Influence of the Refraction in Presence of Various Formed Obstacles

Emil Savov Altimirski[1] and Kliment Nikolaev Angelov[2]

I. INTRODUCTION

Electromagnetic wave propagation in the presence of a wedge-shaped screening obstacle is a well studied phenomenon with corresponding derived mathematical models describing it. It is interesting to examine the field at the receiving point behind an obstacle with non – regular form. It could cause damping or amplification of the field in accordance to the appropriate Fresnel zones and their corresponding degree of closure.

The aim of this examination is to find cases, where obstacle with given form and dimensions is able to significantly influence signal level at receiving point in cases of normal wireless channels and to elaborate a technical method for its rapid determination.

II. THEORETICAL FUNDAMENTALS

A case (fig. 1) is being studied, where in a given cross-section of the wireless channel between transmitter (point A) and receiver (point B) a screening obstacle with a form different from a line lies.

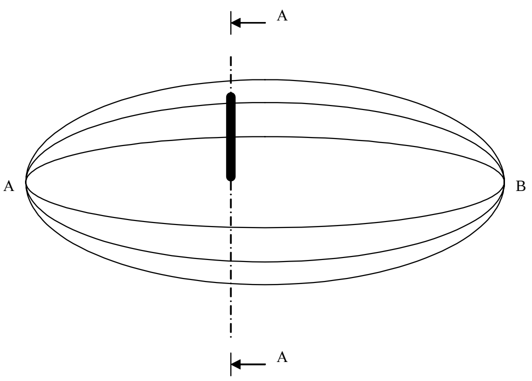

Fig. 1

[1] Ph.D. Emil Savov Altimirski is with Technical University of Sofia, +359 2 965 2230
[2] Kliment Nikolaev Angelov is with Technical University of Sofia, +359 2 965 3447, E-mail: klimbona@gmail.com

The surface of the cross–section, depicted in fig. 2 is being divided into a matrix, consisting of points (rectangles with sufficiently small dimensions). The field is being retransmitted by each point of the matrix in accordance with the Huegens-Fresnel principle. Field amplitude and phase created by each of these points in the receiving point is being derived. Subsequently these single fields are being summed taking into account their corresponding amplitudes and phases in order to derive the resultant field. The result is a complex number, whose modulus is important to be defined for engineering praxis purposes.

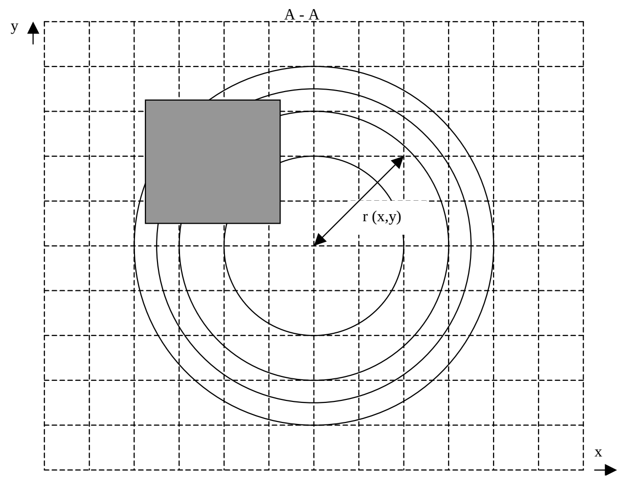

Fig.2

Elementary beams amplitude could be described by means of the following equation (1):

$$\left|E_r\right| = \frac{1+\cos[\theta(r)]}{l(r)}, \quad (1)$$

where ***l(r)*** is the elementary beam way, ***θ(r)*** is the visual angle for the receiving point in accordance with the primary trajectory.

Phases could be derived by means of the following equation (2):

$$\varphi_r = \frac{2.\pi}{\lambda}.\Delta l(r), \quad (2)$$

where **Δl(r)** is the difference in the ways of the elementary and direct beams.

The following equation is being derived for the resultant field in the receiving point (3):

$$E_0 = \sum_{r=0}^{r=r\max} \left|E_r\right| . e^{j\varphi_r} \qquad (3)$$

where **r** is the current radius of the corresponding matrix point to the centre of the Fresnel zones and is function of **x** and **y** (fig. 2).

The obstacle is represented as a matrix m, consisting only of elements equal to 0 or 1, thus reflecting if a given elementary beam retransmits or not (caused by the obstacle) in receivers point direction. Taking into account, that **r = f(x,y)**, the overall field at the receiver point could be described by means of the following equation (4):

$$E_{0obstacle} = \sum \left|E_{(x,y)}\right| . e^{j\varphi(x,y)} . m(x,y) \qquad (4)$$

III. Results

In accordance with the above described method, an examination of the elementary beams field amplitude and phase distribution depending on their corresponding trajectory in the case of an obstacle absence has been carried out. The derived results are depicted in fig. 3 and fig. 4. The part in fig. 3, that juts out corresponds to a higher amplitude value, caused by a shorter way of the beams and respectively smaller degree of natural wave energy dispersion. The sectors in fig. 4 that jut out correspond to phases with a value close to 180 degrees, and the hollow ones – to 0.

