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Performance Analysis of Diffraction Gain (G_d) Due to presence of Knife-Edge as Compared to Free Space E-Field and Identifying the Position of Obstacle in a Fresnel Zone

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Abstract- This paper describes the concepts of diffraction, diffraction gain, diffraction loss, field strength at receiver due to knife-edge obstacles between the propagation path of the signal i.e. b/w transmitter and receiver. This paper also present the complete idea of identifying the position of obstacle in a Fresnel zone, diffraction loss, position of obstacle with varying distances b/w source and field and varying heights of obstacles in a Fresnel-zones represented by tabular forms and appropriate charts. The calculation, based on an approximate evaluation of the contribution of individual Fresnel zones to the total field, leads to the Fresnel theorem: the total field is just one-half that due to the first zone alone.

We show here that if the Fresnel zones are defined on a plane passing through the midpoint of the line joining the source point to the field point, the field due to each Fresnel zone may be calculated exactly. When the Fresnel zones are defined on a plane perpendicular to the line between the source and field points, the contribution of the first zone is equal to the total field multiplied by the factor 1+ (l+ π/nd')-2. Here, n is the wave number and d′ is the distance separating source and field points. Thus, for this geometry, the Fresnel theorem holds only in the limit nd′»1; for arbitrary nd′, the factor quoted must be used.

Index Terms- Diffraction gain(Gd), Knife-edge obstacle, Fresnel-zone geometry,, Fresnel-Kirchhoff's diffraction parameter(v),Diffraction loss, obstructing screen, Field strength(F),Shadowing effect LOS distance.

I. INTRODUCTION

In a mobile radio channel, Signal interference due to the earth and its atmosphere was not considered. Despite the fact that *"free space analysis"* may be adequate to provide a general understanding of radar systems, it is only an approximation. In order to accurately predict radar performance, we must modify free space analysis to include the effects of the earth and its atmosphere[2]. This modification should account for ground reflections from the surface of the earth, diffraction of electromagnetic waves, bending or refraction of radar waves due to the earth atmosphere, and attenuation or absorption of radar energy by the gases constituting the atmosphere.

The earth atmosphere is compromised of several layers. The first layer which extends in altitude to about 20 Km is known as the troposphere. Electromagnetic waves refract (bend downward) as they travel in the troposphere[3]. The troposphere refractive effect is related to its dielectric constant which is a function of the pressure, temperature, water vapour, and gaseous content. Additionally, due to gases and water vapour in the atmosphere radar energy suffers a loss. This loss is known as the atmospheric attenuation[2]. Atmospheric attenuation increases significantly in the presence of rain, fog, dust, and clouds. The region above the troposphere (altitude from 20 to 50 Km) behaves like free space, and thus little refraction occurs in this region. This region is known as the interference zone. The ionosphere extends from about 50 Km to about 600 Km. It has very low gas density compared to the troposphere. It contains a significant amount of ionized free electrons. The ionization is primarily caused by the sun's ultraviolet and X-rays. This presence of free electrons in the ionosphere affects electromagnetic wave propagation in different ways. These effects include refraction, absorption, noise emission, and polarization rotation. Diffraction allows radio signals to propagate around the curved surface of the earth, beyond the horizon ,and to propagate behind obstacles[8].

II. DIFFRACTION

Diffraction is the term used to describe the phenomenon of electromagnetic waves bending around the obstacles. In a radar system it is very important at very low altitudes[3]. Hills, mountains, buildings diffract radio energy and make possible to perform detection in regions that are physically shadowed. However, in these situations many assumptions made, here knife-edge obstacle is the very important and it is consider to be perfect conductor.

III. FRESNEL-ZONE GEOMETRY

The concept of diffraction loss as a function of the path difference around an obstacle is explained by Fresnel-zones. Fresnel zones represent successive regions secondary waves have a path length from the Tr to Re which are nλ/2 which is greater than the total path length of a line-of-sight path[4].

