Vegetation Use for Resolving Electromagnetic Compatibility and Ecology Issues

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Abstract. The wide spread of Information and Communication Technologies and the development of Internet-enabled mobile applications have aggravated electromagnetic compatibility and ecology problems. Inability to excite electromagnetic field of a desired structure and strength with traditional approaches actualizes additional actions, including providing diffraction on propagation path, to resolve these issues. Diffraction on a stand-alone obstacle along the propagation path and the one on set of obstacles near receive antenna location can be considered as the additional actions in ultrashort band. The accomplished studies have shown that one the most effective means to lower electromagnetic field strength is to shield the receive antenna with vegetation from jamming radio equipment. Moreover, vegetation resolves electromagnetic ecology issues, for the energy flux density can be lowered by about two orders of magnitude.

1. Introduction

Up-to-date society development is accompanied by an extensive use of Information and Communication Technologies [1]. The aggravation of electromagnetic compatibility and ecology issues are the disamenities of this process. In addition, the hardest problems of the electromagnetic compatibility lie within radio spectrum overflow [2]. These problems arise when several communication services and similar services operators use adjacent service bands. For instance in [3] it is shown, that rapid evolution of land mobile telecommunications of GSM-900 standard aggravated electromagnetic compatibility with short-range navigation and landing devices working in P-GSM band (890-915/950-960 MHz) essentially. Moreover, solving this problem by switching into E-GSM band (880-890/925-935 MHz) has severe constraints.

Electromagnetic ecology issues aggravation is caused by expansion of Internet-enabled mobile applications [4]. As a result, in high-populated areas a complete cover of non-ionizing radiation from base station aerials is formed [5]. Thus, electromagnetic field of base station antenna transmitters has a constant round-the-clock health impact on residents, including children, elderly and disabled. The consequences of this impact can be harmful under specific conditions [6].

Solving the issues of electromagnetic compatibility and ecology usually starts with known structure management techniques of electromagnetic field directly excited by antenna. As an example, construction design can presume composite materials application upon antenna carcass, as it I shown in [7, 8]. For this technique the results and extended recommendations on electromagnetic field structure management of an antenna are given in [9]. It should, however, be noted that desired field structure cannot always be managed with conventional techniques.

In the paper the applicability of additional actions based on consideration of ground-wave propagation characteristics in ultra-short band is estimated. As it is shown in ITU recommendations [2, 10, 11], signal strength can be lowered on propagation path by artificial diffraction effects, produced when first Fresnel zone of a radio wave is tangent to a stand-alone obstacle or when energy is scattered near receiver on the set of obstacles. In the paper the first diffraction source is simulated by a stand-alone high-rise building, while another one is simulated by vegetation. The applicability of these actions for electromagnetic ecology issues resolution is estimated simultaneously. At that, the obtained field strength is estimated according to regulatory documents [12-15].

Thus, the paper objective is the estimation of objects (buildings, vegetation) effect on electromagnetic strength attenuation near the receiver.

2. Calculation methodologies

Diffraction loss estimation on objects located on propagation path near the receiver is analyzed with ITU recommendations [2, 10, 11]. The vegetation effect on energy flux density is estimated through electromagnetic environment studies near residential building with regulations [14, 15] and the methodology given in monograph [16]. All the results regarding electromagnetic ecology were obtained with «preventive principle» recommended by the World Health Organization [17]. The principle calls for preventive actions to reduce possible harmful influence of radiation on human, even if the influence is not proven and is presumed out of the current scientific knowledge level.

Efficiency of additional actions will be estimated in two steps. The first step research is aimed to estimate the diffraction effect on electromagnetic compatibility issues, while the second stage is linked to electromagnetic ecology issues.

2.1. Stand-alone obstacle diffraction effect

To estimate the effect of obstacle in the form of a building a model of double isolated knife-edge edges will be used, as it is recommended in [10]. The problem geometry is shown on Figure 1 taken from [10].

