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Influence of Urban Architecture Features on Attenuating of a Field Strength Levels of Mobile Communication

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ABSTRACT: Knowing the levels of the distribution patterns of the field strength in urban environments can correctly determine the number of base stations required to provide high-quality mobile communication. High quality of mobile communications, in turn, creates the best conditions for a quick payback on the development of a mobile network. In this article, there are derived the expressions for calculating the attenuation of the field strength of mobile communication stations in the megapolis on the example of the capital of Uzbekistan - Tashkent in the frequency bands 900 and 1800 MHz. Expressions allow to take into account factors that affect the signal attenuation in detail.

KEYWORDS: Attenuation, Tension Of Mobile Communications Field, Urban Construction, Base Stations, Effective Conductivity, Frequency Bands 900 and 1800 MHz.

I. INTRODUCTION

Currently, there is a rapid increase in the number of base stations of mobile communications (BSMC) in Uzbekistan, which co-radiation of electromagnetic fields and their significant mutual influence creates intense electromagnetic environment in the regions of their location. For optimal placement of the BS, it is necessary to know the laws of attenuation of electromagnetic field levels, which are determined by the architecture of urban development.

II. STATEMENT OF A PROBLEM

So, in Tashkent there is its own specific architecture, conditioned by national traditions and the usage of sun protection elements.
The intensity of the loss that interests us in the field defined by L is determined in dB by level difference between the field intensity E_0 in free space and the level of the field strength E obtained during the experiment or calculation.

$$E = E_0 - L, dB. \quad (1)$$

III. THE CONCEPT OF THE PROBLEM DECISION

As a result of analysis of the applicability of a number of calculation models, for further usage selected the model named "Okumura-Hata" to calculate the transmission loss L in the urban area (the model recommended by the ITU) for transmit antenna suspension heights h_b = 30...200 m, height of the suspension receiving antenna h_m= 1...10 m and the distance r = 1...20 km. The expression is based on a simplified "Okumura-Hata" model for the "middle city" [1]:

$$L = 68{,}75 - 13{,}82\, lg\, h_b + 27{,}72 lgf - [1{,}1 lgf - 0{,}7]h_m + [44{,}9 - 6{,}55 lgh_b] \cdot lgr, dB; \quad (2)$$

where the values of f frequency are taken in MHz, and the distance r accepted in km.

But that presented expressions record is actually not entirely correct, because there are taken the logarithms of numbers with the physical dimension. In connection with the above, this formula is offered in the following form:

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$$L = 68{,}75 - 13{,}82\, lg(h_b/h_0) + 81{,}89\, lg(f/f_0) - [4{,}88 lg(f/f_0) - 0{,}7](h_m/h_0) + [44{,}9 - 6{,}55 lg(h_b/h_0)] \cdot lg(r/r_0), dB; \quad (3)$$

where h_b - the height of the unit is equal to 1 m;
f_0 - single frequency is equal to 1 MHz;
r_0 - unit distance is equal to 1 km.

IV. EXPERIMENTAL RESULTS

Before the beginning of researches, areas and cities, where it was planned to carry out measurements, were conditionally divided into areas with a high density of buildings (multi-storey buildings), areas with a low density development (one- and two-storey buildings, a suburb), the radial and transverse tracks (with respect to the antenna one of the base stations of mobile communication). Trails measurements were chosen so that the propagation conditions on them were about the same.
To conduct a research there was used the mobile measuring system of the firm Rohde & Schwarz. In data processing, we used the widely practiced for the research value of the confidence level β=0,95. The values of the field strength which does not fall within the confidence interval were discarded in the processing of the measurement data.
As a result of processing the experimental data there were obtained upgraded expressions for 900 MHz "Okumura-Hata" model for Tashkent city of the following form [2-5]:

- for areas of the city at an average density of building:

$$L = -27{,}55 - 13{,}82\, lg(h_b/h_0) + 27{,}72\, lg(f/f_0) - [1{,}1 lg(f/f_0) - 0{,}7](h_m/h_0) + [31{,}9 - 6{,}55 lg(h_b/h_0)] \cdot lg(r/r_0), dB; \quad (4)$$

- for areas of the city with low-density development:

$$L = -32{,}17 - 13{,}82\, lg(h_b/h_0) + 27{,}72\, lg(f/f_0) - [1{,}1 lg(f/f_0) - 0{,}7](h_m/h_0) + [25 - 6{,}55 lg(h_b/h_0)] \cdot lg(r/r_0),\ dB; \quad (5)$$

