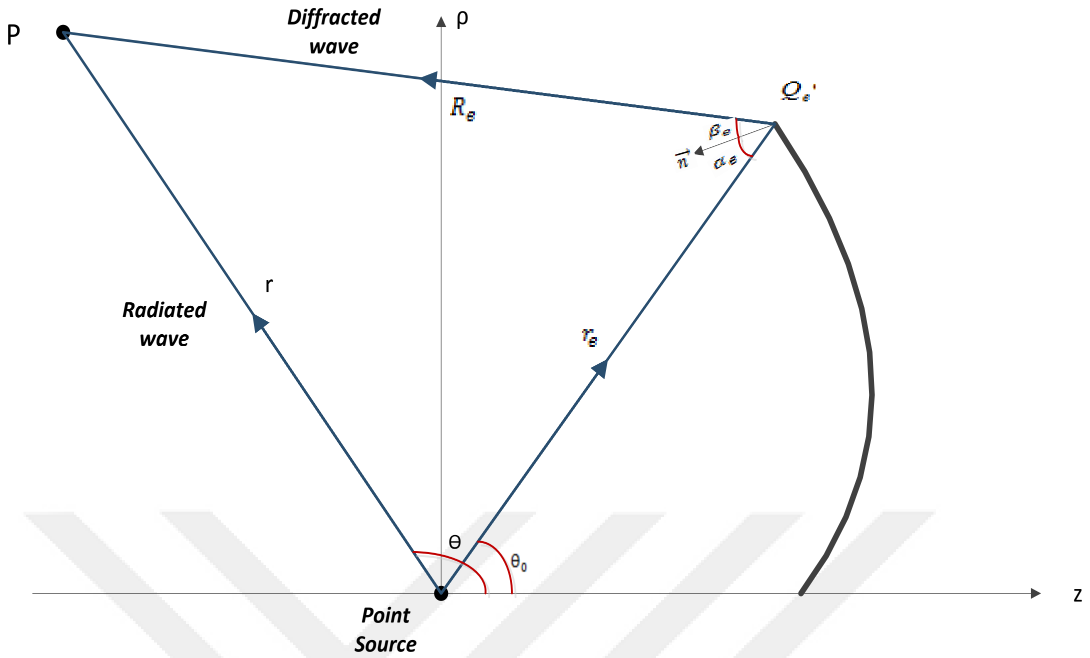

Figure 5 Geometry of the Edge Diffracted Waves

The edge diffracted fields can be evaluated separately from Eq. (3.17) for the transmitted and reflected waves by using the edge points method. In Fig. 5. gives the geometry of the problem. Where Q_e shows the edge points reflector. The diffracted waves θ' equal to θ . α_e .can be defined as $\theta_0/2$ .The value of β_e can be evaluated as

$$\beta_e = \pi - \theta + \frac{\theta_0}{2} - \sin^{-1}\frac{r_e \sin(\theta - \theta_0)}{R_e}, \tag{3.29}$$

at the edge of the scatterer where R_e is the ray path from edge to observation point

$$R_e = \sqrt{r^2 + r_e^2 - 2rr_e \cos(\theta - \theta_0)}, \tag{3.30}$$

r_e is defined by the equation of

$$r_e = \frac{2f}{1 + \cos\theta_0}. \tag{3.31}$$

It can be evaluated from the integral Eq.(3.16). Edge diffracted field can be examined the method of edge point in parabolic reflector. Edge points integral is given at Eq. (2.10). According to this phase function can be written;

$$g(e) = r_e + R_e \tag{3.32}$$

The phase function of Eq. (3.16) is written as;

$$f(e) = e^{-j\frac{\pi}{4}} \frac{-jk}{\sqrt{2\pi}} \frac{\sqrt{r_e \sin\theta'}}{\cos\frac{\theta'}{2}} \frac{1}{\sqrt{r\sin\theta}} \frac{1}{\sqrt{R_e}} \left(\sin\frac{\beta_e - \alpha_e}{2} + \cos\frac{\beta_e + \alpha_e}{2} \right). \tag{3.33}$$