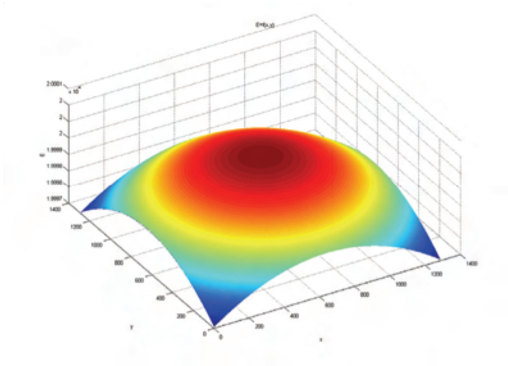

Fig. 3

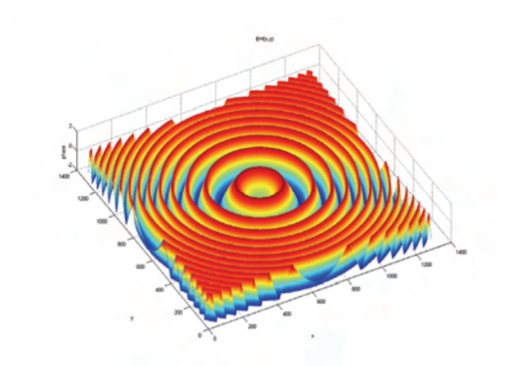

Fig. 4

Fig. 5 represents the influence of a screening obstacle with different forms in the surface of the first ten Fresnel zones. From the figure it is visible that when the center of the obstacle is being moved away from Fresnel zones center at a distance three times greater than the radius of the first Fresnel zone, the influence of the obstacle itself is so week, that it could be further neglected for engineering calculations purposes. In accordance to the above statement and for the reason of a better readability of the figures, only the results, corresponding to distances of a thrice first Fresnel zone dimensions magnitude are being represented further in this work.

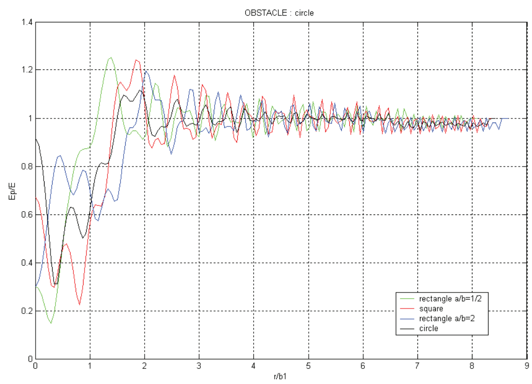

Fig. 5

The influence of an obstacle with a square (fig.6), rectangular 1:2 (fig. 7), as well as rectangular 2:1 (fig.8) forms with different side dimensions has been examined.

It is obvious from the results, that in the case of greater screening object dimensions, damping curve becomes similar to that of a wedge–shaped obstacle. Significant field amplification in the case of a rectangular (2:1) hindrance by a 2,5 – 3 times first Fresnel zone radius dislocation is observed. This phenomenon could be useful from a passive retranslation point of view.

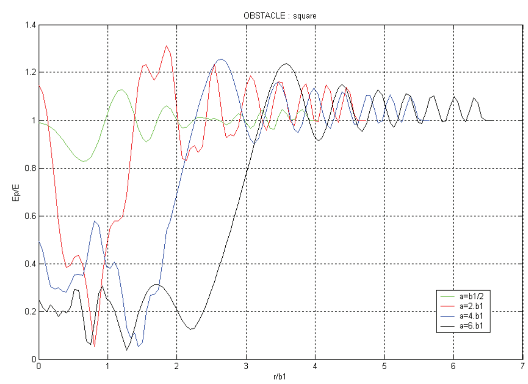

Fig. 6

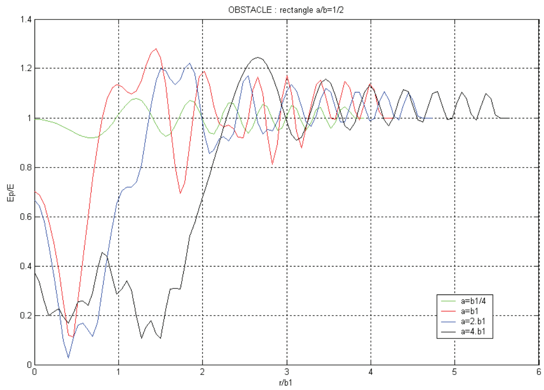

Fig. 7

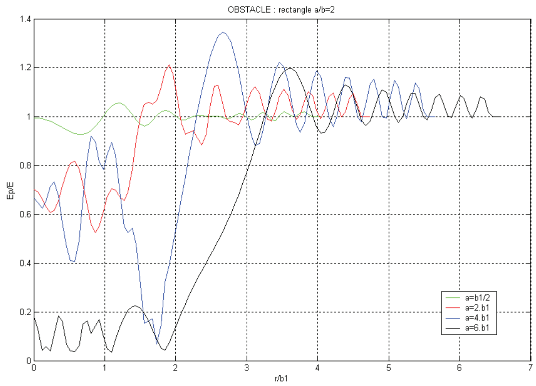

Fig. 8

A comparison of different square dislocations, depending of its side dimensions is being carried out in fig. 9. A greater field peak is being observed in the case of an approximate equality between square side and first Fresnel zone radius and a dislocation two times greater than the radius.