Let we consider heights of antennas are htr and hre of same heights, when a signal transmitted from source it encounters a knife-edge obstructing screen of effective h with infinite width height hkeo due to this obstacle signal is diffracted around it, which causes some loss of signal strength when compared to free space transmission. The loss occurs due to this obstacle is known as "Diffraction loss"[7][2]. Assume hkeo<< dtkeo, dreko (terminal distances from obstacle), λ << hkeo, then the difference b/w the direct path and diffracted path, called the excess path length or path difference(Δ) it can be obtained from the geometry and is given by

$$\Delta = ho^2(dtkeo+drkeo)/ 2(dtkeo)(drkeo) \text{ ------(1)}$$

dtkeo = distance b/w source to knife-edge
drkeo = distance b/w receiver to knife-edge

The corresponding path difference is given by

$$\Phi = 2\prod \Delta / \lambda \text{ ------------------------------------ -(2)}$$

From figure -1 tanx=x, then

$$\alpha = \beta + \Upsilon \text{ from figure-1}$$

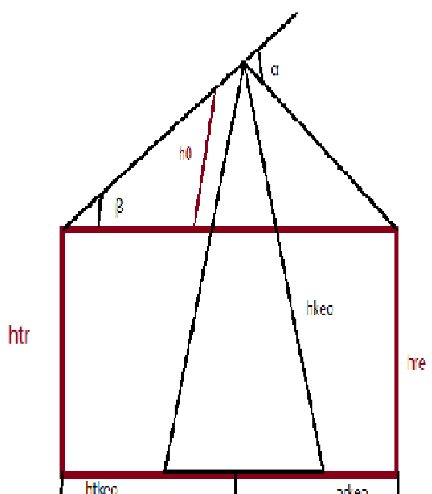
$$= ho(dtkeo + drkeo)/(dtkeo)(drkeo) \text{ ------------(3)}$$

from equations 1&2 we can derive dimensionless Fresnel's - Kirchhoff diffraction parameter v which is given by

$$v=h\sqrt{2(dtkeo+ drkeo)/ \lambda(dtkeo)(drkeo)} \text{-----(4)}$$

where α in radians and Φ can be expressed as

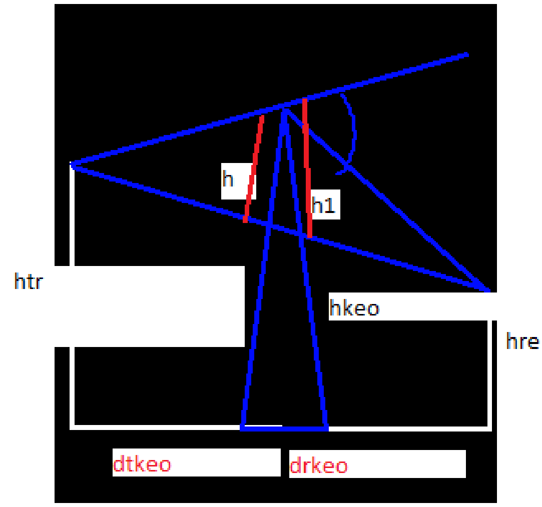
$$\Phi = \pi\ v^{2/2} \text{--(5)}$$



Knifedge-edge diffraction model with same heights i.e.htr=hre

Figure-1

By using the above formulas we can estimate the diffraction parameter(v) with respect to obstructing screen of height(h). V changes accordingly with has shown in table-1 and graph-1



Knife-edge diffraction model with different heights i.e htr not equal to hre

figure-2

IV. Variation of Diffraction Parameter(v) with Obstructing Screen of Effective Height(h) λ=1/3,d1=1km, d2=1km

S.NO	Height(h)	Diffraction parameter(v)
1	*0*	*0*
2	*5*	*0.547*
3	*10*	*1.095*
4	*15*	*1.6425*
5	*20*	*2.19*
6	*25*	*2.74*
7	*-5*	*-0.547*
8	*-10*	*-1.095*
9	-15	-1.6425
10	-20	-2.19
11	-25	-2.74

TABLE-

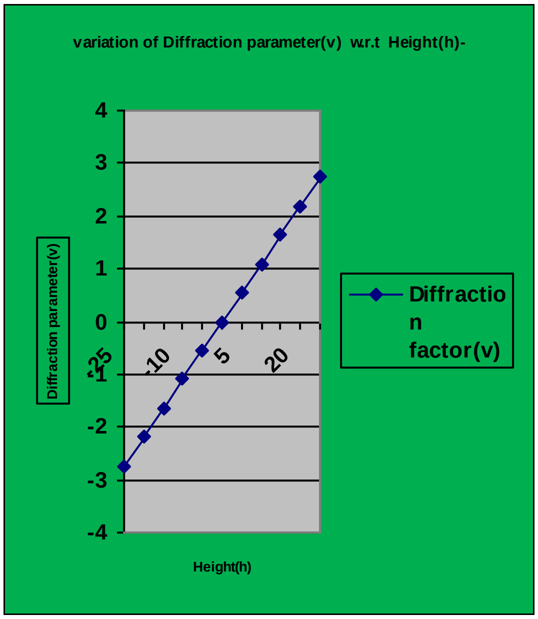


Figure-3

V. ANALYSIS ON RADIOUS OF FRESNELZONES WITH TERMINAL DISTANCES OF OBSTACLE

$r_{n=}$ $\sqrt{n\lambda}$(dtkeo)(drkeo)/ (dtkeo+ drkeo)--- (6) is only for dtkeo, drkeo>>r_n