As a result of the edge diffracted fields can be evaluated as

$$E_d = \frac{\sqrt{r_e \sin\theta_0}}{\sqrt{2\pi r \sin\theta R_e}} \frac{e^{-jk(r_r + R_e)}}{r_e} \left(\frac{1}{\cos\frac{\beta_e + \alpha_e}{2}} - \frac{1}{\sin\frac{\beta_e - \alpha_e}{2}} \right), \tag{3.34}$$

In Eq. (3.34) the first term is reflected diffracted wave. the second term of equation is the transmitted diffracted field at the shadow boundary.

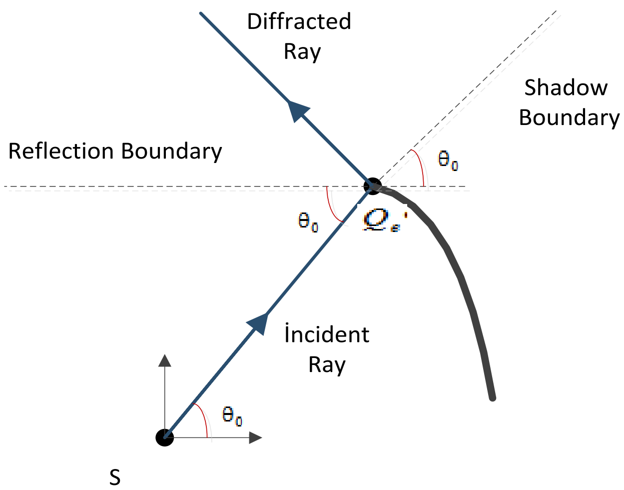

Figure 6 Transition Region

Figure 6 shows the places of the transition regions. The reflection and shadow boundaries are determinated according to boundary of the parabolic reflector.

3.4 -Numerical Results

In this part, the scattering and edge diffracted waves from the parabolic reflector will be analyzed numerically. The distance of focal point is 2λ. λ is a wavelength. Initially the distance between the source points to the observation point will be taken as 6λ, 4λ and 2λ. The value of θ_0 is $\pi/4$. In the second phase, r will be taken as 6λ and θ_0 will vary from $\pi/3, \pi/4, \pi/6$. The results will be analysed by using the graphs, obtained in MATLAB.