Fig. 10 represents the influence of objects with a different form and the same surface, equal to that of the first Fresnel zone. A similarity between the curves corresponding to square and circle, differing from those, typical for rectangulars is being observed.

An algorithm and a program for MatLab, given in the appendix have been elaborated. They could be used for field determination in the presence of a obstacle with arbitrary form and different distances to receiver and transmitter.

The results from the calculations for determining the influence of an obstacle with a complicated geometric form, depending on the distance between the obstacle and the transceiver, are illustrated on Fig. 11. The form of the complex obstacle is shown on Fig. 12.

The presented method gives the opportunity not only to determine the field in the receiver and to optimize the heights of the transceiving and receiving antenna, but also to search for possibilities for passive retranslation and to calculate the geometric dimensions of the retranslators.

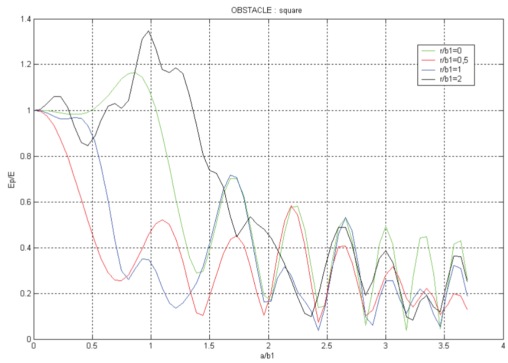

Fig. 9

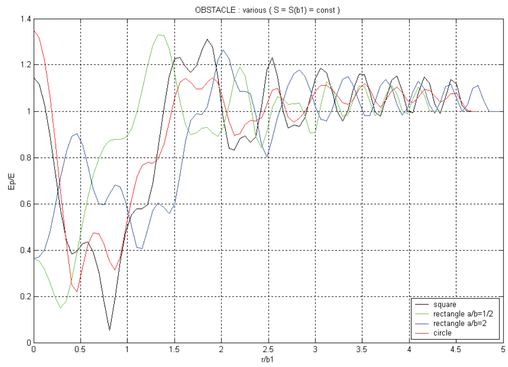

Fig. 10

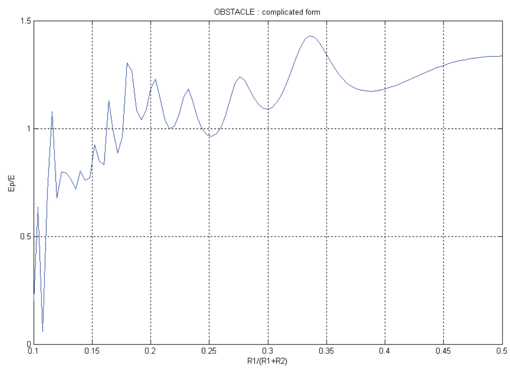

Fig. 11

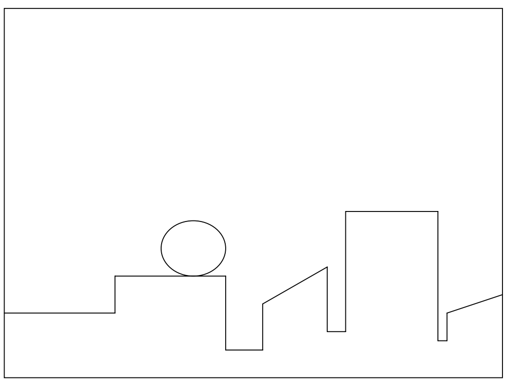

Fig. 12

APPENDIX

```
lm=0.03;
k=32;
s=1;


for p=0:100
rt(p+1)=40*p+1000;
r1=rt(p+1);
r2=10000-r1;

x=-k:s:k;
y=-k:s:k;
[x,y]=meshgrid(x,y);

r=sqrt(x.^2+y.^2);
l1=sqrt(r.^2+r1.^2);
l2=sqrt(r.^2+r2.^2);
dl=l1+l2-r1-r2;
alfa=atan(r./r1);
beta=atan(r./r2);
tao=alfa+beta;

e=(1+cos(tao))./(l1+l2);
f=(2*pi*dl)./lm;
ek=e.*(cos(f)+(i*sin(f)));

e0=0;
for q=1:(2*k./s)+1
for j=1:(2*k./s)+1
e0=e0+ek(q,j);
end
end

e0m=abs(e0);

e0r=0;
for q=1:(2*k./s)+1
for j=1:(2*k./s)+1
e0r=e0r+((ek(q,j))*m(q,j));
end
end


e0mr=abs(e0r);

Lost(p+1)=e0mr./e0m;
end

r1n=rt/10000;
plot(r1n,Lost);
title('OBSTACLE : complicated form');
xlabel('R1/(R1+R2)');
ylabel('Ep/E');
```