Radius of Fresnel zone with d_{tkeo} =2km, d_{rkeo} =1km, λ=1/3m, dtkeo, drkeo >> r, f=3Ghz.

n=number of Fresnel zones, r=radius of Fresnel zone

S. no	n	r	Path length	Path loss
1	1	13	λ/2	168.012dB
2	2	18	λ	
3	3	22	3λ/2	
4	4	26	2λ	
5	5	29	5λ/2	

Table-2

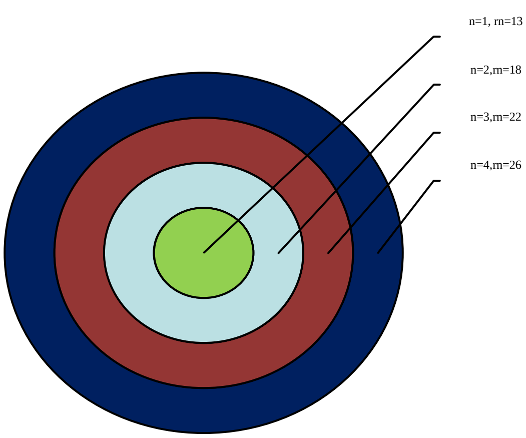


Figure-4 Circles which represents the boundaries of Fresnel zones.

From the tabular values it is observed that path travelling through the smallest circle corresponding to n=1 .If n increases then path length increased by λ/2(excess path length) as shown in figure. It is understood from the above analysis that shadowing is sensitive to frequency as well as the position of the obstacle with reference to Tr&Re[5].

VI. DIFFRACTIONLOSS

In mobile communication systems during the propagation of signal the direct line-of-sight is obstructed by a single object (of height hkeo), such as a mountain or building, the attenuation caused by diffraction over such an object can be estimated by treating the obstruction as a diffracting knife-edge. Diffraction loss takes place due to knife-edge diffraction it occurs from blockage of secondary waves such that only some portion of the energy is diffracted round an obstacle[6]. Due to this it allows some portion to the receiver. Depending on the Fresnel geometry energy will be a vector sum of the energy received from all unobstructed Fresnel zones, this loss will be clearly understood from the following numerical approximations.

Diffraction gain due to the presence of Knife-edge obstacle as compared to free space E-field i.e.

$G_{d\ (Db)}=20\log|F(v)|$ ---(7)

VII. VARIATION OF (GD) WITH DIFFRACTION PARAMETER(V) DUE TO PRESENCE OF KNIFE-EDGE OBSTACLE.

VIII.

s.no	height(h)	diffraction parameter (v)	diffraction gain (Gd) in dB
1	0	0	-6.02 ≈6
2	5	0.54	-14.27≈14
3	10	1.09	-14.55≈15
4	15	1.642	-17.5≈18
5	20	2.19	-20≈20
6	25	2.74	-21.711≈22
7	-5	-0.54	-1.568≈2
8	-10	-1.09	0≈0
9	-15	-1.642	0≈0
10	-20	-2.19	0≈0
11	-25	-2.74	0≈0

Table-3

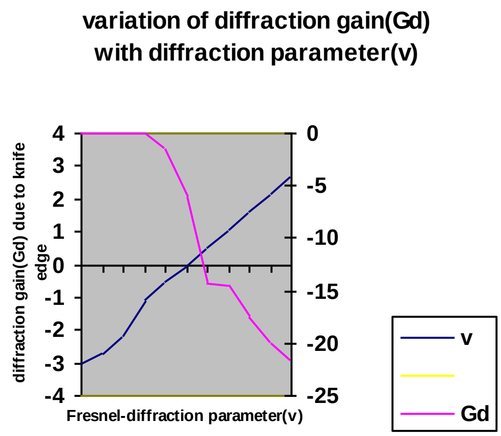


Figure-5

IX. IDENTIFING THE POSITION OF OBSTACLE IN A FRESNEL ZONE

Number of zones n=2 Δ/ λ----------(8) where

$\Delta = ho^2(dtkeo+drkeo)/ 2(dtkeo)(drkeo)$----(9)

d1=2km, d2=1km

S. no	h	Δ	(λ)	n	Comment on the position of the obstacle
1	0	0	1/3	1	Tip lies in the 1st zone.
2	5	0.025	1/3	1	Tip lies in the 1st zone.
3	10	0.1	1/3	1	Tip lies in the middle of 1st zone.
4	15	0.225	1/3	2	Tip of the obstacle completely covers 1st Fresnel zone
5	20	0.4	1/3	3	Tip of the obstacle completely covers 2ND Fresnel zone
6	25	0.625	1/3	4	Tip of the block completely covers 3 Fresnel zones
7	-25	0.625	1/3	4	Obstruction is below the LOS(since height is negative)