3.4.1 - Reflected GO Fields

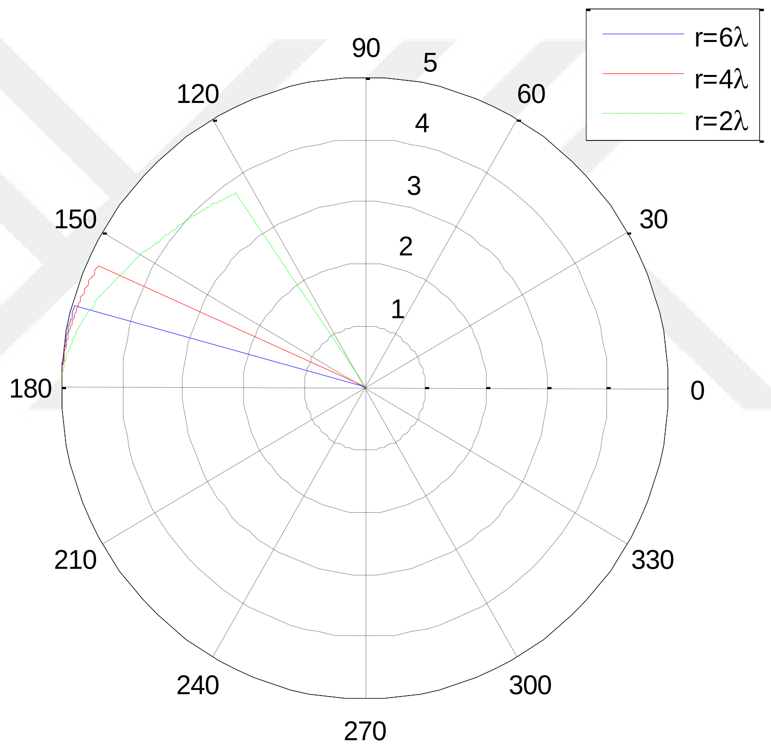

Figure 7 Reflected GO Field for Different Values of r

The field variation of the reflected GO field according to the angle of observation θ_0 is by using Eq. (3.26). θ_1 equals to $\sin^{-1}(\frac{r_0}{r}\sin\theta_0)$. Figure7 shows the reflected GO wave from parabolic reflector. The variation of the distance between the source to the observation point, which is shown r, versus the observation angle θ. The value of r is taken as 6λ, 4λ and 2λ.

θ_0 eqauls to $\pi/4$ It can be observed thatsource is became distance from observation point the value of θ' is increased and the width of the reflected wave is increased.

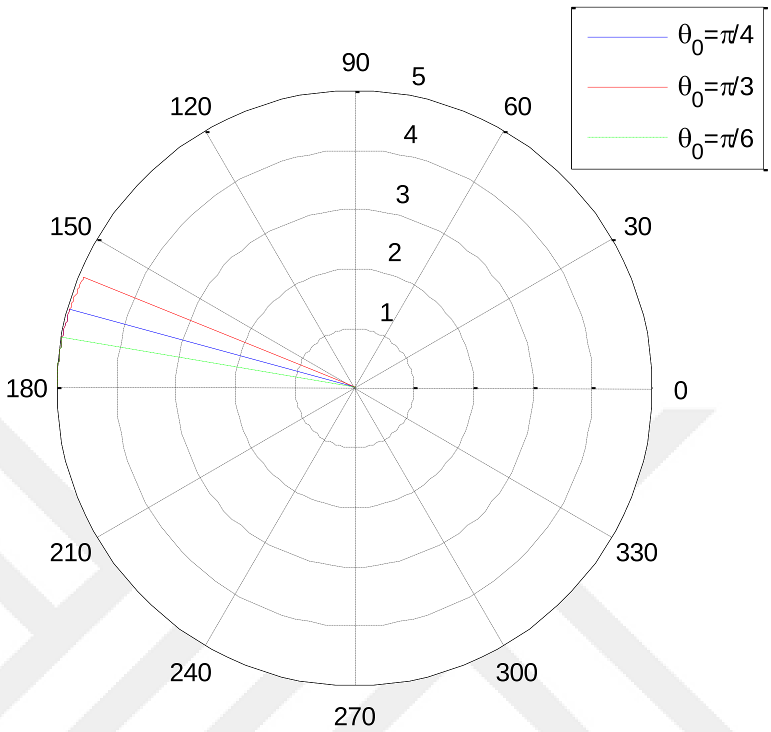

Figure 8 Reflected GO Field for Different Values of θ_0

In Fig. 8 shows the variation of the reflected GO wave from the PEC parabolic reflector for different value of incident angle (θ_0) which changes $\pi/4$, $\pi/3$ and $\pi/6$. The focal length and the distance of observation (r) are taken as 2λ and 6λ respectively.It can be seen that if θ_0 is taken as increasing value,reflected region will enlarge.Amplitude's value does not changed.