- for wide radial streets:

$$L = -29{,}55 - 13{,}82\, lg(h_b/h_0) + 27{,}72\, lg(f/f_0) - [1{,}1 lg(f/f_0) - 0{,}7](h_m/h_0) + [27 - 6{,}55 lg(h_b/h_0)] \cdot lg(r/r_0), dB; \quad (6)$$

- for wide transverse streets:

$$L = -27{,}41 - 13{,}82\, lg(h_b/h_0) + 27{,}72\, lg(f/f_0) - [1{,}1 lg(f/f_0) - 0{,}7](h_m/h_0) + [37 - 6{,}55 lg(h_b/h_0)] \cdot lg(r/r_0), dB. \quad (7)$$

In studies [6] proposed the introduction of coefficient that takes into account the rolling hills in the "Okumura-Hata" model, as the model is designed to calculate the field-weakening levels of quasi-smooth surface of the earth. The correction factor, taking into account the rolling countryside, has a look:

$$K_x = A \cdot \Delta h,\ dB, \quad (8)$$

where A - empirical coefficient equal to 0,2 *dB*/m for hilly terrain roughness heights within Δh = 20...40 m and 0,225 *dB*/m - within the heights of roughness Δh = 40...80 m.

In addition to knowledge of the distribution of the field levels in urban environments with different types of buildings (areas with medium density development, areas with a low density development; wide radial streets, broad cross streets) it is also necessary to know what weakening will make single standing tall buildings. For these purposes, it was conducted additional research, which is to determine the level of the field in front of the same building, and behind them. As a result of the measurement data processed, revealed that the single standing tall buildings, provide additional attenuation of the order of 15...25 *dB*. In some cases, there was the phenomenon of "strengthening by knife-edge" [7].
The magnitude of the losses introduced by the single standing building can be considered by the introduction of an upgraded model of the "Okumura-Hata" L_{hrb} term [7]. This technique is most justified for areas with low-density buildings.

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Taking into account the factors that characterize the individual as a attenuating introduced by high-rise buildings and hilly terrain, the upgraded model, "Okumura-Hata" take the following form [8]:

- for areas of the city at an average density of building:

$$L = -27{,}55 - 13{,}82\,lg(h_b/h_0) + 27{,}72\,lg(f/f_0) - [1{,}1lg(f/f_0) - 0{,}7](h_m/h_0) + [31{,}9 - 6{,}55lg(h_b/h_0)] \cdot lg(r/r_0) + K_x + L_{hrb}, dB; \quad (9)$$

- for areas of the city with low-density development:

$$L = -32{,}17 - 13{,}82\,lg(h_b/h_0) + 27{,}72\,lg(f/f_0) - [1{,}1lg(f/f_0) - 0{,}7](h_m/h_0) + [25 - 6{,}55lg(h_b/h_0)] \cdot lg(r/r_0) + K_x + L_{hrb},\ dB \quad (10)$$

- for wide radial streets:

$$L = -29{,}55 - 13{,}82\,lg(h_b/h_0) + 27{,}72\,lg(f/f_0) - [1{,}1lg(f/f_0) - 0{,}7](h_m/h_0) + [27 - 6{,}55lg(h_b/h_0)] \cdot lg(r/r_0) + K_x, dB; \quad (11)$$

- for wide transverse streets:

$$L = -27{,}41 - 13{,}82\,lg(h_b/h_0) + 27{,}72\,lg(f/f_0) - [1{,}1lg(f/f_0) - 0{,}7](h_m/h_0) + [37 - 6{,}55lg(h_b/h_0)] \cdot lg(r/r_0) + K_x + L_{hrb}, dB. \quad (12)$$

Let us remind that all these expressions are valid for the 900 MHz frequency band.
It is interesting to note that the correction value for expressions COST 231-Hata [2] for the "middle" city, recommended by the ITU in the frequency range 1500...2000 MHz is equal to ΔL = 10,1 *dB*. Consequently, the amount of losses in the "middle" city at a frequency of 1800 MHz will be an average of 10,1 *dB* greater than in 900 MHz band. In this regard, it must adjust the attenuation introduced by individual high-rise buildings and hilly terrain, and upgraded models "Okumura-Hata" for the frequency range of 1800 MHz take the following form:

- for areas of the city at an average density of building:

$$L = -17{,}45 - 13{,}82\,lg(h_b/h_0) + 27{,}72\,lg(f/f_0) - [1{,}1lg(f/f_0) - 0{,}7](h_m/h_0) + [31{,}9 - 6{,}55lg(h_b/h_0)] \cdot lg(r/r_0) + K_x + L_{hrb}, dB; \quad (13)$$

- for areas of the city with low-density development:

$$L = -22{,}07 - 13{,}82\,lg(h_b/h_0) + 27{,}72\,lg(f/f_0) - [1{,}1lg(f/f_0) - 0{,}7](h_m/h_0) + [25 - 6{,}55lg(h_b/h_0)] \cdot lg(r/r_0) + K_x + L_{hrb},\ dB; \quad (14)$$

- for wide radial streets:

$$L = -9{,}45 - 13{,}82\,lg(h_b/h_0) + 27{,}72\,lg(f/f_0) - [1{,}1lg(f/f_0) - 0{,}7](h_m/h_0) + [27 - 6{,}55lg(h_b/h_0)] \cdot lg(r/r_0) + K_x, dB; \quad (15)$$

- for wide transverse streets:

$$L = -17{,}31 - 13{,}82\,lg(h_b/h_0) + 27{,}72\,lg(f/f_0) - [1{,}1lg(f/f_0) - 0{,}7](h_m/h_0) + [37 - 6{,}55lg(h_b/h_0)] \cdot lg(r/r_0) + K_x + L_{hrb}, dB. \quad (16)$$

Also it is widely known that the wall materials of buildings affect the signal attenuation indoors and the level of the reflected wave. According to the ITU [9], the electrodynamics parameters of brick, have the following meanings: the relative permittivity ε = 3,75; the conductivity σ = 0,038 S/ m.
Experiments carried out by us in Tashkent in areas of brick walls from local materials at 900 MHz showed the following results:

- for yellow bricks - ε = 2,5; σ = 0,004 S /m;
- for the red brick - ε = 2,2; σ = 0,04 S /m.

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Thus, it was found that the walls of yellow brick weakening significantly less than in the walls of red brick. That is, compared with the ITU data for yellow bricks from local materials, the relative dielectric constant has decreased for 1,5 times and has decreased conductivity 9.5 times. For red brick conductivity remained almost unchanged, and the relative permittivity decreased by 1.7 times.

Since the reflective properties of the brick walls of buildings also depend on ε and σ values, then in case of normal incidence of the wave to the yellow brick module reflectance value decreased for 1.41 times, and in the case of red brick – at 1.59 times.

In conclusion, you can make the results of that reflection of electromagnetic waves from the brick walls from local materials is much less, and the penetration of waves through the walls is much greater than in the brick walls of the foreign materials.

Any megapolis, including Tashkent, is impossible to imagine without the road tunnels. Naturally, in the tunnel weakening of field levels will be observed. For getting calculation expressions, the tunnel can be represented as a rectangular hollow waveguide with semi conductive walls. For this case, we introduced the concept of "effective conductivity" σ_{ef} tunnel walls. This is the basis for the expression of the attenuation coefficient in rectangular metal waveguide. Dependence of "effective conductivity" of the frequency is well approximated by an exponential function of the form:

$$\sigma_{ef} = -9769{,}9 + 9260{,}3 \cdot \exp(1{,}3011 \cdot 10^{-4} f), \text{ S/m.} \quad (17)$$

Knowing the value of the "effective conductivity", you can calculate the value of the specific attenuation in the tunnel with the help of expression:

$$\alpha = 1{,}585 \cdot \left[\frac{1}{b} + \frac{\lambda^2}{2a^3}\right] \cdot \left\{\lambda\sigma_{ef}\left[1 - \left(\frac{\lambda}{2a}\right)^2\right]\right\}^{-2}, \frac{dB}{m}. \quad (18)$$

V. CONCLUSION

Summarizing the results of the research, we point out that the paper presents the results of the influence of the orientation of streets, urban density, individual high-rise buildings, hills and tunnels at reducing levels of the field strength of frequency bands 900 and 1800 MHz.

Thus, there is established science-based utility model for the capital of Uzbekistan - Tashkent city, for an intense and satisfying the requirements of the time, development of mobile communication.

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