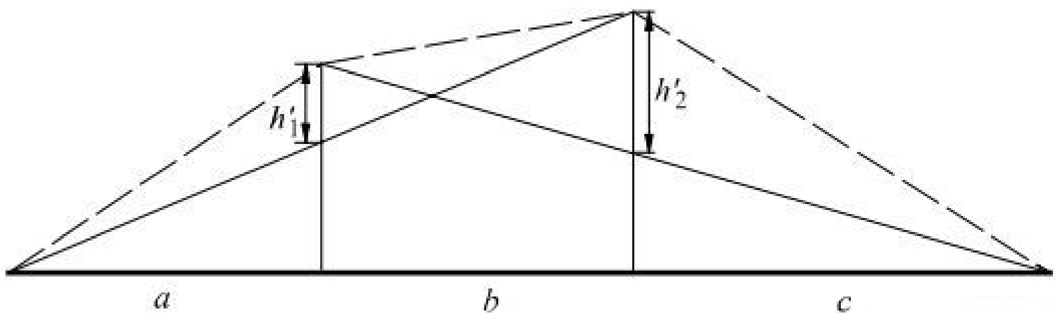

Figure 1. Method for double isolates edges

This method consists of applying single knife-edge diffraction theory successively to the two obstacles, with the top of the first obstacle acting as a source for diffraction over the second obstacle. The first diffraction path, defined by the distances *a* and *b* and the height h'_1, gives a loss L_1 (dB). The second diffraction path, defined by the distances b and c and the height h'_2, gives a loss L_2 (dB). The total diffraction loss is then given by:

$$L_{ds} = L_1 + L_2 - L_c . \quad (1)$$

L_1 and L_2 are calculated using formulae [10]:

$$L_{1,2} = -20\lg\left(0.5\sqrt{(1-C(\nu)-S(\nu))^2+(C(\nu)-S(\nu))^2}\right), \quad (2)$$

where

$$\nu = -h\sqrt{\frac{2}{\lambda}\left(\frac{1}{d_1}+\frac{1}{d_2}\right)}, \quad (3)$$

d_1 and d_2 - distances of the two ends of the path from the top of the obstacle;
λ- wavelength (m);
h - height of the top of the obstacle above the straight line joining the two ends of the path. If the height is below this line, h is negative;

$$h'_1 = h_1 - h_2\frac{a}{a+b}; \qquad h'_2 = h_2 - h_1\frac{c}{c+b}. \quad (4)$$

A correction term L_c (dB) must be added to take into account the separation b between the edges. L_c may be estimated by the following formula:

$$L_c = \left(12 - 20\lg\left(\frac{2}{1-\frac{\alpha}{\pi}}\right)\right)\left(\frac{q}{p}\right)^{2p}, \quad (5)$$

where

$$p = h_1\sqrt{\frac{2}{\lambda}\frac{a+b+c}{(b+c)a}};\ q = h_2\sqrt{\frac{2}{\lambda}\frac{a+b+c}{(a+b)c}};\ \tan\alpha = \sqrt{\frac{b(a+b+c)}{ac}}.$$

2.2. Diffraction effect on set of objects
To analyze the diffraction loss on objects near the receiver the ITU recommendations [2] will be used. The problem geometry and legend are shown on Figure 2 taken from [2].

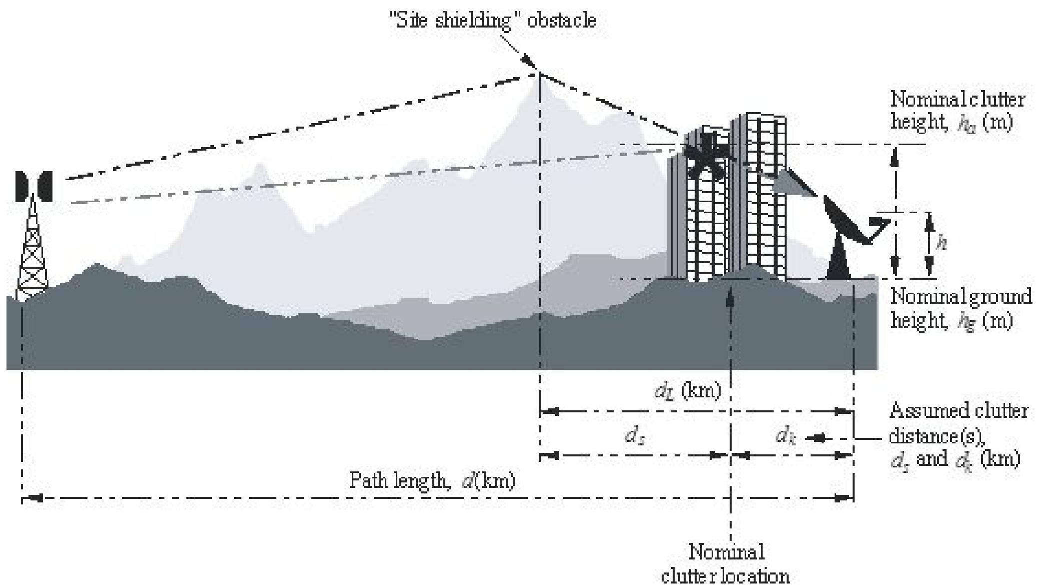

Figure 2. Geometry of tasks

According to ITU [2] recommendations, benefit, in terms of protection from interference, can be derived from the additional diffraction losses available to antennas which are imbedded in local ground clutter (buildings, vegetation, etc.). The maximum additional loss is 20 dB above 0.9 GHz, and progressively less at lower frequencies, down to 5 dB at 0.1 GHz.