3.4.2 Transmitted Waves

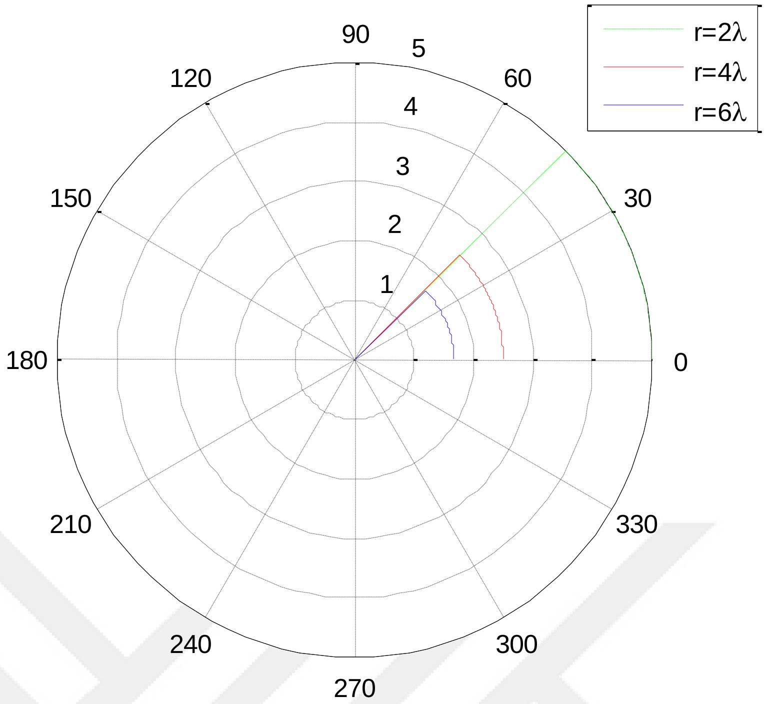

Figure 9 Transmitted GO Field for Different Values of r

Using Eqn.(3.28) is plotted that the field of variation of the transmitted GO field according to angle of observation point.Transmitted field is same as incident field and the parabolic surface blocking for this wave the same for the angle values which is θ_s equal to θ.In Fig.8the variation of the transmited field by a parabolic reflector versus to r.The value of r is taken as 6λ and 4λ and 2λ. and θ_0 eqauls to $\pi/4$ and the focal point is 2λ. It can be observed from the figure that the amplitude of field decreases,while r increased.

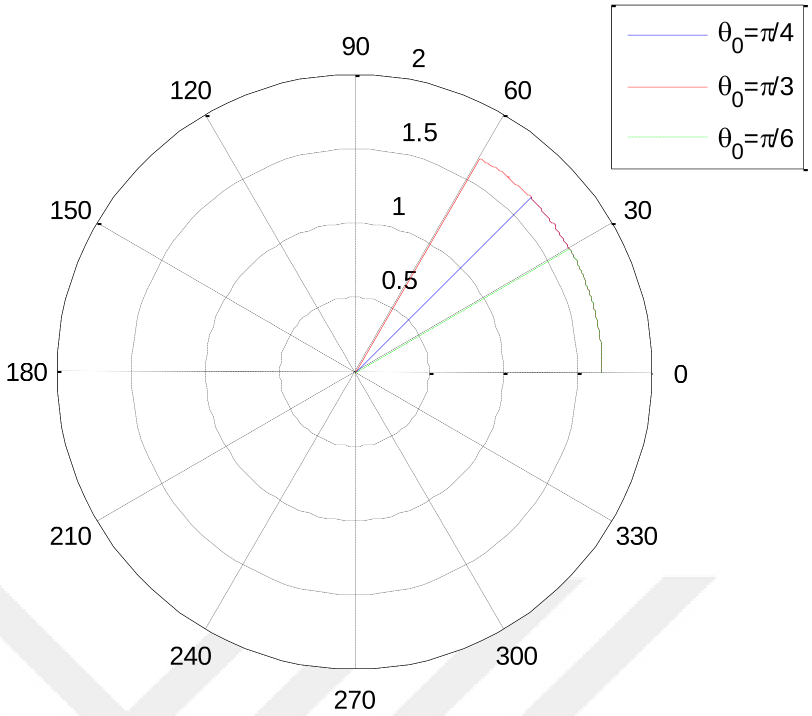

Figure 10 Transmitted GO Field for Different Values of θ_0

The figure depicts the transmitted wave is plotted for various values of θ_0 by using Eqn (3.28) the angles of θ_0 changes $\pi/4, \pi/3$ and $\pi/6$ .r is takes as 6λ and the value of f 2λ It can be seen that the level of transmitted fields decreasea the parabola widthdecrease.(θ' is decreased.) İt can be observed that the amplitude of the field does not change.