Table-4

Note:-If path difference increases number of zones increased.

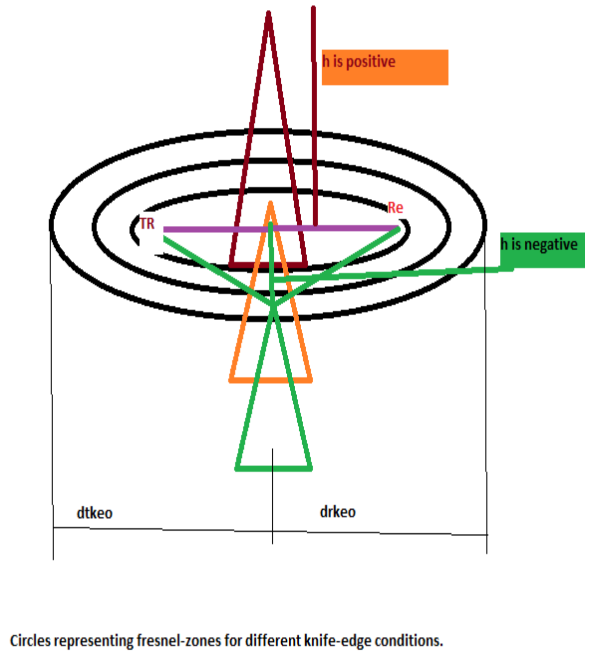


Figure-6

X. VARIATION OF PATH DIFFERENCE(Δ) WITH OBSTRUCTING SCREEN OF HEIGHT(HO) D1=2KM, D2=1KM, Λ= 1/3M

s. no	ho	Δ
1	0	0
2	5	0.025
3	10	0.1
4	15	0.225
5	20	0.4
6	25	0.625
7	0	0
8	-5	0.025
9	-10	0.1
10	-15	0.225
11	-20	0.4
12	-25	0.625

Table-5

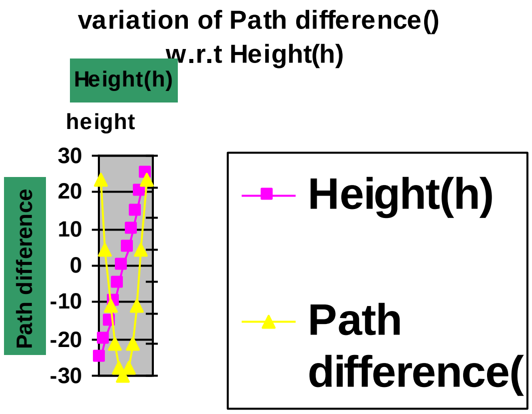


Figure-7

XI. VARIATION OF FIELD STRENGTH(F) WITH TERMINAL DISTANCE(DTRRE)

LOS Distance=4.12($\sqrt{h_t}+\sqrt{h_r}$)--------(10)
=4.12($\sqrt{100}+\sqrt{16}$)=57.68km

Field strength at 10km

$E_r=88(\sqrt{P_t})ht\ hr/\ d_{tr\ re}{}^{2}\ \lambda$ v/m----(11)

s.no	λ	ht	hr	P_t	d_{trre}	F
1	3	100	25	40kw	5km	58.6mv/m
2	3	100	25	40kw	10km	147mv/m
3	3	100	25	40kw	15km	65.1mv/m
4	3	100	25	40kw	20km	58.6mv/m
5	2	100	25	40kw	5km	880mv/m
6	2	100	25	40kw	10km	220mv/m
7	2	100	25	40kw	15km	97.7mvm
8	2	100	25	40kw	20km	55mv/m
9	1/3	100	25	40kw	5km	5.285v/m
10	1/3	100	25	40kw	10km	1.321v/m
11	1/3	100	25	40kw	15km	0.587v/m
12	1/3	100	25	40kw	20km	0.330v/m