The additional loss due to protection from local clutter is given by the expression:

$$A_h = 10.25\, F_{fc} \cdot \exp(-d_k) \left(1 - \tanh\left[6 \left(\frac{h}{h_a} - 0.625 \right) \right] \right) - 0.33 \ \text{dB} \quad (6)$$

where

$$F_{fc} = 0.25 + 0.375\{1 + \tanh[7.5(f - 0.5)]\},$$

d_k - distance (km) from nominal clutter point to the antenna;

h - antenna height (m) above local ground level;

h_a - nominal clutter height (m) above local ground level;

f – frequency (GHz).

The additional protection available is height dependent, and is therefore modelled by a height-gain function normalized to the nominal height of the clutter. Where the clutter parameters are more accurately known they can be directly substituted for the values taken from Table 1 [2].

Table 1. Nominal clutter heights and distances

Clutter (ground-cover) category	Nominal height, h_a (m)	Nominal distance, d_k (km)
High crop fields Park land Irregularly spaced sparse trees Orchard (regularly spaced) Sparse houses	4	0.1
Village centre	5	0.07
Deciduous trees (irregularly spaced) Deciduous trees (regularly spaced) Mixed tree forest	15	0.05
Coniferous trees (irregularly spaced) Coniferous trees (regularly spaced)	20	0.05
Tropical rain forest	20	0.03
Suburban	9	0.025
Dense suburban	12	0.02
Urban	20	0.02
Dense urban	25	0.02
High-rise urban	35	0.02
Industrial zone	20	0.05

2.3. Electromagnetic environment estimation

To estimate electromagnetic environment according to offered methods of signal strength depression the correlations from [15] were used for frequencies over 300 MHz. To calculate energy flux density (EFD) Π let's use the following formula

$$\Pi = E^2 / 3.77 , \quad (7)$$

where E - electric field intensity amplitude (V/m).

For mobile communication systems maximum permissible level of radiation power, which does not cause permanent changes in human body, is equal to 10 μW/cm^2 [14, 15].

3. Results and discussion

3.1. Solving the electromagnetic compatibility issue

In the research the transmitter power was assumed to be equal to 100 W. Antenna centers were placed at the following heights: 100 m for mobile communications base station antenna and 10 m for receiver. Obstacle distance from the transmitter was assumed to be equal 10 km; it consisted of two peaks of equal height spaced 100 m apart. As it is shown in [10], the assumed model describes high-rise building. In the research the building height was variated in the range from 30 to 90m. Moreover, clutter distance was variated in the range from 0.1 to 0.02 km; clutter parameters were taken from Table 2. Path length changed within line-of-sight range for used antenna height.

For spatial separation is required for radiation sources by electromagnetic compatibility rules, let us also assume that the path length is also variated in the range from 15 to 25 km. In Table 3 the results of loss forecast for the considered transmission path are given for a dense urban zone. It follows from Table 2 that the distance from transmitter will be equal to 200 m and clutter height will be equal to 20 m in this case.

Table 2. Loss structure forecast at reception point

Path length, km	Loss, dB				Signal strength at reception point, dB
	Total	Basic	Obstacle diffraction	Clutter	
Stand-alone obstacle (building) height 30 m					
15	136.73	114.32	6.26	16.10	-116.42
20	139.96	116.86	6.23	16.10	-119.96
25	141.18	118.84	6.22	16.10	-121.18
Stand-alone obstacle (building) height 60 m					
15	130.41	114.32	6.29	16.10	-110.41
20	139.96	116.86	6.23	16.10	-119.96
25	141.18	118.84	6.22	16.10	-121.18
Stand-alone obstacle (building) height 90 m					
15	136.73	114.32	6.26	16.10	-116.42
20	139.96	116.86	6.23	16.10	-119.96
25	141.18	118.84	6.22	16.10	-121.18

The analysis of table data shows, that basic loss contribution to total losses is about 83.9%, diffraction loss contribution is 4.5% and clutter loss near the receiver is 11.6%.