3.4.3Edge Diffracted Waves

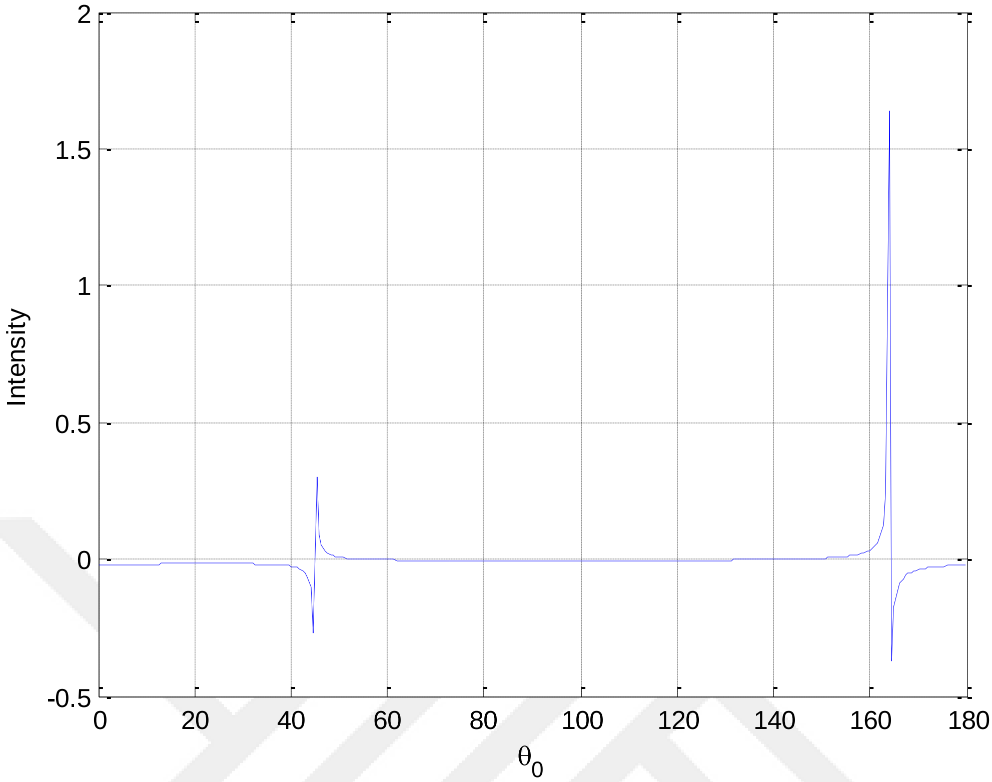

Figure 11 Edge Diffracted Field

The field variation of the edge diffracted field according to the angle of observation θ_0 is by using Eq. (3.34). This equation is plotted for analyzing edge diffracted waves. In this figure shows that diffracted edge waves from the parabolic surface. The distance of observation point (r) is taken 2λ and $\theta_0 = 45^0$ .It can be observed from the figure discontinuities points are at $\theta_e = 45^0$ and $\theta_e = 163.5^0$. 45^0 shows shadow boundary and 163.5^0 depicts reflection boundary .

CHAPTER 4

CONCLUSION

In this study; we obtained scattering integral for a point source fed parabolic PEC reflector by using surface integral of MTPO. When although the MTPO scattered field included the edge diffraction it gives wrong values. The problem was found by using spherical coordinates. MTPO integral evaluated asymptotically. Asymptotic evaluations of the integrals gave the GO fields (reflected and transmitted) and edge diffracted fields. Reflected and transmitted fields were found by using SPM. Inıtially; the stationary phase point of the scattering integral can be found by equating the first derivative of phase function to zero. Two values of stationary phase points were found. These values were evaluated for the reflected and transmitted scattered waves. As a result of SPM; reflectedfield was plane wave and transmitted wave was the same with the incident field. Then edge point theorem was used to find edge diffracted fields. The scattering integrals were evaluated for transmitted and reflected scattered waves. Finally; the GO fields and edge diffracted fields were analyzed numerically for some parameters such as the distance between observation point and focal point and incident angle.

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APPENDICES A

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