Table-6

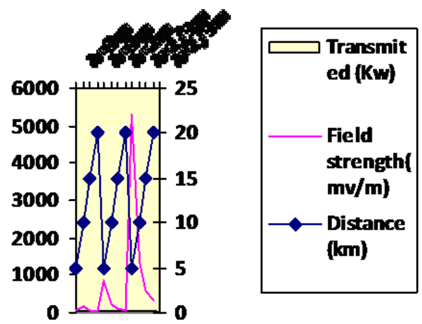


Figure-6 Field strength(F) w. r. t Distance(d_{trre}) b/w T_r & Re

XII. VARIATION OF BASIC PATHLOSS(Δ) W. R. T DISTANCE B/W TERMINALS

Basic path loss= $32.45+20\log_{10}$fMhz+20logdkm-----(12)

Path loss calculations f=3Ghz

s.no	d trre	f=3Ghz	path loss in db
1	1000	3Ghz	161.992
2	5000	3Ghz	175.971
3	10000	3Ghz	181.99
4	15000	3Ghz	185.51
5	20000	3Ghz	188.01
6	25000	3Ghz	189.95
7	30000	3Ghz	191.534

Table-7

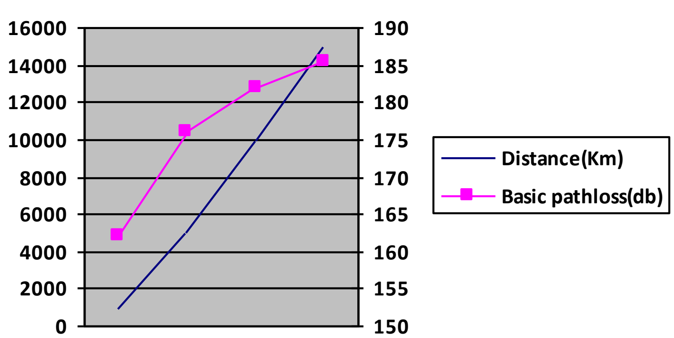


Figure-7 Basic path loss w. r. t Distance b/w T_r &R_e

This is the simplest of diffraction models, and the diffraction loss in this case can be readily estimated using the classical Fresnel solution for the field in the shadow behind a half-plane[1]. Thus, the electric field strength, Ed, of a knife-edge diffracted wave is given by field strength in the shadowed region is given by

Ed/Eo=F(v)=(1+J)/2 ∫exp((-j∏t^2)/2)dt---------------(13)

where E_0 is the free space field strength in the absence of the knife-edge and F(*v)* is the complex Fresnel integral which is a tabulated function of the diffraction parameter[2].

v=h√2(dtkeo+ drkeo)/ λ(dtkeo)(drkeo) ---(14)

.

Where 'dtkeo' and 'drkeo' are the terminal distances from the knife edge. The diffraction loss, additional to free space loss and expressed in dB, can be closely approximated

XIII. CONCLUSION

Now a days, an increasing demand of mobile communications requires high quality of transmission with less price, it is possible only with high quality research .This paper may gives complete idea to minimize diffraction losses by adopting the above numerical approximations, graphical representations and tabular forms.

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REFERENCES

[1] John D Kraus, Ronald J Marheka, Ahmad S Khan, Antennas and Wave propagation, 4thEdition(2010), Tata McGraw Hill, New Delhi.
[2] Theodore S. Rappaport, Wireless Communications, Principles and practice, second edition.
[3] K.D. Prasad, Antenna and Wave propagation, 3rdEdition, New Delhi.
[4] Fock, V.A Electromagnetic Diffraction and Propagation Problems, pp 254-275, Pergamon Press,New York, 1965.
[5] Wait, J.R: "Electromagnetic surface waves", Advances in Radio Research,1, New York, Academic press pp. 157-219,1964.Academic press
[6] Walker, J., Halliday, D., & Resnick, R. (2011). Fundamentals of physics. Hoboken, NJ: Wiley.
[7] Soundara Rajan. V.: Antenna Theory and and Wave propagation", Scitech Publications(India) Pvt.Ltd,Chennai,2001. 3rdEdition, New Delhi. " Anderson, Leland I. (2002).
[8] Dhar,p.c.: "Electromagnetic Field Theory, "Antenna Theory and and Wave propagation", Dhanpat Publishing Co. Pvt Ltd, New Delhi ,2001.
[9] Gautam, A.K.: "Antenna and Wave propagation", S.K. Kataria and Sons, Delhi, IIND Edition,2004.
[10] C. Balannis, Antenna Theory-Analysis and Design. .New York: Wiley, 1982.

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