In the analysis process of clutter influence, the path length was considered to be equal to 25 km and the stand-alone obstacle height was equal to 30 m. Stand-alone objects were used as clutter sets of objects from the Table 2; the object properties were set equal to the properties of the set. The simulation results are shown in Figure 3.

The simulation results analysis shows, that the highest signal loss (in the range from 18.5 to 15.6 dB) caused by multipath effect can be observed in cities and close to deciduous trees. Mixed tree forest also causes signal loss, but the contribution of this clutter is only 7.03 dB. Stocky vegetation, low-rise buildings and sparsely built suburban areas have no significant influence on signal loss.

Thus, we can conclude that shielding the first Fresnel zone does not solve the receiver broadside radiation problem, which is one of electromagnetic compatibility issues. The most effective approach is linked to planting vegetation near the receiver in the direction of jamming radio equipment.

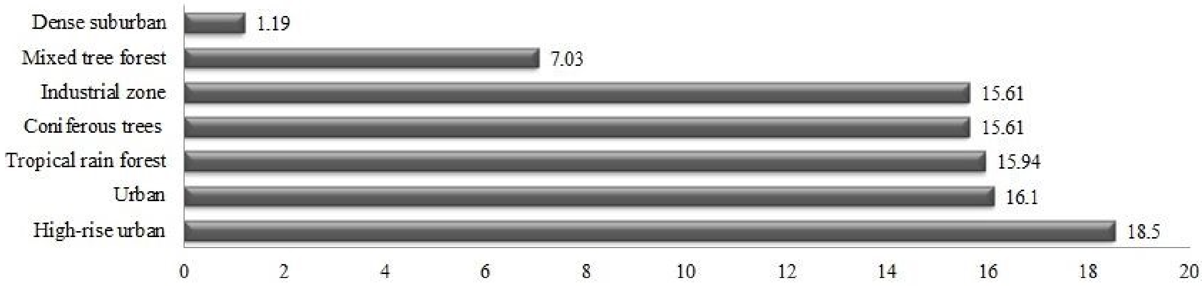

Figure 3. Forecasted clutter level for different objects

3.2. Solving the electromagnetic ecology issue

In [18-20] it was shown that sanitary protection zone size, in which the energy flux density is lower than the maximum permissible level of 10 μW/cm^2, is about 30 m for GSM antenna with transmission power 100 W. Let's consider the gain in energy flux density loss for different vegetation types. In Table 3 calculated gain values are given for reference point placed 10 m high (second floor of residential building).

Table 3. Achievable field loss at point of receive with vegetation clutter

Clutter (ground-cover) category	Nominal height, h_a (m)	Nominal distance, d_k (km)	Signal strength with reflections, dB	Signal loss, dB	Gain in energy flux density loss, times
Coniferous trees	20	0.028	-59.67	19.57	90.52
Mixed tree forest	15	0.028	-59.65	19.55	90.15
Park land	4	0.02	-56.12	16.02	40.72

The analysis of table data shows, that vegetation use lowers energy flux density by about two orders of magnitude. At that, the most rational choice is green belt zones of high-rise coniferous and mixed tree. Park land with stocky vegetation is less effective to lower energy flux density level in residential areas. This conclusion is proved true by recommendations of monograph [16]. It is said that long attenuation of electromagnetic wave propagating through vegetation is between 0.15 and 0.26 dB/m depending on polarization type in frequency band of about 1 GHz.

Therefore, vegetation resolves electromagnetic ecology issues in residential areas.

4. Conclusions

The carried out research in additional actions efficiency (i.e. building stand-alone high-rises in mobile communications radio paths, using vegetation near the reception point) in resolving the issues of electromagnetic compatibility and ecology has shown the following:

- Planting vegetation near the receiver in the direction of jamming device provides signal loss of about 10 dB greater than the stand-alone high-rise on the radio path.
- Coniferous trees provide maximum gain in signal loss. The difference to the next best choice of mixed trees planting is 7.03 dB. Stocky vegetation has no significant influence on signal loss.
- Vegetation also provides energy flux density loss of about two orders of magnitude.

- It is necessary to consider nominal tree height when choosing vegetation type to resolve electromagnetic ecology issues. Park zones with stocky vegetation are less effective for energy flux density decrease in residential areas.

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